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Trends and insights in e-learning in medical education: A bibliometric analysis

Deborah Oluwadele[1,2] | **Yashik Singh**[1] | **Timothy T. Adeliyi**[2]

[1]Department of Telemedicine, School of Nursing and Public Health, University of KwaZulu-Natal, Durban, South Africa

[2]Department of Informatics, University of Pretoria, Pretoria, South Africa

Correspondence
Deborah Oluwadele and Yashik Singh, Department of Telemedicine, School of Nursing and Public Health, University of KwaZulu-Natal, Durban 4000, South Africa.
Email: deborah.oluwadele@up.ac.za and singhy@ukzn.ac.za

Abstract

Medical education is vital in producing competent healthcare professionals and advancing medical knowledge. The integration of e-learning has emerged as a transformative approach to enhance medical education by improving accessibility, cost-effectiveness and interactive learning experiences. With the COVID-19 pandemic further accelerating e-learning adoption, analysing the trends, publication collaborations and publication patterns in this domain is crucial. This study conducted a bibliometric analysis of published documents on the Scopus database in e-learning in medical education to explore the trends in scientific productivity. Publications in the domain has sporadically increased since the onset of the COVID-19 pandemic. The pandemic introduces a changing focus in research and emerging trends, with COVID-19 becoming a dominant topic and emerging theme. A collaborative research environment exists between authors; however, there is a divide between developed and developing countries in publication distribution, emphasising the need for equitable participation. This study contributes to a comprehensive understanding of e-learning in medical education, emphasising collaboration, publication patterns, emerging trends, and the impact of the COVID-19 pandemic. Researchers can leverage these findings to advance e-learning in medical education and enhance the quality of medical training and education.

KEYWORDS

bibliometric analysis, COVID-19, e-learning, medical education, publication trends, research impact, research performance, scientific collaborations

Context and implications

Rationale for this study

The COVID-19 pandemic reshaped medical education, emphasising e-learning's potential for teaching and learning continuity during lockdowns. Bibliometric analysis is needed to examine trends in e-learning within medical education.

Why the new findings matter

The landscape of publications in e-learning in medical education has changed; the bibliometric analysis of trends in the domain reveals key themes, pandemic response, challenges and opportunities to inform future research in the domain.

Implications for educational researchers and policy makers

Funders and institutions need to encourage collaboration between developed and developing countries to bridge the publication disparities in the domain. Developed countries can share resources, while developing countries bring fresh perspectives in their context. It is important for educators and researcher in medical education to report the implementation of e-learning with specific details on the critical success factor of e-learning in their context. This can provide a baseline for others to understand how to optimise the implementation of e-learning to make it more suitable in their context.

INTRODUCTION

Medical education and the health profession are laced with a plethora of problems. These problems have been termed 'wicked' problems, unyielding to established solutions, and perceived differently by different persons (Mennin, 2021; Rittel & Webber, 1973). The problems such as faculty development, curricular modification, teaching, assessment, program evaluation, scholarship, research, and leadership are ever-revolving and continually in motion. Although they have always been a part of medical education, their impacts are exacerbated by the COVID-19 pandemic. Medical education has also evolved to embrace competency-based education, interprofessional education and the large-scale application of information technology to education. While the COVID-19 pandemic did not initiate these changes, it accelerated their adoption, and they are expected to have a lasting impact on healthcare education (Frenk et al., 2022).

The COVID-19 disruption impacted over 90% of the world population of students in the education system (Nagar, 2020), necessitating the adoption of e-learning as a means to ensure the continuity of the teaching and learning process. Although the development of a well-devised plan should precede the adoption of e-Learning in Medical Education (e-LMED)—the first step is the assessment of needs which will dictate the system requirement and eventual use of the system (Khasawneh et al., 2016; Oluwadele et al., 2023)—many universities took desperate measures and responded to the pandemic with 'emergency e-learning' protocols by making a rapid transition from traditional face-to-face learning to e-learning (Murphy, 2020).

The lack of preparedness on the part of most institutions led to a forced engagement of students, who were previously accustomed to the traditional learning convention, in e-learning. This solution is stated by literature as an 'imperfect yet quick solution to the crises' (Nagar, 2020), resulting in impaired student performance. Scholars in the domain reported challenges amplified by the digital divide between developed and developing countries. This includes partial or complete inaccessibility of online courses due to poor internet speed (Diab & Elgahsh, 2020), and incompatibility between e-learning platforms and Android

smartphones used by most students to access learning materials, leading to deteriorated students' performance (Adedoyin & Soykan, 2020). In low-income families, students find it challenging to afford a personal computer (Fry & Cilluffo, 2019), leading to education inequality (Hasan & Bao, 2020), mental stress and anxiety (Subedi et al., 2020). Also e-learning was reported to not support psychomotor skills, communication skills and research work in dental education (Sil et al., 2023).

The rapid global adoption of e-learning in medical education has led to a simultaneous increase in research in this domain. The literature on e-LMED varies in perspectives on the program, process and outcome evaluation (Barteit et al., 2020; Sawarkar & Sawarkar, 2020; Wang, Zhang, Liu, Jiang, Jia, et al., 2021; Wang, Zhang, Liu, Jiang, Tang, & Liu, 2021) to the evaluation of the cost-effectiveness of e-learning in medical education (Bista et al., 2021; Finucane & McCrorie, 2021; Sandars, 2021; Walsh, 2021), to the challenges and opportunities of e-learning in medical education (Cosnita et al., 2020; Förster et al., 2020; Gray et al., 2021; Hayat et al., 2021) and comparison between e-learning, blended learning and traditional classroom teaching (AlQhtani et al., 2021; Amir et al., 2020; Fitzgerald et al., 2021; Vallée et al., 2020; Venkatesh et al., 2020) to mention just a few. Publications in digital medical education are diverse, and there seems to be no agreement between the methods, tools and techniques used by authors in solving the same problem. Studies evaluating the effectiveness of e-learning in medical education, for instance, are conducted haphazardly with no focus on metrics that evaluate the technology components of e-learning. Authors evaluate performance in e-learning the same way they would traditional learning. Noesgaard and Ørngreen (2015) had identified this pattern earlier and questioned whether e-learning and face-to-face learning should be defined and evaluated similarly.

In order to tackle the challenges that exist in digital medical education, it is imperative to comprehend the structure, dynamics and impact of scientific research in this field. A comprehensive bibliometric analysis of the literature on e-learning in medical education emerges as a crucial first step. Bibliometric analysis is a powerful tool to summarise extensive amounts of bibliometric data, providing insights into the intellectual structure and emerging trends within a specific research topic or domain. Scholars widely recognise its effectiveness in handling vast dimensions of data, generating significant research impact, and revealing research strengths, gaps and collaboration opportunities (Donthu et al., 2021). Its ability to facilitate informed decision-making at the institutional, national and international levels further highlights its importance.

Consequently, this study aims to conduct a comprehensive bibliometric analysis by accessing and quantifying the literature to identify the strengths, gaps, emerging trends and collaboration opportunities in e-learning in medical education. Two research questions were raised and answered by this study:

1. What authors, countries, institutions and journals are most actively involved in e-learning research in medical education?
2. What are the research strengths, gaps, emerging trends and collaboration opportunities in e-learning in medical education?

Citation and co-word analysis are employed as the bibliometric methods to answer the questions and achieve the objectives. Citation analysis was used to identify the top publishing authors, most active country, most active institutions, and the most active journals, while co-word analysis was used to determine the most frequent author keywords, term co-occurrence, trending topics, and the conceptual structure map of the domain. Multiple correspondence analysis (MCA) was used to generate a word map, topic dendrogram, factorial map of the document with the highest contribution, and factorial map of the most cited documents to gain an understanding of the conceptual structure of the domain.

Theoretical background: What does bibliometric analysis do?

Research synthesis is the process of carefully gathering, assessing and combining current research papers on a specific issue to obtain meaningful and trustworthy findings. It entails locating, selecting and critically analysing relevant research, extracting data from them, and synthesising the results to produce a thorough and unbiased overview of the available information (Cooper et al., 2019). Research synthesis has gained popularity as researchers use the method to analyse and synthesise data, findings and results from several studies to draw relevant and trustworthy conclusions that extend beyond individual studies (Leary & Walker, 2018).

Various methodologies are employed for research synthesis, including systematic reviews, meta-analysis, meta-synthesis and bibliometric analysis (Dogan, 2023). These methodologies use a systematic approach to collect, analyse and integrate the results of many studies to answer a specific research question, primarily focusing on generating an overall summary or conclusion based on the combined evidence from individual studies (Leary & Walker, 2018). However, bibliometric analysis quantitatively analyses large amounts of data, focusing on assessing the bibliometric characteristics of publications and authors, such as citations, keywords, and publishing patterns, rather than summarising the findings or outcomes of individual investigations. Bibliometric analysis can assist researchers in understanding the intellectual landscape and the emerging trends in their domain (Donthu et al., 2021; Zupic & Čater, 2015).

Bibliometric methods describe, assess and monitor published research using a quantitative approach. These methods introduce a systematic, clear and replicable review process, thereby enhancing the eminence of these reviews. Bibliometric methods guide the researcher to the most important works and map the research field without subjective bias (Zupic & Čater, 2015). Donthu et al. (2021) classified bibliometric analysis methodologies into performance analysis and science mapping. Performance analysis employs indicators relating to publication and citation (citation analysis), which provide insights into field trends. Citation analysis of a research field examines the most cited studies, authors or journals, typically in the form of top-N lists. It is perceived as a measure of influence if an article is popularly cited. This assumption is based on the perception that authors cite documents they consider to be important for their work. Co-citation, co-authorship and co-word (co-occurrence) analysis, on the other hand, are types of science mapping (Donthu et al., 2021; Zupic & Čater, 2015). Co-citation analysis depicts the interconnection of authors, journals and references based on the frequency with which documents are cited together on the reference list. Mapping the research in the same reference lists illustrates which schools of thought greatly influence the subject. Although co-authorship analysis discloses the social structure of a field, co-word analysis helps to define the area by mapping the actual content of studies. Co-word analysis is used to find connections among concepts that co-occur in document titles, keywords or abstracts (Scherer et al., 2019).

Studies using bibliometric analysis have gained traction in different domains. Particularly in e-learning, bibliometric analysis has been used by scholars to identify trends and issues in science education (Dogan, 2023), evaluate the evolution of topics in education (Huang et al., 2020), examine e-learning research fields (Djeki et al., 2022), and to evaluate literature related to performance evaluation in e-learning in medical education (Oluwadele et al., 2023). Djeki et al. (2022) conducted a bibliometric analysis of research in e-learning between the years 2015 to 2020 using the Web of Science database. The study examined the e-learning research field comprehensively; the study mainly conducted performance and thematic analysis without conducting the science mapping, providing only a 'piecemeal understanding' (Donthu et al., 2021). Other bibliometric

analysis studies in e-learning in medical education (Azer, 2015; Raban & Gordon, 2015; Sweileh, 2021) also presented a fragmentary perspective, although the objectives of the studies may justify this.

Justification for the adoption of bibliometric analysis for this study

The abundance of research in e-learning in medical education makes it difficult for scholars to keep up with the trends of relevant literature in the domain. This is due to the COVID-19 pandemic, which reshaped medical education and the landscape of publications in e-learning in medical education. This necessitates understanding research trends in the domain to unload the subtle differences in the trends and evolution of topics while highlighting the emerging areas and knowledge gaps in the domain.

The application of bibliometric analysis in medicine is affirmed to enable the analysis of vast amounts of publications and their pattern of production on macroscopic and microscopic levels. Hence, there has been an increase in the productivity in the adoption of bibliometric analysis in medical research (Cooper, 2015; Kokol, 2018; Kokol et al., 2021; Thompson & Walker, 2015). This study adopts bibliometric analysis because the method provides the capabilities to investigate extensive scientific data in e-learning in medical education. It allows us to delve into the intricate developments within the field, while also revealing the emerging aspects within that discipline (Donthu et al., 2021). Therefore, this study adopts two bibliometric analysis methods, citation analysis and co-word analysis, to understand the landscape of e-LMED and provide a basis for the relevant findings on aggregated bibliographic data produced by other scientists working in the field. Citation analysis will examine the most cited studies, authors or journals, while co-word analysis will explore the domain's intellectual structure. This will help researchers gain valuable insights into the primary themes, subjects or areas of interest that have been examined in e-learning. The aggregation and analysis of the data generated will produce insights into the structure, social networks and topical interests in the domain of e-LMED.

MATERIALS AND METHODS

Database

The Scopus database was used to retrieve, analyse and map data and provide information about citation and research collaboration related to performance in medical education from 1976 to 2022. This is because Scopus is 100% inclusive of MEDLINE and has a more significant number of indexed journals than other databases. Also, Scopus has many functions that can be leveraged to facilitate citation analysis, counting research collaboration, and exporting data to Microsoft Excel for further tabulation and mapping. Gan et al. (2022) recommend that Scopus be used for medical research trend analysis because it provides a broader range of publications than Web of Science (WoS), although both databases will miss most non-English language publications.

Search strategy

The PICOS (Population, Intervention, Comparisons, Outcomes, and Setting) model ensures scientific diligence and objectivity of reviews by prescribing methodological standards that enhance the value of scientifically published literature reviews and guarantee their robust

reproducibility (Saaiq & Ashraf, 2017). Using the PICOS model, the population of the publications on the Scopus database was identified as e-learning—any online course from across the world. The intervention, comparison and outcome constructs of the PICOS model were not applicable in this context because of the aim of the study. However, the Setting construct defined the context within which we would consider the population—Medical education—and subsequently, the main keywords to be used for creating the search terms. Table 1 presents the inclusion criteria for the review using the PICOS model.

An initial search was conducted on Scopus on 11 June 2022, using keywords and relevant synonyms from the general population and setting. These keywords were obtained by reading published works and noting key terms related to e-learning in the medical education domain. The search was modified as many times as possible to sharpen the result, increase the validity of the search strategy and ensure minimum false-positive and false-negative results.

Data extraction and screening

This phase's first step involved identifying the records through a basic search on Scopus. The search string was first typed into the database to execute this search. A total of 5828 documents were obtained as a result. In the second step, these documents were reviewed, and all studies not published in English (102) and articles in press (27) were excluded. After 129 studies were eliminated, all remaining documents were reviewed for eligibility. After it was determined that there were no errors, a total of 5699 studies were included in the study sample and exported for analysis.

The identification, screening and inclusion process used from the initial to the final searches and the results returned are depicted in Figure 1.

Validation and Quality Assurance of the Search Query

The synonyms of the key search terms were researched and included to ensure maximum inclusivity of published work in the domain. After this, the keywords were modified in several iterations to confirm the validity of the search strategy. The modification helped to eliminate false-positive and false-negative results. The first document results were analysed to ensure they aligned with the scope of the study., thereby reducing the possibility of false-positive results.

TABLE 1 Inclusion criteria.

Criteria for including studies in the review	
Population or conditions of interest	E-learning; any intervention, course, program, or module run online. The population will examine papers from all over the world
Interventions or exposures	Not applicable
Comparisons/control groups	Not applicable
Outcomes of interest	Not applicable
Setting	Medical education; any program, module, training or intervention in medicine
Search string (Population AND Setting)	"E-learning" OR "virtual learning" OR "virtual education" OR "Digital learning" OR "web-based learning" OR "online learning" OR "distance learning" OR "distance education" OR "Teleeducation" OR "tele-education" AND "medical education" OR "medical training" OR "telemedicine" OR "Tele-medicine"

For false-negative results, the number of documents for the top active authors shown in the Scopus database was compared with their research profile in Scopus to assess the extent of agreement between what has been retrieved and what is actually in the Scopus database about the desired research question.

Tools used

The retrieved data was analysed using Biblioshiny, a bibliometric package on R, while the visualisation was done using VOSviewer software for bibliometric indicators such as annual growth, active authors and their collaboration, journals and countries, the frequently used keywords, fields and subject areas. VOSViewer utilises text mining to identify terms within publications and utilises Visualization of Similarities (VoS), a mapping method rooted in co-word analysis, to generate bibliometric maps or visual representations (Kokol et al., 2022). Citation analysis was done directly on Scopus to understand the patterns within the retrieved documents.

Data analysis and visualisation

Citation analysis and co-word analysis were conducted on the retrieved data. Co-word analysis was done to identify the concepts and find connections among concepts that co-occur in document titles, keywords, or abstracts. The analysis reveals the most critical issues in

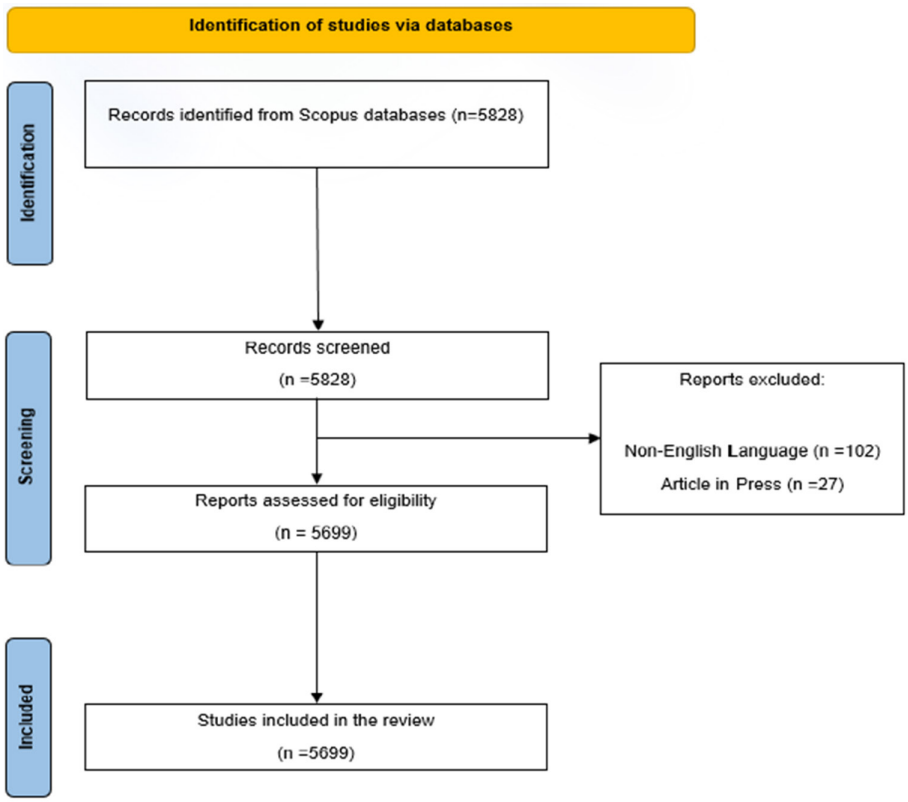

FIGURE 1 The identification, screening, and inclusion process.

e-LMED according to the literature via analysing re-occurring keywords, topic co-occurrence, topics trends and factorial analysis using Multiple Correspondence Analysis (MCA).

RESULTS

General description of the retrieved publications

The general search query on e-learning in medical education returned 5699 documents published between 1976 and 2022 in 29 languages. English was the predominant language ($n = 5384$, 94.5%), followed by German ($n = 163$, 2.9%), Spanish ($n = 72$, 1.3%) and French ($n = 55$, 1.0%). Most of the retrieved documents were published in journals ($n = 4817$, 84.5%), with a few being conference proceedings ($n = 481$, 8.4%), book series ($n = 317$, 5.6%), books ($n = 72$, 1.3%) and trade journals ($n = 8$, 0.14%). Figure 2 presents a detailed description of the types of documents retrieved. Most of the retrieved documents were articles ($n = 3523$), conference papers (821) and reviews (612).

The dominant subject area for the publication was medicine ($n = 3908$), followed by social sciences ($n = 1175$), computer science ($n = 678$), engineering ($n = 610$) and health professions ($n = 545$). Figure 3 shows the various disciplines contributing to the body of knowledge in e-LMED.

Growth of publications

The retrieved documents were published from 1979 to 2022. The first publication on e-LMED was in 1979 when only one paper was published. After that, there were no publications in the domain until 1985, when only one paper was published. The number of publications remained very low, varying from 1 to 4 until 1995. However, from 1996 publications in e-LMED began to experience a steady increase. Figure 4 shows the growth of publications in e-LMED, with the highest number of publications in 2021 ($n = 1076$, 18.9%), followed by 2020 ($n = 673$, 11.8%) and 2022 ($n = 405$, 7.1%). This growth might be due to the advent of the COVID-19 pandemic and the adoption of e-LMED to remedy the lockdown, as there were

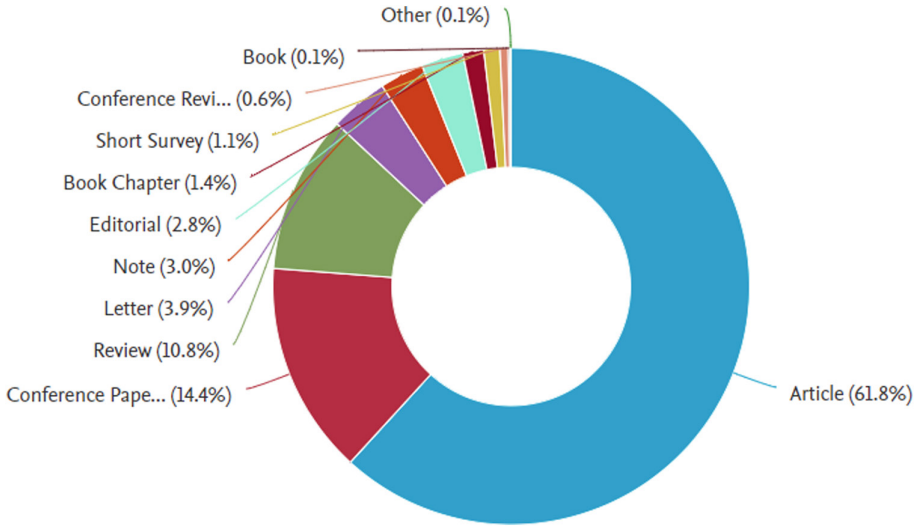

FIGURE 2 Description of the types of documents retrieved.

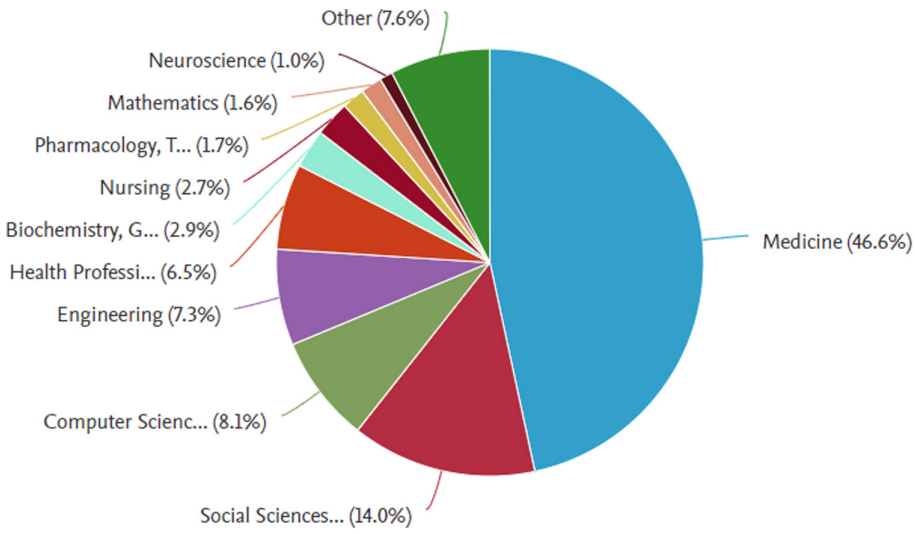

FIGURE 3 Dominant subject area for the publication.

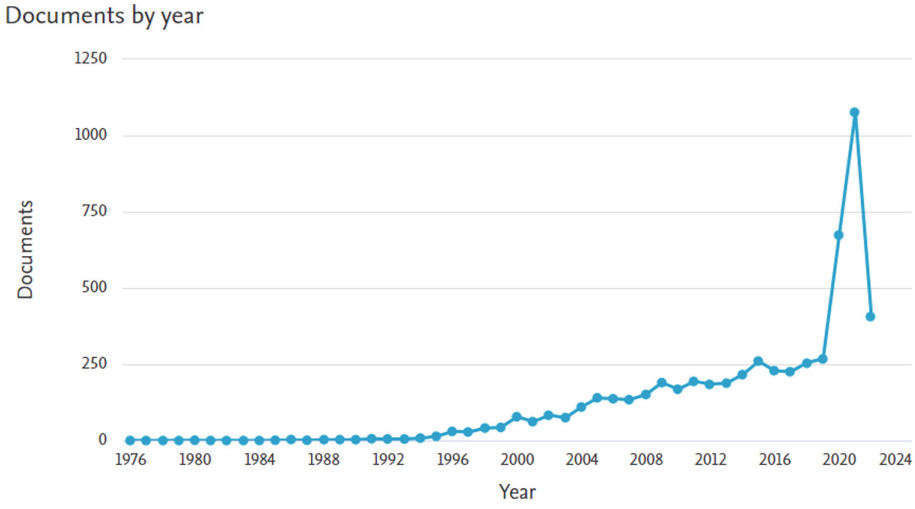

FIGURE 4 Annual publication growth of e-LMED.

only over 200 documents published annually in 5 years between 2019 and 2014. The number of publications since COVID-19 accounts for 38% ($n = 2154$) of the publication in the domain.

Citation analysis

Citation analysis was done directly on Scopus to understand the patterns within the retrieved documents. This includes the most influential documents, authors, journals, countries and institutions in the domain. This will provide researchers in the domain with useful insights into the impact of their research, seminal works and foundational research that have shaped the domain, trends in the literature, collaboration networks and journal quality, and assist them in making educated decisions about their work, identifying influential research and staying current on the newest advancements in their field.

Top publishing authors

In total, 22,185 authors contributed to the retrieved documents, averaging 3.89 authors per document. Table 2 gives insight into the top 20 most prolific authors in e-LMED. The positions were awarded using the number of publications first and then the number of citations where there is a tie in the number of publications between two authors. Of 22,185 authors who published the retrieved documents, 97% (21,563 authors) were involved in multi-authored papers, while less than 3% (622 authors) authored single-authored documents. Professor John Edward Sandars, a professor of medical education, is the most active author, with 36 publications and an average of 10.3 citations per document. He has 233 publications and has collaborated with 240 authors on 36 topics. Professor David A. Cook, another prominent author, has 24 publications but is the most cited author in the field, averaging 61.8 citations per document. Dr Kieran Walsh, a clinical director and adjunct associate professor, ranks third in activity and has published 348 documents, collaborating with notable authors such as Professor Sandars and Professor Cook.

Most active country

Table 3 presents the top 20 actively publishing countries, and Figure 5 shows an overlay visualisation of the top 20 most active countries. The colour bar in the bottom right corner of the visualisation depicts the publications of the top 20 countries within a timeline from

TABLE 2 The top 20 actively publishing authors in e-learning in medical education.

Rank	Author	Number of publications	%$N = 5699$	Number of citations	Number of citations per document
1st	Sandars, J	36	0.63	370	10.28
2nd	Cook, D.A.	24	0.42	1483	61.79
3rd	Walsh, K	23	0.40	164	7.13
4th	Fischer, M.R.	18	0.32	450	25.00
5th	Harden, R.M.	15	0.26	426	28.40
6th	Zary, N	12	0.21	242	20.17
7th	Geissbuhler, A.	11	0.19	349	31.73
8th	Hortsch, M	11	0.19	136	12.36
9th	Mishra, S.K.	11	0.19	132	12.00
10th	Behrends, M.	11	0.19	60	5.45
11th	Wen, C.L.	11	0.19	60	5.45
12th	Mars, M.	10	0.18	339	33.90
13th	Matthies,H.K.	10	0.18	55	5.50
14th	Hege, I.	9	0.16	269	29.89
15th	Kim, K.J.	9	0.16	130	14.44
16th	Back, DA	9	0.16	120	13.33
17th	Caudell, T.P.	9	0.16	117	13.00
18th	Huwendiek, S.	9	0.16	74	8.22
19th	Dev, P.	9	0.16	63	7.00
20th	Bamidis, P.D.	9	0.16	37	4.11

TABLE 3 Top 20 actively publishing countries in e-LMED.

Rank	Country	Number of publications	%$N = 5699$	Citation	Number of citations per document
1st	USA	1716	30.11	22,252	12.97
2nd	UK	774	13.58	10,238	13.23
3rd	Germany	416	7.30	3906	9.39
4th	Canada	394	6.91	5384	13.66
5th	Australia	272	4.77	3500	12.87
6th	India	240	4.21	1305	5.44
7th	Italy	193	3.39	2088	10.82
8th	Netherlands	166	2.91	2045	12.32
9th	Brazil	159	2.79	1058	6.65
10th	Spain	148	2.60	1808	12.22
11th	China	147	2.58	1122	7.63
12th	France	142	2.49	1102	7.76
13th	Switzerland	140	2.46	2035	14.54
14th	Greece	82	1.44	692	8.44
15th	Ireland	77	1.35	1200	15.58
16th	Austria	74	1.30	977	13.20
17th	Poland	73	1.28	525	7.19
18th	Singapore	72	1.26	872	12.11
19th	Saudi Arabia	72	1.26	710	9.86
20th	South Africa	71	1.25	1020	14.37

2014 to 2017. The United States takes the lead with 1716 (30.11%) publications, followed by the United Kingdom (774, 13.58%) and Germany (416, 7.30%). While countries such as the United Kingdom, Italy, France, Austria, and the United States have been publishing since or before 2014, countries like the Netherlands, South Africa, China, Saudi Arabia, and India have only started publishing within the e-LMED domain more recently.

Most active institutions

The most active institution assessed by the number of articles produced is Harvard Medical School in the United States ($n = 107$, 1.8%) (Figure 5), followed closely by the University of Toronto ($n = 100$, 1.75%) in Canada and the Mayo Clinic, United States ($n = 57$, 1.00%). Universidade de Sao Paulo in Brazil takes fourth (55, 0.97%), while the University of Washington in the United States takes fifth (49, 0.86%). Figure 6 shows the top 15 active institutions in e-LMED. The United States takes the lead as 9 of the top 15 most active institutions are based there. Fourteen institutions are from developed countries, while only one (Universidade de Sao Paulo) is from a developing country.

Most active journals

The retrieved documents were published in 2167 different sources. Studies In *Health Technology and Informatics* ($n = 209$, 3.67) was the most active source in the domain.

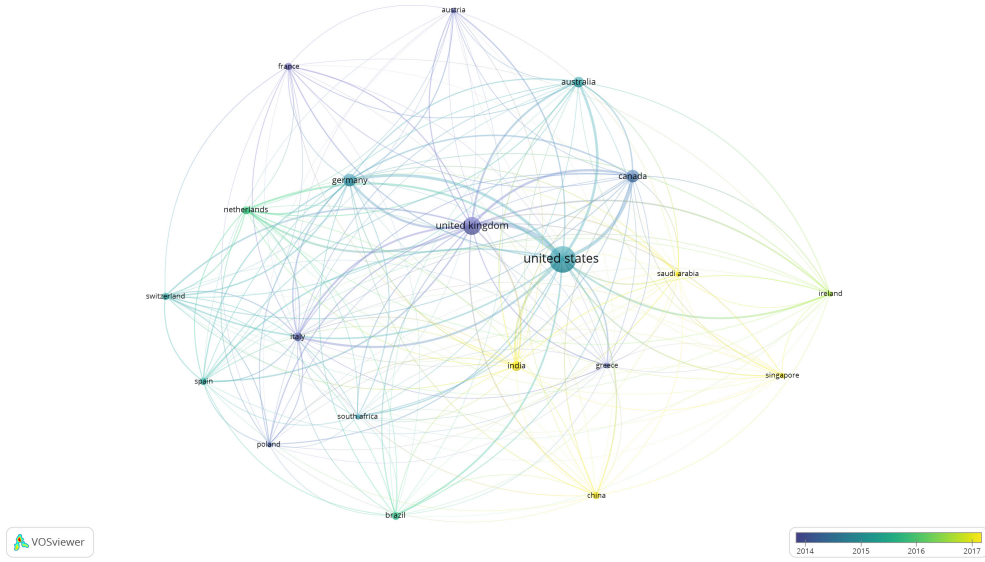

FIGURE 5 Overlay visualisation of the top 20 most active countries.

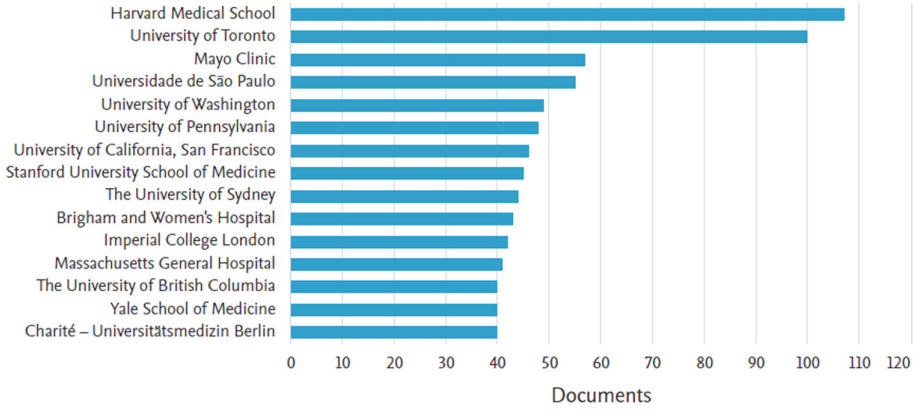

FIGURE 6 The top 15 most active institutions in e-LMED.

The journal is a Netherlands-based journal active since 1991, focusing on biomedical engineering, health information management, and health informatics. *BMC Medical Education* ($n = 163$, 2.86%) was the second most common source of publications. *BMC Medical Education* is a UK-based open-access journal active since 2001, publishing original peer-reviewed research articles about training healthcare professionals, including undergraduate, postgraduate and continuing education. The journal focuses on curriculum development, performance evaluations, training needs assessment, and evidence-based medicine. Next is *Medical Teacher* ($n = 145$, 2.54%); also a UK-based journal active since 1979 and addressing the needs of teachers throughout the world involved in training for the health professions.

Table 4 lists the top 20 actively publishing journals with their citation analysis. *Academic Medicine*, a US-based journal active since 1966, had the highest number of citations per document ($n = 54.65$).

TABLE 4 Top 20 active journals in e-LMED.

Rank	Sources	No. of publications	%*N* = 5699	Citations	No. of citations per document	H-index	Country
1st	*Studies in Health Technology and Informatics*	209	3.67	1305	6.24	61	Netherlands
2nd	*BMC Medical Education*	163	2.86	3561	21.85	68	UK
3rd	*Medical Teacher*	145	2.54	3182	21.94	109	UK
4th	*Telemedicine and E-Health*	84	1.47	1288	15.33	81	USA
5th	*Anatomical Sciences Education*	60	1.05	1850	30.83	51	USA
6th	*Journal of Telemedicine and Telecare*	54	0.95	894	16.56	80	UK
7th	*Lecture Notes in Computer Science Including Subseries Lecture Notes in Artificial Inteligence and Lecture Notes in Bioinformatics*	54	0.95	203	3.76	415	Germany
8th	*Journal of Surgical Education*	51	0.89	1020	20.00	54	USA
9th	*Education for Primary Care*	50	0.88	246	4.92	19	UK
10th	*Academic Medicine*	49	0.86	2678	54.65	162	USA
11th	*Medical Science Educator*	48	0.84	176	3.67	13	USA
12th	*Journal of Continuing Education in the Health Professions*	45	0.79	557	12.38	56	USA
13th	*Medical Education*	41	0.72	1095	26.71	138	UK
14th	*International Journal of Medical Informatics*	40	0.70	670	16.75	106	Ireland
15th	*JMIR Medical Education*	37	0.65	294	7.95	15	Canada
16th	*PLoS One*	36	0.63	466	12.94	332	USA
17th	*GMS Journal for Medical Education*	33	0.58	105	3.18	19	Germany
18th	*International Journal of Environmental Research and Public Health*	29	0.51	48	1.66	113	Switzerland
19th	*BMJ Open*	28	0.49	353	12.61	103	UK
20th	*Academic Radiology*	27	0.47	271	10.04	100	USA

Note: H-index is Hirsch index (obtained from Scimago).

Co-word analysis

Co-word analysis was conducted on VoSViewer and R Biblioshiny to understand the domain's intellectual structure. The keywords used by authors in the domain were analysed to understand how frequently these keywords were used individually by authors and how the keywords occur jointly with other keywords. This will help researchers gain useful insights into the primary themes, subjects or areas of interest that have been examined in e-learning in medical education within the Scopus database. This data can assist researchers in better comprehending existing knowledge, identifying research gaps and determining new study topics for future studies.

Most frequent author keywords

The retrieved documents had a total of 18,028 keywords. The most frequently encountered keywords include medical education ($n = 4339$), human ($n = 3919$), humans ($n = 3233$), article ($n = 2439$), education ($n = 2349$) and e-learning ($n = 2311$). Figure 7 is an overlay visualisation map of the top 100 frequent author keywords representing approximately 0.6% of the total author keywords in the retrieved articles. The map shows the progression of keywords in e-LMED research, with the keywords in purple being the older ones and yellow being the most recent keywords in the literature. Although the initial keywords in the domain include distance education, internet, continuing medical education, computer-assisted instruction, and program evaluation, the most recent keywords revolve around COVID-19 and include pandemic, covid-19, epidemiology and coronavirus infection. This fact gives a sneak peek into the current research focus of e-LMED.

Trending topics

The trending topics were analysed to understand the evolution of keywords in e-LMED. The trend topics in e-LMED were explored on Biblioshiny using method parameters, including Keyword Plus from various authors from 2004 to 2022 and a minimum word frequency of

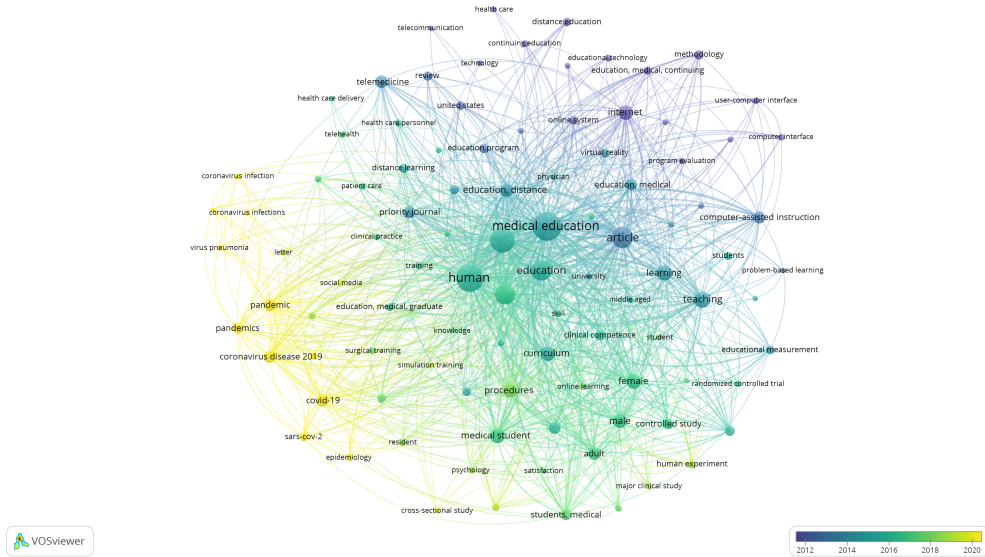

FIGURE 7 An overlay visualisation map of the top 100 frequent author keywords in e-LMED.

200 and 10 words per year to enhance the degree of graphical visualisation. Figure 8 shows the evolution of topics in e-LMED relative to the years of publication. Topics in e-LMED evolved from keywords such as continuing education, distance education, methodology, and user-computer interface around 2004. Program evaluation was a trending topic in 2016 with a frequency of 390; in 2017, telemedicine became a trending topic with a frequency of 1339. Other topics, including social media, curriculum, healthcare personnel and clinical competence, continued to trend until 2020 and 2021, when covid-19 became and continues to be a trending topic in the domain.

Term co-occurrence

The retrieved document was used to create a map on VOSviewer, which depicts the co-occurrence terms in e-LMED. This helps to understand the conceptual structure of e-LMED. A total of 85,235 terms from the titles and abstracts of publications were extracted using the full counting method. The map was created based on the occurrence rate and the terms' relevance. Only terms with a minimum number of 480 occurrences were considered to enhance the readability of the map. Terms with the highest rate of occurrence include students ($n = 6522$), course ($n = 3168$), covid (2504), group ($n = 2424$), technology ($n = 2417$), system ($n = 2394$) and knowledge ($n = 2303$). In comparison, topics with the highest rate of relevance include telemedicine ($n = 3.77$), pandemic ($n = 3.57$), covid ($n = 3.20$), application ($n = 2.51$), paper ($n = 2.24$), and technology ($n = 1.84$).

Terms with the closest link of co-occurrence with the 'student' include change, teaching, impact and face. Terms with the nearest degree of co-occurrence with 'covid' include medical school, response, future, challenge, opportunity, face and students. Notably, the term 'covid' ranks high in both occurrence and relevance in contemporary research on e-learning in medical education. The map reveals a network (Figure 9) of terms grouped into three

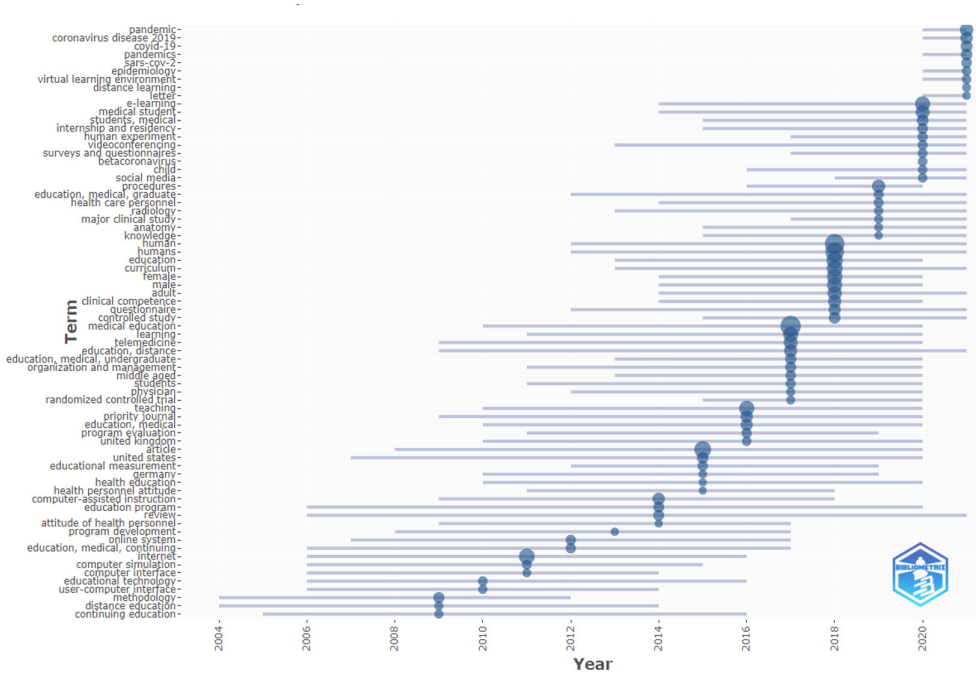

FIGURE 8 Trend topics in e-LMED.

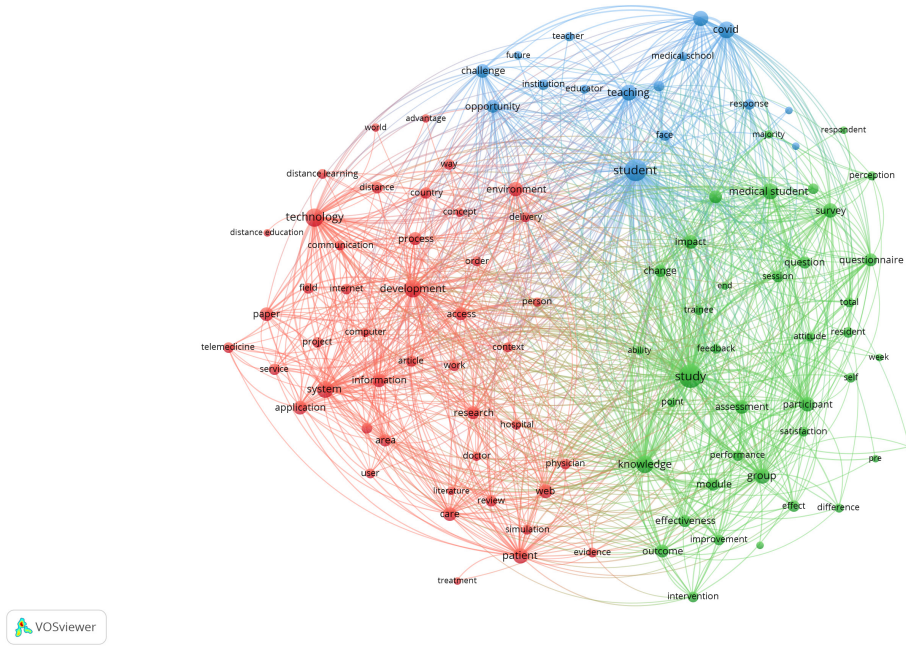

FIGURE 9 A network map of term co-occurrence in e-LMED.

clusters. The sizes of the label indicate the weight and show terms with the highest rate of occurrence, while the cluster grouping indicates the relatedness or co-occurrence of the terms through the links.

Conceptual structure map-method: multiple correspondence analysis (MCA)

The conceptual structure map (CSM) is a visualisation method that uses multiple correspondence analysis (MCA) to represent the relationships between categorical variables in a dataset. The CSM visualises the links between categorical variables, allowing researchers to spot patterns, groupings and dependencies in the dataset. It aids in the discovery of underlying structures and associations that would not be obvious from raw data alone. The conceptual structure feature of Bilioshiny was used to perform factorial analysis. K-means clustering identified clusters in the retrieved documents that elucidate identical concepts (Aria & Cuccurullo, 2017), the topic dendrogram, most contributing papers and most cited papers.

Topic dendrogram

The dendrogram represents the hierarchical order and relationship between the keywords generated by hierarchical clustering. The dendrogram groups the keywords into two clusters using the content of the retrieved document. The underlying method is that when words frequently co-occur in documents, the concepts behind those words are closely related. Figure 10 shows a network of themes and their relations representing the conceptual structure of the body of knowledge on e-LMED. There are two main clusters colour-coded in blue and red. Cluster one, colour-coded red, is linked to more researched concepts in e-LMED. These concepts are grouped based on their interrelatedness to form hierarchical clusters. Cluster 2, colour-coded

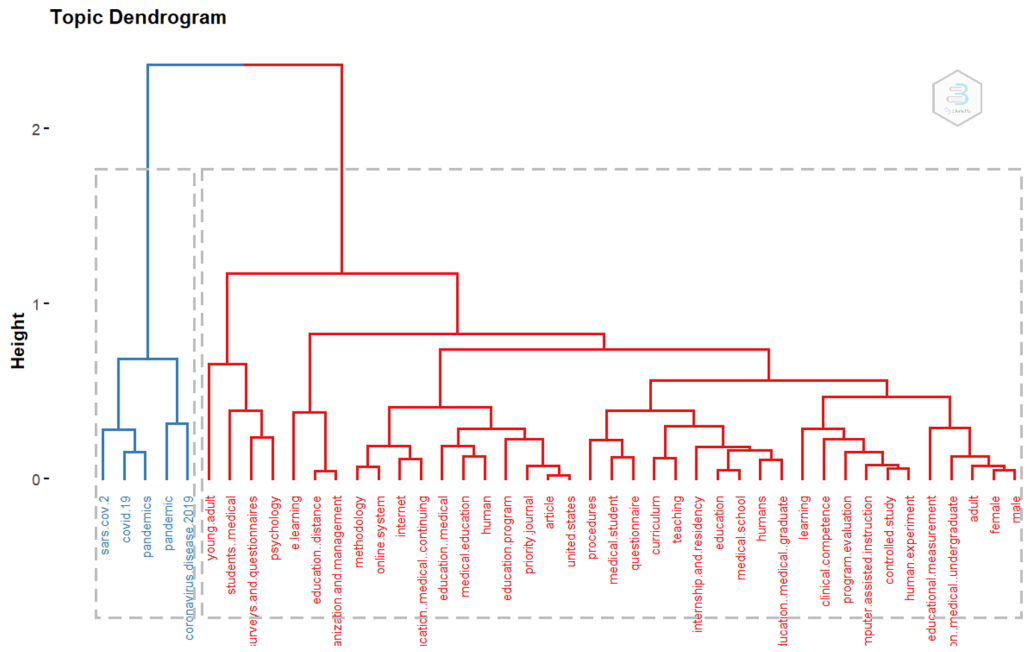

FIGURE 10 Dendrogram of hierarchical cluster analysis of keywords displaying the closeness of association between keywords in e-LMED.

in blue, shows COVID-19-related themes such as sars.cov.2, covid.19, pandemic and coronavirus disease 2019. This cluster appears to be a less explored study area, possibly due to the relatively new topics on this subject because of the COVID-19 condition.

Factorial map of the document with the highest contribution

Figure 11 provides analytical insight into the document with the highest contributions relative to the clusters identified in the word map and the topic dendrogram. Cluster 1 shows five papers, while Cluster 2 shows four papers. The first cluster consists of documents with themes centred on the evaluation of e-LMED. In contrast, the second cluster consists of documents with themes focused on the challenges and impacts of the COVID-19 pandemic in medical education and the strategies adopted by different departments to ensure continuity and sustainability of training during the lockdown period.

Factorial map of the most cited documents

Figure 12 presents a factorial map of the most cited documents based on the provided description. The first cluster represents studies focused on evaluating e-LMED. In contrast, the second cluster comprises documents that discuss the challenges and impacts of the COVID-19 pandemic on medical education and the strategies implemented to ensure training continuity during the lockdown period.

Cluster one is associated with five highly cited papers primarily focusing on program evaluation in e-LMED. These papers have received significant attention and recognition within the field. On the other hand, cluster two consists of four highly cited articles that primarily address the challenges, impacts and mitigation strategies related to the COVID-19 pandemic

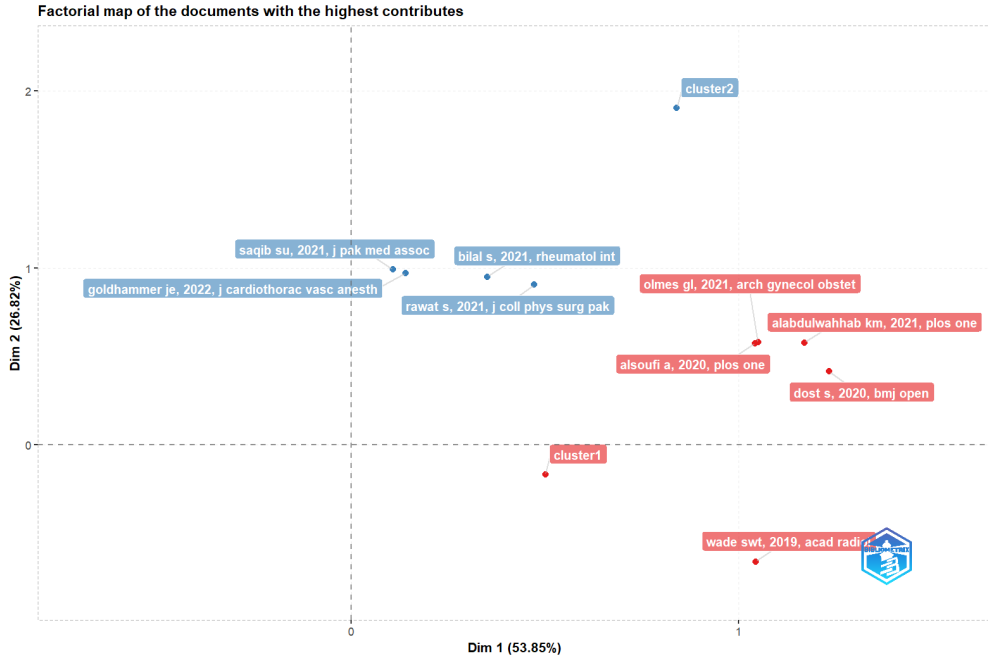

FIGURE 11 Factorial map of the document with the highest contribution.

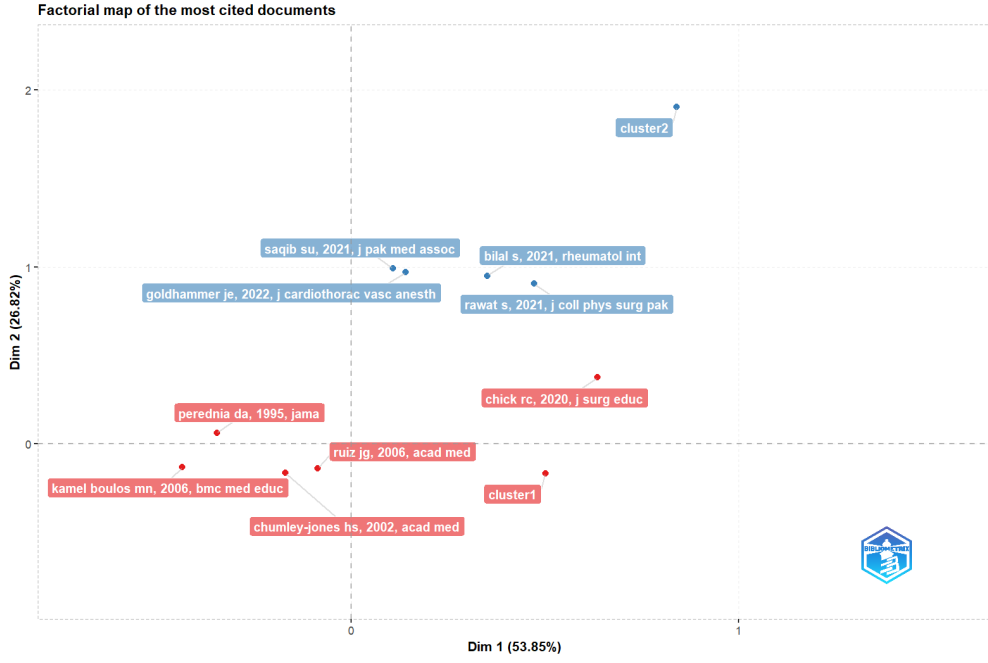

FIGURE 12 Factorial map of the most cited papers.

in medical education. These papers have garnered substantial citations, indicating their importance in understanding and addressing the effects of the pandemic on medical education. Table 5 provides additional insights into their specific details, such as authors, and titles.

TABLE 5 Most cited document by factorial analysis.

	Paper title	Year of publication	Authors	No. of citations (Google scholar)
Cluster 1	Telemedicine technology and clinical applications	February 1995	Perednia and Allen (1995)	1128
	Web-based learning: sound educational method or hype? A review of the evaluation literature	October 2002	Chumley-Jones et al. (2002)	733
	Wikis, blogs, and podcasts: a new generation of web-based tools for virtual collaborative clinical practice and education	August 2006	Boulos et al. (2006)	1785
	The impact of e-learning in medical education	July 2006	Ruiz et al. (2006)	84
	Using technology to maintain the education of residents during the COVID-19 pandemic	July 2020	Chick et al. (2020)	895
Cluster 2	Impact of a global pandemic on surgical education and training- review, response, and reflection	May 2021	Saqib et al. (2021)	1
	Enhancing rheumatology education during the COVID-19 pandemic	January 2021	Bilal and Shanmugam (2021)	3
	How COVID (pandemics) impacted training of medical students, trainees, and residents	July 2021	Rawat et al. (2021)	0
	Survey says… the effects of the COVID-19 pandemic on graduate medical education	September 2022	Goldhammer and Linganna (2022)	1

Content analysis of the most cited document

The analysis of documents with the highest contributions is also clustered similarly. The first cluster focuses on this evaluation aspect, and five papers within this cluster are highlighted for their significant contributions. However, these papers present conflicting evidence regarding the suitability of e-learning for medical education. Wade et al. (2019) studied senior medical students' perception of adaptive tutorials in radiological education. The findings showed that students overwhelmingly supported adaptive tutorials, perceiving them as engaging and helpful for knowledge retention.

In contrast, Dost et al. (2020) investigated medical students' perception of online teaching during the COVID-19 pandemic. Their survey-based study revealed that while new distance-learning platforms were adopted, the most significant perceived benefit was flexibility, and the main challenge was family distraction and network fluctuations. Alsoufi et al. (2020) conducted a large-scale study with medical students in Libya, assessing the adequacy and feasibility of online learning methods during the COVID-19 context. The results showed mixed perceptions, with most respondents disagreeing with the effectiveness of e-learning for clinical aspects but acknowledging its potential for interactive discussions. Olmes et al. (2021) assessed the opinion of medical students in Germany regarding online learning programs during the pandemic. The study revealed broad acceptance of e-learning, with various digital teaching formats receiving positive ratings. However, students preferred learning with actual patients, indicating the importance of bedside teaching. Finally, Alabdulwahhab et al. (2021) explored the types and practices of online resources used by medical students in Saudi Arabia during the pandemic. The study found that male students embraced online learning more than female students, and those with higher academic scores were more likely to utilise online educational resources.

These studies highlight medical students' diverse perspectives and experiences regarding e-learning in medical education. Although some students find it engaging and supportive, others are concerned about its clinical adequacy and emphasise the importance of traditional teaching methods. The findings suggest the need for a balanced approach that combines digital learning tools with in-person interactions and hands-on experiences in medical education.

The studies in the second cluster focus on the challenges and impacts of the COVID-19 pandemic on medical education and the strategies adopted to ensure continuity and sustainability of training during the lockdown period. These studies provide deeper insights into the patterns and themes within this cluster. Bilal and Shanmugam (2021) discuss the need to migrate clinical and educational programs in rheumatology to virtual platforms at George Washington University. They highlight adopting innovative educational models and restructuring the curriculum to maintain clinical and didactic exposure. The study emphasises the importance of conducting a thorough needs analysis rather than hastily adopting e-learning as ‘Emergency Remote Learning’. The authors also highlight implementing a hybrid model combining in-person and virtual teleconsultations, among other strategies, and the plan to leverage learner feedback for continuous improvement.

Saqib et al. (2021) analyse the impact of COVID-19 on surgical education and highlight the challenges faced in surgical training. The study emphasises the mental health impact on professionals and discusses adaptations such as surgical e-learning, tele-clinics, simulation platforms and virtual webinars. Rawat et al. (2021) report on the strategies adopted in India to mitigate the impact of COVID-19 on medical student training. They raise practical questions regarding the suitability of e-learning for medical education and highlight concerns about the transfer of knowledge from virtual training to real-life practice. The study also addresses medical students' psychological challenges and emphasises the potential limitations

of relying solely on e-learning in medical education. Goldhammer and Linganna (2022) assess the impact of COVID-19 on graduate medical education globally. They highlight cancelling elective surgeries and terminating educational activities, including medical research. The study advocates for competency-based training as a long-term solution, focusing on the learner rather than time-based training. These studies provide valuable insights into the COVID-19-related issues being researched in medical education. They underscore the importance of program evaluation in e-learning and the challenges, impacts and mitigation strategies related to the pandemic. The papers within this cluster shed light on the ongoing efforts to adapt and find practical solutions to ensure the quality and effectiveness of medical education during these unprecedented times.

The documents with the highest citation were also clustered in a similar pattern. The papers in the first cluster were published between 1995 and 2020. The number of citations (according to Google Scholar) for these papers varies significantly, ranging from 84 to 1785, suggesting varying levels of influence and impact within the research community. The topics in this cluster focus on telemedicine technology, web-based learning tools, the evaluation of educational methods, and the use of technology in medical education during the COVID-19 pandemic. These papers highlight the growing interest in utilising technology for education and its impact on medical training and practice.

The papers in the second cluster were published between 2021 and 2022, indicating a more recent focus on the impact of the COVID-19 pandemic on surgical education and training, as well as the effects on medical students, trainees and residents. The number of citations for the papers in this cluster is relatively low, ranging from 0 to 3 citations. This suggests that these papers might be more recent and have not yet gained significant recognition or attention within the research community. The topics covered in the cluster emphasise the challenges and responses to the COVID-19 pandemic in medical education and the impact on surgical training and highlight the need to adapt educational methods, utilise technology and address the psychological well-being of medical professionals during the pandemic. Although both clusters focus on the utilisation of technology in medical education and its impact, cluster 1 covers a broader range of topics, including telemedicine and web-based learning, and Cluster 2 specifically addresses the challenges posed by the COVID-19 pandemic.

DISCUSSION

This study aimed to access and quantify the literature and identify the strengths, gaps, emerging trends, and collaboration opportunities in e-learning in medical education. The analysis of top publishing authors in the field of e-learning in medical education reveals a high level of collaboration among authors. This highlights the collaborative nature of research in e-learning in medical education, with most publications resulting from multiple authors working together. This collaboration demonstrates the importance of interdisciplinary efforts and knowledge exchange in advancing the field and addressing the complex challenges and opportunities in e-learning in medical education. The dominance of multi-authored papers suggests that researchers recognise the value of diverse perspectives and expertise in addressing the complex challenges and opportunities of e-learning in medical education. Professor John Edward Sandars' prolific publication record and high citation count indicate his significant contributions to the field. His sustained impact over the years, with increasing citations, reflects his work's enduring relevance and influence. The absence of citations in the early years of his publication may indicate that his research gained recognition and scholarly attention over time, leading to increased citations and visibility.

Professor David A. Cook's distinction as the most cited author underscores the impact of his research on e-learning in medical education. His high citation rate per document suggests that other researchers have widely acknowledged and cited his work, indicating its influence and importance. The spike in citations in 2021 suggests a special recognition and relevance of his contributions during that period. A previous bibliometrics of e-learning in health sciences also identified Professor Cook as the most prolific author in the domain (Sweileh, 2021). Dr Kieran Walsh's substantial publication record and collaborations with prominent authors such as Professor Sandars and Professor Cook demonstrate his active involvement in the field. His collaboration with these prolific authors signifies the recognition and respect he has gained among his peers. Previous scholars have identified this collaboration (Oluwadele et al., 2023; Sweileh, 2021) to showcase the interconnectedness of researchers and the collective effort to advance knowledge and practice in e-learning in medical education.

The publication distribution in the field of e-learning in medical education highlights a divide between developed and developing countries. This is reiterated in the study by Sweileh (2021). Developed countries, such as the United States, the United Kingdom and Germany, have a significant presence and long-standing contributions with established research outputs. In contrast, developing countries, including China and Brazil, have only recently started publishing in the e-LMED domain. This divide reflects the disparities in resources, infrastructure and research capabilities between developed and developing countries. Developed countries, with their advanced healthcare systems and robust educational institutions, have the necessary resources and expertise to engage in research on e-learning in medical education actively. They have established themselves as leaders in the field due to their early involvement and continuous contributions. During COVID-19, Ladha et al. (2021) confirmed that rapid collaboration and innovation in dermatologic education in Canada resulted in unique initiatives such as the deployment of a variety of internet-enabled group learning activities and a major increase in digital telehealth and virtual care. On the other hand, developing countries face challenges such as partial or complete inaccessibility of online courses due to poor internet speed (Diab & Elgahsh, 2020) and incompatibility between e-learning platforms and Android smartphones used by most students to access learning materials, leading to deteriorated students' performance (Adedoyin & Soykan, 2020). In low-income families, students find it challenging to afford a personal computer (Fry & Cilluffo, 2019), leading to education inequality (Hasan & Bao, 2020), mental stress and anxiety (Subedi et al., 2020).

The digital divide is mirrored by the divide in publication output between developed and developing countries and highlights the need for bridging the gap and promoting equitable participation. Nevertheless, the emerging presence of developing countries like China and Brazil signifies their growing commitment and efforts to contribute to the field. Collaboration and knowledge exchange between developed and developing countries can benefit both sides. Pathak and Singh (2023) revealed that China and the USA have a maximum number of collaborations, while India, the United Kingdom, Singapore and New Zealand have comparatively weaker collaboration networks in the mainstream e-learning space. This collaboration needs to be extended to e-learning in the medical education space. Developed countries can share their experiences, best practices and resources to support capacity building in developing countries.

Meanwhile, developing countries can bring fresh perspectives, unique challenges and innovative approaches to enrich the domain of e-learning in medical education. Efforts should be made to foster collaboration, promote partnerships and support capacity-building initiatives in developing countries. This will help bridge the publication divide and ensure that advancements in e-learning in medical education are accessible and applicable across different regions and healthcare contexts. By fostering inclusivity and equal participation, the

domain can comprehensively understand e-learning approaches, address global healthcare challenges, and enhance medical education practices worldwide.

The analysis of published sources in the field of e-learning in medical education reveals several prominent journals researchers can consider for publishing their work. Among the top sources, *Studies in Health Technology and Informatics*, focusing on biomedical engineering, health information management and health informatics; *BMC Medical Education*, a UK-based open-access journal focusing on training healthcare professionals and curriculum development; and *Medical Teacher*, another UK-based journal, addressing the needs of teachers involved in health professions training, emerged as the leaders. The list of the top 20 actively publishing journals highlights *Academic Medicine* as a leading journal with the highest number of citations per document. It is the official journal of the Association of American Medical Colleges and covers a wide range of topics, including education and training issues, health and science policy, and clinical practice in academic settings. *Academic Medicine* serves as an international forum for addressing challenges and exchanging ideas in the academic medicine community.

Choosing an appropriate journal for publishing research findings is crucial for researchers in the field of e-learning in medical education. *Studies in Health Technology and Informatics, BMC Medical Education, Medical Teacher, Telemedicine and E-Health, Journal Anatomical Sciences Education* and *Academic Medicine* stand out as active and reputable sources for disseminating research in this domain. These journals focus on various aspects of medical education, including informatics, curriculum development, teacher training, telemedicine and anatomical sciences education. Among these journals, *Academic Medicine* stands out with its high citation impact, indicating its influence and recognition within the academic medicine community. It covers various topics relevant to medical education and serves as a platform for addressing critical challenges and advancing the field. Researchers aiming to maximise the visibility and impact of their work should consider *Academic Medicine* as a potential outlet for publication. Previous studies analysing research trends in e-learning in medical education also identified *BMC Medical Education, Academic Medicine, Medical Teacher and Telemedicine and E-health* as the top publication sources (Hopcan et al., 2023; Sweileh, 2021). Choosing the right journal involves considering factors such as the journal's scope, its target audience, the relevance of the research to the journal's focus, and its reputation within the academic community. In e-learning in medical education, researchers should assess these factors when deciding where to submit their work. Exploring other journals beyond the top ones mentioned can also provide opportunities to target specific subfields, reach diverse audiences and contribute to the overall knowledge base in this rapidly evolving field.

The analysis of the evolution of keywords over the years shows the changes in topics within e-LMED across publication years. Initially, keywords like continuing education, distance education, methodology and user-computer interface dominated around 2004, indicating the early focus of e-learning on enhancing distance education and continuing medical education. In 2016, program evaluation emerged as a prominent topic, followed by the rise of telemedicine in 2017. Additional trending topics included social media, curriculum, healthcare personnel and clinical competence, which remained relevant until 2020 and 2021. However, the most significant trend has been the emergence and persistence of COVID-19 as a dominant topic in the field.

Analysing co-occurring terms in e-learning in medical education provides further valuable insights into the research landscape. By examining the closest links of co-occurrence with the terms ‘student’ and ‘covid’, we can delve deeper into the underlying themes and trends in the literature. The term ‘student’ is closely associated with terms like change, teaching, impact and face. This suggests that research in e-learning and medical education often explores how educational practices and approaches are evolving, the influence

of teaching methods on students, the impact of e-learning on student outcomes, and the importance of face-to-face interactions in the learning process. On the other hand, the term 'covid' shows significant co-occurrence with terms such as medical school, response, future, challenge, opportunity, face and students. This indicates that COVID-19 has become a central focus in the research on e-learning in medical education. The presence of 'covid' in both co-occurring terms highlights its pervasive influence on the research landscape. It suggests that researchers are actively studying the intersection of COVID-19 and e-learning in medical education, examining the effects, responses and potential adaptations in light of the pandemic. This provides insights into the specific focus areas and the evolving research landscape in e-learning and medical education, highlighting the growing significance of COVID-19 and its influence on teaching and learning practices in the field. Previous studies also identified a sharp incline in publications in the domain due to the COVID-19 pandemic (Dehnad & Abdekhoda, 2023; Oluwadele et al., 2023; Sweileh, 2021).

The findings from the analysis of co-occurring terms in the field of e-learning in medical education are confirmed by the findings from the analysis of the conceptual structure of the domain. The analysis of the studies clustered in multiple correspondence analysis reveals patterns, groupings and dependencies in the dataset, validating that the term co-occurrence indeed implies the direction and focus of research in the domain. The topic dendrogram groups studies together according to their hierarchical structure based on their interrelatedness. The first cluster colour-coded in blue shows COVID-19-related themes such as sars. cov.2, covid.19, pandemic and coronavirus disease 2019 and indicate relatively new areas of study that are less explored. Cluster two, colour-coded red, is linked to more researched concepts in e-LMED.

Several clusters of studies with the highest contributions were analysed. These clusters shed light on the evolving landscape of medical education, with varying perspectives on e-learning and a growing focus on technology and pandemic-related challenges. The first cluster examined the evaluation of e-learning in medical education. These studies presented conflicting evidence on its suitability. Although some found it engaging and supportive, others questioned its clinical adequacy, emphasising the importance of traditional teaching methods.

The second cluster focused on the challenges and impacts of the COVID-19 pandemic on medical education. It highlighted strategies to ensure training continuity, including the adoption of e-learning and telemedicine. These studies emphasised the mental health impact on professionals and the need for a balanced approach combining in-person and virtual training.

Another cluster examined highly cited papers from 1995 to 2020, indicating a growing interest in technology's role in medical education. These papers covered telemedicine, web-based learning and technology's impact during the pandemic. A newer cluster, from 2021 to 2022, addressed the pandemic's effects on surgical education and medical professionals' well-being, although these papers had fewer citations, suggesting emerging research.

CONCLUSION

This study evaluated the scientific productivity and impact of published documents in e-learning in the medical education domain, analysing the Scopus database and providing valuable insights into e-learning in medical education, highlighting key trends, collaborations and publication patterns. The analysis of top publishing authors emphasises the collaborative nature of research in this field, with multi-authored papers being predominant. Prominent

authors such as Professor John Edward Sandars and Professor David A. Cook have made significant contributions and garnered substantial citations, indicating their influence and impact on the field. The publication distribution analysis reveals a divide between developed and developing countries, underscoring the need for bridging the gap and promoting equitable participation. The analysis of top publishing journals identifies notable sources for researchers to consider when publishing their work, with *Academic Medicine* standing out as a highly cited and influential journal.

The evolution of keywords over the years highlights the changing focus and emerging trends in e-learning in medical education, with COVID-19 becoming a dominant topic. The analysis of co-occurring terms provides deeper insights into the research landscape, revealing the importance of teaching methods, student impact and face-to-face interactions in e-learning, as well as the profound influence of COVID-19 on medical education. The conceptual structure analysis and document clustering confirm the direction and focus of research in the field, with COVID-19-related themes emerging as newer areas of study. This study contributes to a comprehensive understanding of e-learning in medical education, shedding light on collaboration, publication patterns, emerging trends, and the impact of COVID-19. It underscores the importance of interdisciplinary efforts, knowledge exchange and addressing the unique challenges and opportunities in medical education. Researchers can leverage these insights to inform their future work and contribute to the advancement of e-learning in medical education, ultimately enhancing the quality and effectiveness of medical training and education.

Limitation

The research relies on a bibliometric examination of published papers, and its reliability hinges on the comprehensiveness of the studies encompassed within this review. Any noteworthy studies omitted from this review could potentially lead to incomplete or biased findings. Furthermore, the study's sole reliance on the Scopus database, despite its expansiveness, might result in the findings not accurately reflecting the entirety of the e-learning performance evaluation landscape in medical education. Additionally, while several data analysis and visualisation tools were employed, they may not encompass all facets of the data, potentially overlooking significant data patterns or trends.

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None.

CONFLICT OF INTEREST STATEMENT
There are no conflicts of interest.

DATA AVAILABILITY STATEMENT
The data that support the findings of this study are available from the corresponding author upon reasonable request.

ETHICS STATEMENT
Approval for conducting this research was received from the Research and Ethics Committee of the University of KwaZulu-Natal, Durban, South Africa.

ORCID
Deborah Oluwadele https://orcid.org/0000-0002-1425-8278

REFERENCES

Adedoyin, O. B., & Soykan, E. (2020). Covid-19 pandemic and online learning: The challenges and opportunities. *Interactive Learning Environments*, *31*(2), 1–13.

Alabdulwahhab, K. M., Kazmi, S. Y., Sami, W., Almujel, K. N., Alanazi, M. H., Alanazi, K. F., Moyana, A. M., Ahmad, M. S., Alasbali, T. A., & Al Alwadani, F. (2021). Use of online resources by undergraduate medical students at College of Medicine, Majmaah University, Kingdom of Saudi Arabia. *PLoS One*, *16*(8), e0255635.

AlQhtani, A., AlSwedan, N., Almulhim, A., Aladwan, R., Alessa, Y., AlQhtani, K., Albogami, M., Altwairqi, K., Alotaibi, F., AlHadlaq, A., & AlHadlaq, A. (2021). Online versus classroom teaching for medical students during COVID-19: Measuring effectiveness and satisfaction. *BMC Medical Education*, *21*(1), 1–7.

Alsoufi, A., Alsuyihili, A., Msherghi, A., Elhadi, A., Atiyah, H., Ashini, A., Ashwieb, A., Ghula, M., Ben Hasan, H., Abudabuos, S., Alameen, H., Abokhdhir, T., Anaiba, M., Nagib, T., Shuwayyah, A., Benothman, R., Arrefae, G., Alkhwayildi, A., Alhadi, A., … Abudabuos, S. (2020). Impact of the COVID-19 pandemic on medical education: Medical students' knowledge, attitudes, and practices regarding electronic learning. *PLoS One*, *15*(11), e0242905.

Amir, L. R., Tanti, I., Maharani, D. A., Wimardhani, Y. S., Julia, V., Sulijaya, B., & Puspitawati, R. (2020). Student perspective of classroom and distance learning during COVID-19 pandemic in the undergraduate dental study program Universitas Indonesia. *BMC Medical Education*, *20*(1), 1–8.

Aria, M., & Cuccurullo, C. (2017). Bibliometrix: An R-tool for comprehensive science mapping analysis. *Journal of Informetrics*, *11*(4), 959–975.

Azer, S. A. (2015). The top-cited articles in medical education: A bibliometric analysis. *Academic Medicine*, *90*(8), 1147–1161.

Barteit, S., Guzek, D., Jahn, A., Bärnighausen, T., Jorge, M. M., & Neuhann, F. (2020). Evaluation of e-learning for medical education in low-and middle-income countries: A systematic review. *Computers & Education*, *145*, 103726.

Bilal, S., & Shanmugam, V. K. (2021). Enhancing rheumatology education during the COVID-19 pandemic. *Rheumatology International*, *41*(3), 503–508.

Bista, S., Basnyat, R. S., Ranjit, R., & Subedi, N. (2021). Embracing electronic learning in medical education during COVID-19 pandemic. *Journal of Gandaki Medical College-Nepal*, *14*(1), 68–72.

Boulos, M. N. K., Maramba, I., & Wheeler, S. (2006). Wikis, blogs and podcasts: A new generation of web-based tools for virtual collaborative clinical practice and education. *BMC Medical Education*, *6*(1), 1–8.

Chick, R. C., Clifton, G. T., Peace, K. M., Propper, B. W., Hale, D. F., Alseidi, A. A., & Vreeland, T. J. (2020). Using technology to maintain the education of residents during the COVID-19 pandemic. *Journal of Surgical Education*, *77*(4), 729–732.

Chumley-Jones, H. S., Dobbie, A., & Alford, C. L. (2002). Web-based learning: Sound educational method or hype? A review of the evaluation literature. *Academic Medicine*, *77*(10), S86–S93.

Cooper, H., Hedges, L. V., & Valentine, J. C. (Eds.). (2019). Potentials and limitations of research synthesis. In *The handbook of research synthesis and meta-analysis* (pp. 517–525). Russell Sage Foundation.

Cooper, I. D. (2015). Bibliometrics basics. *Journal of the Medical Library Association*, *103*(4), 217–218.

Cosnita, R. M., Cimpean, A. M., & Raica, M. (2020). E-learning and E-assessement: Two big challenges of medical education management in Romania. *Journal of Innovative Business and Management*, *12*(1), 61–71.

Dehnad, A., & Abdekhoda, M. (2023). Mapping the publications of e-learning during the COVID-19 pandemic: A bibliometric analysis. *Journal of Scientometric Research*, *12*(1), 35–43.

Diab, G., & Elgahsh, N. F. (2020). E-learning during COVID-19 pandemic: Obstacles faced nursing students and its effect on their attitudes while applying it. *American Journal of Nursing*, *9*(4), 300–314.

Djeki, E., Dégila, J., Bondiombouy, C., & Alhassan, M. H. (2022). E-learning bibliometric analysis from 2015 to 2020. *Journal of Computers in Education*, *9*(4), 727–754.

Dogan, O. K. (2023). Trends and issues in science education in the new millennium: A bibliometric analysis of the JRST. *Science Insights Education Frontiers*, *16*(1), 2375–2407.

Donthu, N., Kumar, S., Mukherjee, D., Pandey, N., & Lim, W. M. (2021). How to conduct a bibliometric analysis: An overview and guidelines. *Journal of Business Research*, *133*, 285–296.

Dost, S., Hossain, A., Shehab, M., Abdelwahed, A., & Al-Nusair, L. (2020). Perceptions of medical students towards online teaching during the COVID-19 pandemic: A national cross-sectional survey of 2721 UK medical students. *BMJ Open*, *10*(11), e042378.

Finucane, P., & McCrorie, P. (2021). Cost-effective undergraduate medical education. In *Cost effectiveness in medical education* (pp. 5–13). CRC Press.

Fitzgerald, D. A., Scott, K. M., & Ryan, M. S. (2021). Blended and e-learning in pediatric education: Harnessing lessons learned from the COVID-19 pandemic. *European Journal of Pediatrics*, *181*(2), 447–452.

Förster, C., Eismann-Schweimler, J., Stengel, S., Bischoff, M., Fuchs, M., von Luckner, A. G., Ledig, T., Barzel, A., Maun, A., Joos, S., Szecsenyi, J., & Joos, S. (2020). Opportunities and challenges of e-learning in vocational training in general practice–a project report about implementing digital formats in the KWBW-Verbundweiterbildungplus. *GMS Journal for Medical Education*, *37*(7), Doc97.

Frenk, J., Chen, L. C., Chandran, L., Groff, E. O., King, R., Meleis, A., & Fineberg, H. V. (2022). Challenges and opportunities for educating health professionals after the COVID-19 pandemic. *The Lancet*, *400*(10362), 1539–1556.

Fry, R., & Cilluffo, A. (2019). *A rising share of undergraduates are from poor families, especially at less selective colleges*. https://vtechworks.lib.vt.edu/bitstream/handle/10919/92670/LowIncomesUndergradStudents.pdf?sequence=1&isAllowed=y

Gan, Y.-n., Li, D.-d., Robinson, N., & Liu, J.-p. (2022). Practical guidance on bibliometric analysis and mapping knowledge domains methodology–a summary. *European Journal of Integrative Medicine*, *56*, 102203.

Goldhammer, J. E., & Linganna, R. E. (2022). Survey says… the effects of the COVID-19 pandemic on graduate medical education. *Journal of Cardiothoracic and Vascular Anesthesia*, *36*(1), 84–85.

Gray, M. M., Dadiz, R., Izatt, S., Gillam-Krakauer, M., Carbajal, M. M., Falck, A. J., Bonachea, E. M., Johnston, L. C., Karpen, H., Vasquez, M. M., Chess, P. R., & Vasquez, M. M. (2021). Value, strengths, and challenges of e-learning modules paired with the flipped classroom for graduate medical education: A survey from the National Neonatology Curriculum. *American Journal of Perinatology*, *38*(S 01), e187–e192.

Hasan, N., & Bao, Y. (2020). Impact of "e-learning crack-up" perception on psychological distress among college students during COVID-19 pandemic: A mediating role of "fear of academic year loss". *Children and Youth Services Review*, *118*, 105355.

Hayat, A. A., Keshavarzi, M. H., Zare, S., Bazrafcan, L., Rezaee, R., Faghihi, S. A., Amini, M., & Kojuri, J. (2021). Challenges and opportunities from the COVID-19 pandemic in medical education: A qualitative study. *BMC Medical Education*, *21*(1), 1–13.

Hopcan, S., Polat, E., & Albayrak, E. (2023). Research trends in e-learning practices for postgraduate medical education: A systematic review. *Education and Information Technologies*, 1–25. https://doi.org/10.1007/s10639-023-12035-6

Huang, C., Yang, C., Wang, S., Wu, W., Su, J., & Liang, C. (2020). Evolution of topics in education research: A systematic review using bibliometric analysis. *Educational Review*, *72*(3), 281–297.

Khasawneh, R., Simonsen, K., Snowden, J., Higgins, J., & Beck, G. (2016). The effectiveness of e-learning in pediatric medical student education. *Medical Education Online*, *21*, 29516.

Kokol, P. (2018). Funding patterns of bibliometrics research. *Informatologia*, *51*(3–4), 142–148.

Kokol, P., Blažun Vošner, H., & Završnik, J. (2021). Application of bibliometrics in medicine: A historical bibliometrics analysis. *Health Information & Libraries Journal*, *38*(2), 125–138.

Kokol, P., Kokol, M., & Zagoranski, S. (2022). Machine learning on small size samples: A synthetic knowledge synthesis. *Science Progress*, *105*(1), 368504211029777.

Ladha, M. A., Lui, H., Carroll, J., Doiron, P., Kirshen, C., Wong, A., & Purdy, K. (2021). Medical student and resident dermatology education in Canada during the covid-19 pandemic. *Journal of Cutaneous Medicine and Surgery*, *25*(4), 437–442.

Leary, H., & Walker, A. (2018). Meta-analysis and meta-synthesis methodologies: Rigorously piecing together research. *TechTrends*, *62*(5), 525–534.

Mennin, S. (2021). Ten global challenges in medical education: Wicked issues and options for action. *Medical Science Educator*, *31*(Suppl 1), 17–20.

Murphy, M. P. A. (2020). COVID-19 and emergency eLearning: Consequences of the securitization of higher education for post-pandemic pedagogy. *Contemporary Security Policy*, *41*(3), 492–505. https://doi.org/10.1080/13523260.2020.1761749

Nagar, S. (2020). Assessing Students' perception toward e-learning and effectiveness of online sessions amid COVID-19 lockdown phase in India: An analysis. *Tathapi with ISSN 2320-0693 is an UGC CARE Journal*, *19*(13), 272–291.

Noesgaard, S. S., & Ørngreen, R. (2015). The effectiveness of e-learning: An explorative and integrative review of the definitions, methodologies and factors that promote e-learning effectiveness. *Electronic Journal of E-Learning*, *13*(4), 278–290.

Olmes, G. L., Zimmermann, J. S. M., Stotz, L., Takacs, F. Z., Hamza, A., Radosa, M. P., Findeklee, S., Solomayer, E.-F., & Radosa, J. C. (2021). Students' attitudes toward digital learning during the COVID-19 pandemic: A survey conducted following an online course in gynecology and obstetrics. *Archives of Gynecology and Obstetrics*, *304*(4), 957–963.

Oluwadele, D., Singh, Y., & Adeliyi, T. T. (2023). *E-learning performance evaluation in medical education—A bibliometric and visualization analysis*. Paper presented at the Healthcare.

Pathak, S., & Singh, N. (2023). Trends in E-learning research: Bibliometric analysis on Scopus publications post COVID-19 in Asian context. *Journal of Economic and Administrative Sciences*. https://doi.org/10.1108/JEAS-03-2022-0072

Perednia, D. A., & Allen, A. (1995). Telemedicine technology and clinical applications. *JAMA*, *273*(6), 483–488.
Raban, D. R., & Gordon, A. (2015). The effect of technology on learning research trends: A bibliometric analysis over five decades. *Scientometrics*, *105*(1), 665–681.
Rawat, S., Sharma, P. K., & Narang, A. (2021). How COVID (pandemics) impacted training of medical students, trainees, and residents? *Journal of the College of Physicians and Surgeons–Pakistan*, *31*(7), 147–148.
Rittel, H. W., & Webber, M. M. (1973). Dilemmas in a general theory of planning. *Policy Sciences*, *4*(2), 155–169.
Ruiz, J. G., Mintzer, M. J., & Leipzig, R. M. (2006). The impact of e-learning in medical education. *Academic Medicine*, *81*(3), 207–212.
Saaiq, M., & Ashraf, B. (2017). Modifying "Pico" question into "Picos" model for more robust and reproducible presentation of the methodology employed in a scientific study. *World Journal of Plastic Surgery*, *6*(3), 390–392.
Sandars, J. (2021). Cost-effective e-learning in medical education. In Taylor and Francis (Ed.), *Cost effectiveness in medical education* (pp. 40–47). CRC Press.
Saqib, S. U., Saleem, O., Riaz, A., Riaz, Q., & Zafar, H. (2021). Impact of a global pandemic on surgical education and training-review, response, and reflection. *Journal of the Pakistan Medical Association*, *71*(1 (Suppl 1)), S49.
Sawarkar, G., & Sawarkar, P. (2020). Critical appraisal of e-learning through mobile devices in medical education. *Indian Journal of Forensic Medicine and Toxicology*, *14*(4), 6733–6736.
Scherer, R., Siddiq, F., & Tondeur, J. (2019). The technology acceptance model (TAM): A meta-analytic structural equation modeling approach to explaining teachers' adoption of digital technology in education. *Computers & Education*, *128*, 13–35.
Sil, A., Das, A., Patra, A. C., Kumar, R., Pandhi, D., De, D., Seetharam, K., Bhari, N., Gupta, N., Rao, R., Mittal, A., Rathore, S., Poojary, S., Barua, S., Jagadeesan, S., Mohanty, S., Padhi, T., Sankar, V., Betkerur, J., & Rao, R. (2023). Impact of COVID-19 pandemic on dermatology teaching program in India: A survey on the faculty and residents' perspective. *Indian Dermatology Online Journal*, *14*(5), 643–652.
Subedi, S., Nayaju, S., Subedi, S., Shah, S. K., & Shah, J. M. (2020). Impact of E-learning during COVID-19 pandemic among nursing students and teachers of Nepal. *International Journal of Science and Healthcare Research*, *5*(3), 68–76.
Sweileh, W. M. (2021). Global research activity on e-learning in health sciences education: A bibliometric analysis. *Medical Science Educator*, *31*(2), 765–775.
Thompson, D. F., & Walker, C. K. (2015). A descriptive and historical review of bibliometrics with applications to medical sciences. *Pharmacotherapy*, *35*(6), 551–559.
Vallée, A., Blacher, J., Cariou, A., & Sorbets, E. (2020). Blended learning compared to traditional learning in medical education: Systematic review and meta-analysis. *Journal of Medical Internet Research*, *22*(8), e16504.
Venkatesh, S., Rao, Y. K., Nagaraja, H., Woolley, T., Alele, F. O., & Malau-Aduli, B. S. (2020). Factors influencing medical students' experiences and satisfaction with blended integrated E-learning. *Medical Principles and Practice*, *29*(4), 396–402.
Wade, S. W., Moscova, M., Tedla, N., Moses, D. A., Young, N., Kyaw, M., & Velan, G. M. (2019). Adaptive tutorials versus web-based resources in radiology: A mixed methods analysis of efficacy and engagement in senior medical students. *Academic Radiology*, *26*(10), 1421–1431.
Walsh, K. (2021). Cost effectiveness in medical education: Conclusion and next steps. In Taylor and Francis (Ed.), *Cost effectiveness in medical education* (pp. 130–134). CRC Press.
Wang, Z.-Y., Zhang, L.-J., Liu, Y.-H., Jiang, W.-X., Jia, J.-Y., Tang, S.-L., & Liu, X.-Y. (2021). The effectiveness of E-learning in continuing medical education for tuberculosis health workers: A quasi-experiment from China. *Infectious Diseases of Poverty*, *10*(1), 1–11.
Wang, Z.-Y., Zhang, L.-J., Liu, Y.-H., Jiang, W.-X., Tang, S.-L., & Liu, X.-Y. (2021). Process evaluation of E-learning in continuing medical education: Evidence from the China-gates foundation tuberculosis control program. *Infectious Diseases of Poverty*, *10*(1), 1–11.
Zupic, I., & Čater, T. (2015). Bibliometric methods in management and organization. *Organizational Research Methods*, *18*(3), 429–472.

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