Research article

Mapping the research landscape: A bibliometric analysis of e-learning during the COVID-19 pandemic

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ABSTRACT

The COVID-19 pandemic has considerably affected e-learning, leading to a surge in research output from 2020 to 2022. This increase is attributed to the rapid transition to online education, presenting challenges and opportunities for teachers. The shift to online education has also prompted the exploration of innovative approaches and educators' as well as learners' perceptions and experiences in e-learning. In this study, the research output on e-learning from 2020 to 2022 has been analyzed to reveal the major research trends. The study employs bibliometric techniques to explore the data retrieved from Scopus. Particularly, an analysis of metadata such as the geographical distribution of publications, authorship, keywords, and the impact of works has been conducted. The results reveal the most influential authors and works, as well as the emerging topics in the field. The data has been processed by utilizing bibliometric tools such as VOSviewer, Citespace, and Harzing's Publish or Perish.

1. Introduction

The COVID-19 pandemic has profoundly influenced the field of e-learning, leading to an increase in research output on this topic from 2020 to 2022. This rise can be attributed to several factors. Firstly, the swift shift to online education due to the pandemic has presented both challenges and opportunities for educators, particularly in addressing the needs of special education students [1,2]. Additionally, the pandemic has necessitated the identification of factors impacting e-learning effectiveness, such as engagement and the use of technology [3]. Furthermore, the shift to online education has prompted a need for innovative approaches (e.g., upgrading Enhanced Learning Management Systems (LMS); refining virtual classrooms and video conferencing tools; introducing more interactive and gamified learning; developing AI and Adaptive Learning Technologies; adopting more open educational resources; using virtual labs and simulations, etc.) and the exploration of teachers' perceptions and experiences in online teaching [4–6]. The opportunities and challenges for higher education institutions amid the pandemic have also been largely investigated, particularly in terms of infrastructure, student, and teacher effectiveness in online classes [7,8]. Finally, the pandemic has highlighted the importance of understanding learners' perceptions and experiences in online language education, providing insights for planning and implementing effective online learning strategies [9,10].

The COVID-19 pandemic has not only accelerated the adoption of e-learning but has also underscored the need for comprehensive research into the challenges, impacts, and effective implementation of e-learning systems during the crisis. The surge in e-learning research output during the pandemic reflects the urgency and significance of addressing the evolving landscape of education in the face of global crisis. Therefore, this study aims to map the research landscape of this surge in research output on e-learning during COVID-

19 pandemic. Specifically, the goal is to identify key trends and quantify the volume of research output, map out collaborative networks among scholars, institutions, and countries, and analyze the geographical distribution of research output. Additionally, the researcher will examine the main areas of focus in the research body, determine the most influential and frequently cited publications as well as identify primary contributors to the field of e-learning research.

1.1. Literature review

Before the COVID-19 pandemic, research on e-learning focused on understanding the benefits and challenges of blended learning, which combines online and face-to-face instruction. Studies explored different design approaches for blended courses and classified them based on their impact on the existing teaching program and student learning experience [11]. The goal was to guide teachers in choosing the most appropriate approach for designing blended courses.

Research showed that recent developments in education post-COVID-19 pandemic have been multifaceted, encompassing various aspects of educational delivery and student experiences. The pandemic has prompted a significant shift in educational practices, with a surge in online learning and the adoption of technology-based educational modalities [12]. This transition has not been limited to a specific region, as it has been observed in various countries [12,13].

The shift to online learning has not been without challenges, and the impact of this shift on educational activities has been profound, leading to disruptions in educational activities at all levels and fields globally [14]. The sudden outbreak of COVID-19 has created a major crisis in the education sector, prompting a reevaluation of traditional teaching methods and the exploration of alternative pedagogies. The crisis was precipitated by two primary factors: students' technological unpreparedness and the increase in educators' workload, both inciting overall concern regarding the quality of education [15].

Furthermore, the pandemic has necessitated a change in curriculum and pedagogical approaches to sustain the teaching and learning of various subjects [16]. The impact of the pandemic on medical education has been particularly noteworthy, prompting a rapid shift to online teaching for medical students [17]. Additionally, the pandemic has led to an increased appreciation for the merits of e-learning and related technology-based educational modalities [12].

While the pandemic has presented challenges, it has also created numerous opportunities for transformation and innovation. The COVID-19 global pandemic outbreak has prompted higher education institutions to adapt to new curricula, pedagogies, and educational management, leading to the rapid development and adoption of e-learning as the new normal in educational activities [18]. This shift to e-learning has been observed globally, specifically in higher education institutions, where avenues for the adoption of e-learning in a post-COVID-19 environment have been outlined [12]. The pandemic has accelerated the digitalization and internationalization efforts in higher education, providing an impetus for long-standing transformations in education [19].

Furthermore, the pandemic has led to a reevaluation of traditional teaching methods and the exploration of alternative pedagogies, with a focus on sustaining teaching and learning through changes in curriculum and pedagogical approaches. The adoption of e-learning has also been associated with increased student participation in online classes, highlighting the comfort and preference for online learning over traditional offline classes [20]. Additionally, the pandemic has paved the way for introducing digital learning and has provided opportunities for successful online learning factors, such as attitudes to e-learning, adaptability, and increased perceived usefulness [21,22].

Close observation on the recent developments on online transition during Covid-19 pandemic also revealed that many educational institutions are adopting hybrid learning models as well, combining both online and in-person instruction [23,24]. This approach allows for flexibility and accommodates varying student needs and preferences while also adhering to safety guidelines. Also, the pandemic has spurred innovation in online teaching tools and technologies. EdTech companies (e.g., Zoom, Google Classroom, Microsoft Teams, Blackboard, Moodle, Coursera, Khan Academy, edX, Peason) and educational institutions (e.g., Massachusetts Institute of Technology (MIT), Columbia University, The Open University) have been developing and refining platforms for virtual classrooms, interactive learning experiences, and assessment tools to enhance the quality of online education. These platforms offer free access to course materials, interactive learning experiences, and assessment tools to learners worldwide. Additionally, efforts are being made to address equity and accessibility issues in online learning [25,26]. This includes ensuring access to technology and internet connectivity for all students, providing support for students with disabilities, and designing inclusive online learning environments that accommodate diverse learning needs. Last but not least, it is noteworthy that governments and educational authorities have started implementing policies and funding initiatives to support online learning initiatives [27,28]. This includes investing in infrastructure for remote learning, providing grants for technology adoption in schools, and developing guidelines and standards for online education.

In general, the pandemic has led to the identification of key priorities and opportunities for improved advocacy and outcomes in education. As a result, the post-COVID-19 era has witnessed a transformation in educational practices, with a significant emphasis on online learning, digital transformation, and the exploration of alternative pedagogies. While the pandemic has posed challenges, it has also provided opportunities for innovation and improvement in educational delivery.

Overall, the pandemic accelerated the adoption of e-learning and highlighted the need to understand its benefits, challenges, and best practices. Therefore, the research output on e-learning during the COVID-19 pandemic has been extensive, covering various aspects of education.

To date, only a limited number of research studies have employed bibliometric analysis to chart and illustrate the knowledge structure of e-learning adoption during COVID-19 pandemic. Djeki et al. (2022) analyzed the e-learning research field by performing a bibliometric analysis of 12,272 publications from the Web of Science (WoS) database between 2015 and 2020 [29]. In addition, Fauzi (2022) made a comprehensive evaluation of e-learning in higher education institutions during the COVID-19 epidemic [30]. However,

the study focused on research output from 2020 to 2021 (incomplete year) in WoS database. Therefore, the current paper can be seen as an extension of an ongoing investigation of the subject matter. Most important, the current study examines the three-year period (from 2020 to 2022) that represents a significant turning point in the field of e-learning, as the emergence of the COVID-19 epidemic ushered in a completely new age of research in this domain starting from February 2020.

Other bibliometric studies have approached e-learning from various perspectives. E-learning in higher education was studied by Prioteasa et al. (2023) [31]. The period of the data ranged from January 1, 2020 to November 1, 2022. Zhang et al. (2023) examined the evolution of online learning research in medical education during and after the COVID-19 pandemic [32]. The findings indicate a significant increase in research production and a transition from immediate pandemic responses to refined strategies and interdisciplinary perspectives, highlighting global scholarly engagement and collaboration networks. Tonbuloğlu & Tonbuloğlu (2023) analyzed blended learning (BL) studies worldwide, focusing on social sciences, computer, medicine, and engineering [33]. It revealed an increase in BL studies since 2006, with the USA, UK, China, and Australia being the most cited countries. This research analyzed 4, 059 publications from 1965 to 2022, focusing on social sciences, computer, medicine, and engineering. According to the authors, BL practices have positive effects on learning and performance, offering more options and effective teaching methods. However, they have limitations, such as rising costs, fewer personalized learning options, and teacher-centered configuration. Martinez-Garcia et al. (2023) reviewed and analyzed research on distance learning and e-learning since 1970, revealing an exponential increase in publications [34]. The study focused on pedagogical processes, ICT, perceived value, and pandemic-related strategies, contributing to existing literature on e-learning structure. Wijaya et al. (2023) analyzed 1074 bibliographic sources from Scopus to identify current and future research in learning style detection [35]. As the authors state, popular topics include classification, adaptive learning, MOOCs, and learning style models like Felder-Silverman, VARK, and Kolb. Emerging areas include EEG signals, online learning, and feature extraction.

2. Methodology

2.1. Rationale

Although extensive study has been conducted on e-learning, it is necessary to systematically analyze the existing body of research and understand its overall structure. Hence, the author deems it imperative to carry out a bibliometric analysis on the subject in order to generate a thorough assessment. An in-depth analysis of e-learning would be beneficial for scholars and researchers as it would enable them to discern and examine any current deficiencies in research within this discipline, comprehend its research framework, and formulate projections regarding developing patterns and future endeavors. Therefore, the study intends to employ bibliometric techniques to analyze publications from 2020 to 2022 in the field of e-learning retrieved from Scopus. The metadata (i.e. research domains) will be processed through VOSviewer, Citespace, and Harzing's Publish or Perish to answer the following research questions posed in the present study:

1. What are the major characteristics of the research body on e-learning from 2020 to 2022?
2. What are the key areas of focus in response to COVID-19 pandemic?
3. Who are the major contributors to the research body on e-learning from 2020 to 2022?
4. What are the most cited and impactful publications in e-learning research?
5. What are the collaborative networks and partnerships among countries?

2.2. Tools

Bibliometrics is a quantitative method used to measure various aspects of scholarly publications and research impact. The application of bibliometrics has become widespread in research evaluation, scientific specialties, and research assessment methodologies [36]. It is mainly used to understand trends in scientific fields, delineate fields, and identify thematic structures [37]. The current study is based on the dataset retrieved from Scopus. The dataset was analyzed through the following software applications: Citepace, VOSviewer, and Harzing's Publish or Perish (Harzing's PoP), all of which are tools for conducting bibliometric analysis. The purpose of using all these programs was to perform a thorough analysis of the data, as each of these applications has the ability to carry out different tasks with varying levels of success. In addition, Scopus analytic tool was used to conduct descriptive analysis. Finally, qualitative analysis was also conducted by the author for each data set in order to interpret the results.

The rationale behind the author's decision to utilize the following software programs - Citepace, VOSviewer, and Harzing's Publish or Perish (Harzing's PoP) was as follows:

1. CiteSpace provides robust tools for temporal analysis, allowing users to track the development of scientific fields over time. The software is also well-known for its burst detection algorithm, which identifies sudden increases in the frequency of citations, highlighting emerging trends. Lastly, the software has rich analytical features and thematic mapping tools. The limitation of the software is its user complexity (e.g. steep learning curve) [38,39].
2. VOSviewer is a software tool for constructing and visualizing bibliometric networks. It is renowned for its advanced visualization capabilities, allowing users to create detailed maps that are easy to interpret. It can also process large datasets, making it suitable for extensive bibliometric studies. Lastly, its availability as a free tool makes it accessible to a wide range of users. Compared to Citespace, VOSviewer has a more user-friendly interface and focuses on straightforward visualization of bibliometric networks,

making it accessible to a broader audience, though it may lack some of the advanced analytical features (e.g. burst detection, temporal analysis, cluster analysis) of CiteSpace [40].

3. Harzing's Publish or Perish is a software program designed to help academics to present their research output and to provide evidence of their research impact. It predominantly retrieves and analyzes academic citations, offering a range of metrics to evaluate the research impact of authors and journals. This can be regarded as both the software's strength and its limitation as well. The software provides a wide array of citation metrics, including total citations, h-index, g-index, and others like the annual citation rate. This variety allows researchers to get a nuanced view of their impact. Lastly, users can analyze citation trends over time and identify highly cited papers [41,42].

The research process in the current paper started with retrieving the dataset from Scopus on July 22, 2023. The dataset was obtained by executing a keyword search using the string demonstrated in Appendix A. The search aimed to locate English-language publications related to e-learning (EL) during the COVID-19 pandemic outbreak published between 2020 and 2022. As a result, a total of 10,881 publications were obtained. The search criteria and procedures are illustrated in Fig. 1.
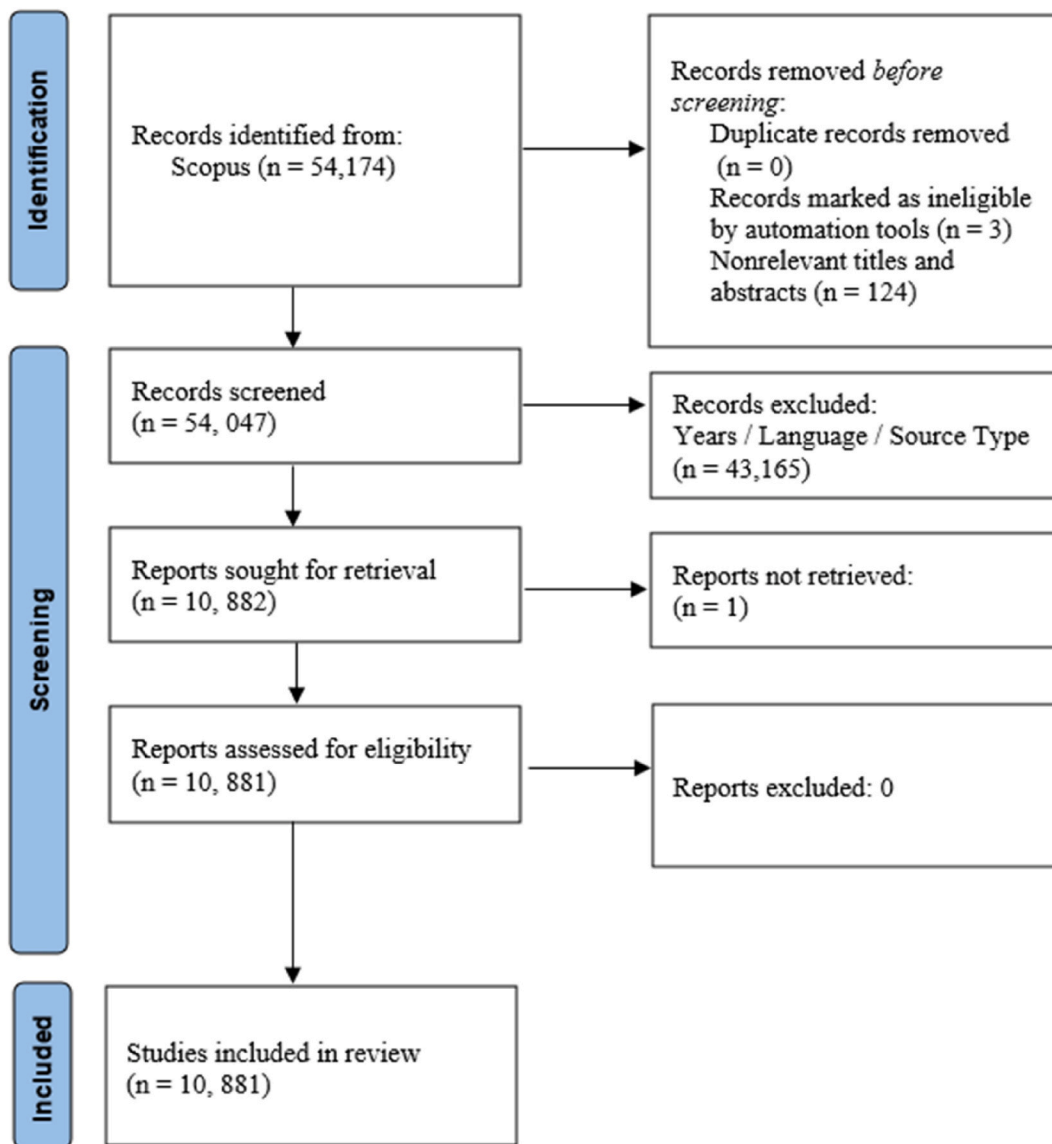

Fig. 1. Flow diagram of the search strategy.
Source: Adapted from Page et al. (2020) [43].

3. Results

3.1. Documents and source types

Prior to analyzing the data in VOSviewer, Citespace, and Harzing's PoP, it was intriguing to discover some noteworthy trends in e-learning-related research output between 2020 and 2022 on Scopus. Scopus analytics demonstrated a significant rise in research output during these years, as seen in Fig. 2.

The research output amounted to 2579 documents in the year 2020. Remarkably, it had a substantial increase of 62.76 % in the subsequent year of 2021 which can be predominantly attributed to the outbreak of COVID-10 pandemic. In 2022, the research output reached 4193 publications.

Subsequently, the author sought to retrieve the list of top ten contributors to the research body on the topic of e-learning. Table 1 presents the top ten most productive affiliations that have contributed to the research body in the field of e-learning from 2020 to 2022. Bina Nusantara University ranks first with 112 publications, while Universitas Negeri Malang and Universitas Pendidikan Indonesia follow with 110 and 67 articles, respectively.

According to Harzing's PoP analysis, the combined number of citations for all the papers in the dataset was 68146 over the course of three years (Table 2). The mean citation per publication is 6.3, whereas the mean citation per author is 3.35. The cumulative H-index has reached 94.

3.2. Geographical distribution of publications

An analysis of the geographical distribution of countries in bibliometrics is highly advantageous for research purposes as it enables researchers to obtain quantitative data regarding the distribution of research output through geographical domains and ascertain prominent research groups through countries.

Most Influential Countries. In order to perform analysis of geographical distribution of publications in e-learning, the Scopus data was analyzed in VOSviewer. In this analysis, the minimum number of documents of a country was set at 10. Of the 296 countries, 91 met the threshold. Fig. 3 presents the visualization of impact of countries in e-learning among 91 countries. Here, Total link strength (TLS) presents the intensity of the links between the nodes. Table 3 represents the data in Fig. 3.

Co-authorship and Cluster Analysis of Countries. Co-authorship analysis facilitates understanding collaboration patterns among countries in a specific field of study. It provides insights into the relationships and networks formed through research collaborations. While processing the data in the VOS viewer software, an approach of full counting was adopted, where each action, such as co-authoring a publication, is given equal weight. Fig. 4 illustrates the international co-authorship network in the field of e-learning, involving 105 countries grouped in 9 clusters.

The weight attribute Total link strength (TLS) determines the size of each node. With the increase in the intensity of collaboration, the size of nodes and the diameter of respective output lines increase as well. The strongest links in co-authorship among the above-visualized countries are the links between the USA and the UK.

Table 4 shows the data visualized in Fig. 4. The ten countries topping the list with the highest TLS are China, the United States, the United Kingdom, Malaysia, Saudi Arabia, India, Indonesia, Australia, Germany, and Spain. China holds the highest ranking (with TLS = 346) among all 105 listed countries. Next is the USA with TLS = 323 followed by the UK with TLS = 244. Table 4 lists the weight links, clusters, academic paper output, and citations along with the TLS attributes.

Additionally, it is worth noting that VOSviewer analysis of countries produced nine clusters. Through careful examination of the clusters, we were able to distill the factors contributing to the creation of the following clusters: factor 1. geographical proximity; factor 2. belongingness to a linguistic and/or cultural group; or factor 3. combination of 1 and 2. These factors contributed to more intense collaborations that formed the foundation of clustering., e.g.:

1. Cluster 1 – predominantly European countries (factor 1); Cluster 5 - predominantly Asian countries (factor 1)
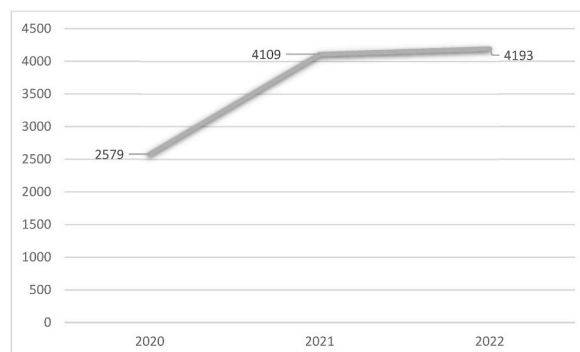

Fig. 2. Research document output on E-learning in scopus from 2020 to 2022.

Table 1

Top ten most productive affiliations.

Affiliation	Total Publications (TP)
Bina Nusantara University	112
Universitas Negeri Malang	110
Universitas Pendidikan Indonesia	67
Universitas Negeri Jakarta	62
Central China Normal University	58
Universiti Kebangsaan Malaysia	54
Universitas Negeri Yogyakarta	54
Universiti Teknologi Malaysia	53
Universiti Teknologi MARA	49
Universiti Malaya	48

Table 2

Harzing's PoP metrics of Research Output on E-learning between 2020 and 2022.

Harzing's POP metrics	Results
Papers	10881
Citations	68146
Years	3
Cites_Year	22715.33
Cites_Paper	6.3
Cites_Author	26072.71
Papers_Author	4557.97
Authors_Paper	3.35
H_index	94
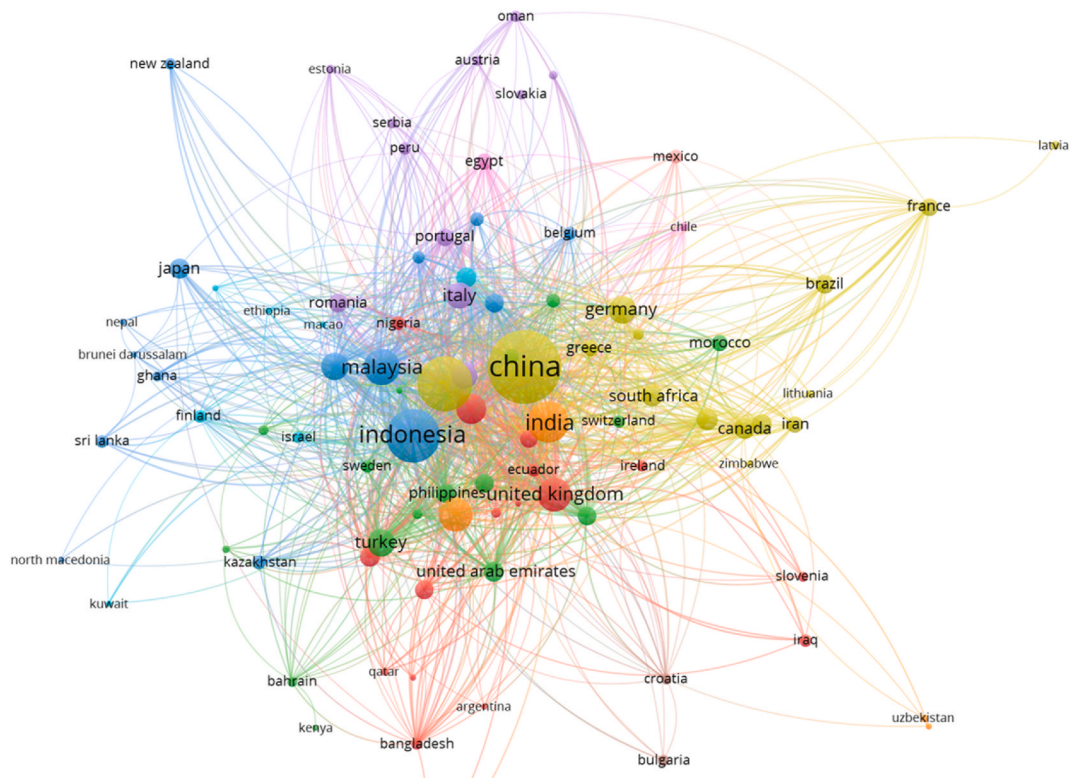
Fig. 3. Most influential countries.

Table 3
Most influential countries ranked by citations.

No.	Country	Documents	Scopus cites	TLS
1	The United States	1103	9116	478
2	China	1983	9028	1022
3	Indonesia	1071	4674	589
4	Saudi Arabia	341	4393	438
5	The United Kingdom	426	4224	449
6	India	626	4156	407
7	Malaysia	506	3924	551
8	Australia	285	3669	273
9	Spain	269	3353	275
10	Pakistan	148	2457	184
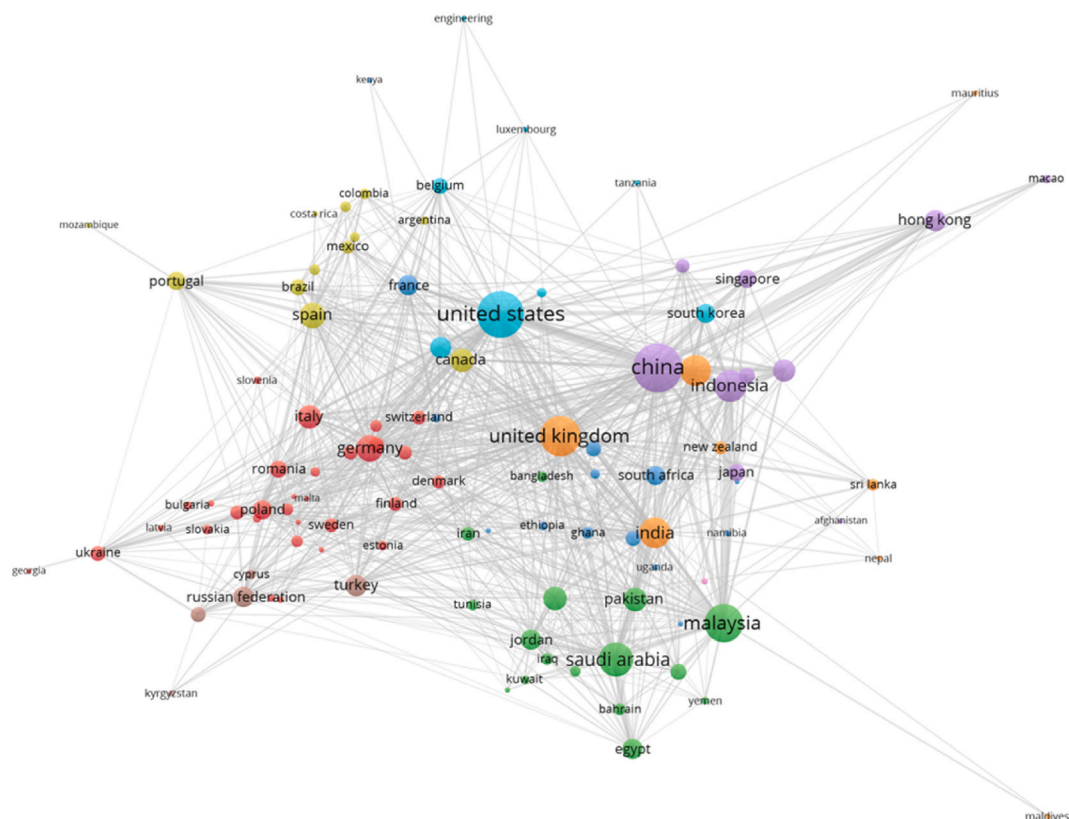
Fig. 4. Network visualization map of the Co-authorship among countries.
Note. Unit of analysis = Countries.
Tribute: TLS attribute.
Counting method: Full counting.
Minimum number of documents of a country = 5.
Minimum number of citations of a country = 5.
Minimum number of countries per document = 25.

  2. Cluster 2 – predominantly Arabic-speaking countries and/or Islamic countries (factor 2)
  3. Cluster 4 – predominantly Spanish-speaking countries and South America (factor 3)

3.3. Keywordsand emerging trends

Discovering connections between different themes or ideas within a given dataset is often achieved through analyzing keyword co-occurrence. By examining the frequency with which certain words or phrases appear together, researchers can develop a deeper understanding of the main themes and trends present within the research body. This knowledge can then be utilized to enhance research in fields such as natural language processing, search engine optimization, and data analysis. In the current study, VOSviewer

Table 4
Top 10 collaborating countries in E-learning.

Rank	Country	TLS	Cluster	Links	Documents	Citations
1	China	346	5	74	1983	9028
2	The United States	323	6	82	1103	9116
3	The United Kingdom	244	7	77	426	4224
4	Malaysia	221	2	57	506	3924
5	Saudi Arabia	169	2	50	341	4393
6	India	150	5	54	1071	4674
7	Indonesia	145	7	70	626	4156
8	Australia	139	7	68	285	3669
9	Germany	103	1	58	277	1892
10	Spain	100	4	57	269	3353

has been used for conducting a keyword co-occurrence analysis to uncover the most recent trends in the research field of e-learning from 2020 to 2022. Identification of "hotspots" (keywords or phrases that appear frequently in a dataset or text) can be particularly helpful in identifying patterns and connections within the data. Such hotspots can signal topics of high interest or relevance and can aid in the fields of study.

In this analysis, the minimum number of occurrences of keywords was set at 10. Of the 18057 keywords, 1116 met the threshold. The number of keywords to be selected was set at 50. As a result, we received a list that included the search target keywords as well, such as "e-learning". After eliminating the search target keywords, the list was further reduced to 38 keywords constituting five clusters. Appendix B shows the list of top 38 keywords sorted according to Total Link Strength (TLS) while Fig. 5 visualizes networks of keyword occurrences.

According to the data shown in Appendix B, the top ten keywords with the highest TLS are as follows: "higher education," "education," "pandemic," "COVID-19 pandemic," "students," "learning," "technology," "teaching," "gamification," and "medical education."

The clusters of active learning, challenges, perception, satisfaction, and technology in education are all related to the field of education. Active learning involves students actively engaging in the learning process, while challenges involve the COVID-19
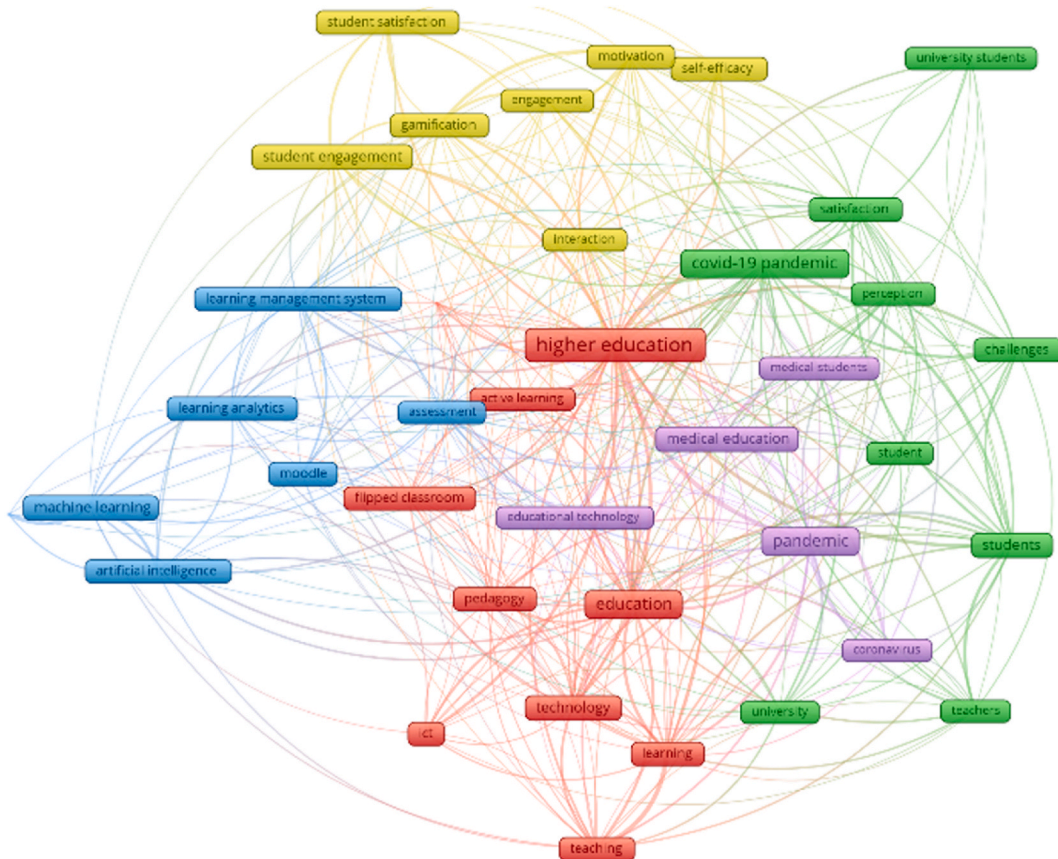
Fig. 5. Keyword Co-occurrence Visualization in VOSviewer.

pandemic's impact on traditional educational practices and the shift in perception towards online education. The COVID-19 pandemic has also influenced students and teachers' satisfaction levels, leading to the adoption of online and remote learning methods. The clusters of artificial intelligence, machine learning, and learning analytics are related to the integration of technology in education, highlighting the potential of these technologies to enhance assessment practices, support personalized learning experiences, and improve educational content management.

The COVID-19 pandemic has significantly impacted medical education, requiring the adoption of educational technology to facilitate remote learning and teaching. Factors such as engagement, gamification, interaction, motivation, self-efficacy, student engagement, and student satisfaction contribute to effective and satisfying learning experiences. The pandemic has also impacted medical students, with the closure of clinical placements and face-to-face teaching sessions disrupting their learning experiences. However, the use of technology has shown potential benefits, such as the ability to provide ongoing education and incorporate innovative approaches like gamification and virtual reality. These factors are interconnected and play important roles in promoting active learning, motivation, and positive learning outcomes.

3.4. Analysis of authorship

Authorship analysis is crucial in bibliometric research for at least two reasons. Firstly, it allows for the identification of prominent authors contributing to a specific research area. This is essential for understanding the key players and their impact on the field. Additionally, authorship analysis provides insights into collaboration patterns and networks.

Most Prolific Authors. To identify the most prolific authors, 10881 papers were analyzed on the topic of e-learning from 2020 to 2022 and authorship was illustrated from the perspective of productivity and their citation impact, specifically Citation per Paper (CPP) in Table 5. According to Table 5, the author who has produced the greatest number of documents on e-learning is Serevina, V. with 20 publications. Luo, H. and Tawafak, R. M. both have 12 publications, while Malik, S.I. has 11 publications. The other authors on the list have 9 publications each. Collectively, these scholars contributed to 109 papers, which accounts for 1 % of the whole research output on e-learning. Their combined work garnered a total of 530 citations, or 0.78 % of the overall citation count of 68,146.

The authors listed in Table 5 exerted significant effort in addressing the many challenges encountered during online instruction. To illustrate, in 2022 Vina Serevina together with his/her coauthors aimed to determine the feasibility of e-learning media for improving scientific literacy among high school students using the ADDIE model and investigated the impact of e-learning on students' scientific literacy skills [44]. The study concluded that e-learning can improve students' science literacy skills. Therefore, according to the authors, the development of e-learning can improve students' science literacy skills. Luo, H. aimed to understand the interplay among three constructs of online learning (self-regulated learning, perceived presences, and learning motivation) in China during the pandemic, considering demographic and contextual factors [45]. The study hypothesizes that self-regulated learning (SRL) positively predicts online students' CoI-presences, affects teaching, social, and cognitive presence, and can be influenced by demographic variables such as age, gender, education level, and discipline. The study also explored the role of college type in SRL. The results showed moderate correlations between SRL and learning motivation, with college rank and academic rank having a stronger correlation. The study concluded that SRL is largely determined by students' cognitive presence during the learning process.

Tawafak, R. M. and Malik, S. I. collaborated on a study that aimed to create an application for undergraduate students to learn Java language using an e-learning model [46]. The application was evaluated using an application questionnaire, with a 31.7 % agreement rate. The authors state that it was found to be easy to use, providing students with the necessary information and resources. The study also highlighted the benefits for students, teachers, and parents, such as access to educational content, the ability to follow the student's progress, and the ability to explain complex concepts. Doni Purnama Alamsyah, in 2022, in collaboration with several other co-authors examined the relationship between expected benefits, e-learning adoption, and psychological motivation of students and suggested that e-learning adoption can mediate between expected benefits and psychological motivation, providing valuable information for universities to improve the quality of e-learning assessed by students to improve performance [47].

Most Cited Authors. The author citation variable is a subject of significant interest in the academic community as it indicates the authors that have had the most influential impact on other publications. In other words, author citations serve as a quantifiable

Table 5
Top 10 most prolific authors and their impact in E-learning studies from 2020 to 2022.

Author	No. of publications	%	No. of citations	CPP
Serevina, V.	20	0.18	7	0.35
Luo, H.	12	0.11	43	3.58
Tawafak, R.M.	12	0.11	130	10.83
Malik, S·I.	11	0.10	121	11.00
Alamsyah, D.P.	9	0.08	34	3.78
Hirche, S.	9	0.08	74	8.22
Ouya, S.	9	0.08	4	0.44
Thi Van Pham, A.	9	0.08	1	0.11
Zhang, L.	9	0.08	45	5.00
Zhang, M.	9	0.08	71	7.89
Sub total	109	1.00	530	4.86
Total	10881	100	68146	6.26

Table 6
Most cited authors in E-learning studies from 2020 to 2022.

Citation	Centrality	Label
660	0.21	GARRISON D.R.
481	0.19	HAIR J.F.
396	0.1	DAVIS F.D.
390	0.07	CRESWELL JW
368	0.02	VENKATESH V
362	0.05	DHAWAN S
358	0.26	BANDURA A
321	0.03	HODGES C
174	0.04	ANDERSON T
163	0	MARTIN F

indicator of the significance of a specific piece of scholarly literature among the academic community. An analysis of author citation in Citespace allowed the author to extract the top ten most cited authors in e-learning studies from 2020 to 2022 (Table 6). The centrality-based calculations reveal that Garrison, D. R. has the top position in the ranking followed by Hair, J.F. with 481 citations, and others with citations ranging from 396 to 163 counts downwards.

These authors rightfully top the list above. For instance, D. Randy Garrison is distinguished in the field of education, particularly in the areas of online learning, blended learning, and educational technology, for his research contributions and theoretical frameworks. His work includes seminal publications on the topic of community of inquiry framework, which has provided a theoretical foundation for understanding and designing effective online learning environments. The theoretical frameworks developed by him have been widely adopted and applied in research and practice. Overall, his work has had a profound impact on the theory, practice, and policy of online education. Another author, Fred D. Davis, is also a distinguished figure in the field of Information Systems (IS) research, particularly in the area of technology acceptance and adoption. One of his notable models - Technology Acceptance Model (TAM) - has become one of the most widely used theoretical frameworks in IS research. TAM provides a foundation for understanding and predicting individuals' acceptance and usage of new information technologies. It has been extensively cited and applied in various contexts, contributing to the advancement of IS theory and practice.

Author Co-citation. Author co-citation analysis allows for the identification of author collaboration networks based on their works being cited together by other authors [48]. It provides insights into the intellectual structure of a research field by revealing the connections and interactions between authors and their ideas [49]. In the current study, of 10881 papers, 350866 authors were extracted. The minimum number of citations of an author was set at 10 where 12986 authors met the threshold. Fig. 6 illustrates the top ten most co-cited authors in the research output on e-learning from 2020 to 2022.

Table 7 displays the rankings of authors based on the number of citations they have received. "Wang y." holds the top position with 955 citations, while "graham c. r." follows closely behind with 884 co-citations. The remaining authors on the list were cited in a range from 873 to 511, with decreasing numbers.
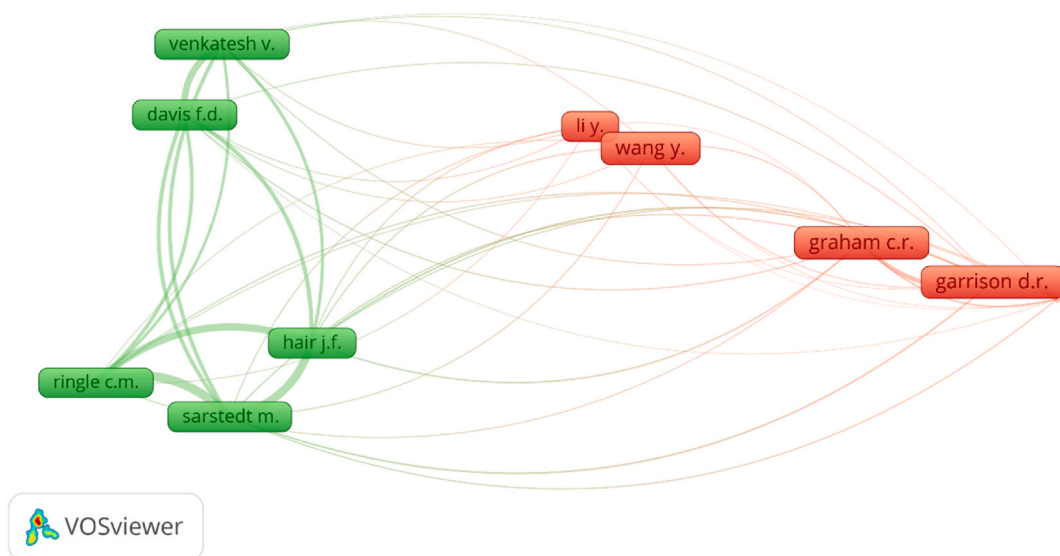

Fig. 6. Most Co-cited authors.

Table 7
Most Co-cited authors.

Rank	Author	TLS	Co-citation
1	wang y.	989	955
2	graham c.r.	1717	884
3	garrison d.r.	2662	873
4	anderson t.	1856	750
5	li y.	879	733
6	sarstedt m.	4914	720
7	venkatesh v.	2984	685
8	davis f.d.	3339	671
9	hair j.f.	4540	653
10	ringle c.m.	4254	511

Note. The data is depicted as presented by the software.

3.5. Impact of works – document citation and Co-citation analysis

Citation analysis is a fundamental tool in bibliometrics for assessing research impact and quality. It involves the study of citations, which reflects the usage and impact of a document [50]. Bibliometric methods such as citations and co-citations are essential for understanding the dynamics related to document production and impact, as well as the mutual influence between disciplines and scholars [51].

Most Influential Works. For the purpose of getting an insight into all the above mentioned, the author sought to analyze the data in Harzing's PoP software to extract the list of the most-cited works on the topic of e-learning between 2020 and 2022 years. Table 8 shows a list of the top ten most cited works which can be regarded as the most influential documents in the research field of e-learning during COVID-19 pandemic. Each of these works have an impressive count of citations and referenced by multiple authors. All of these landmark papers addressed the challenges, practices, and perspectives related to the sudden transition to online education during the pandemic. To illustrate, Bao (2020) explored a case of Peking University during the COVID-19 outbreak [52]. The study provides six instructional strategies for online education, including emergency preparedness, dividing content into smaller units, emphasizing voice in teaching, working with teaching assistants, strengthening active learning, and combining online and offline learning. Five high-impact principles for online education are also identified in the paper. In addition, Mishra and his/her co-authors explored how Mizoram University, India, adapted to e-learning and exams during the COVID-19 lockdown [53]. They addressed the challenges of online education and the use of virtual classes. The paper includes both quantitative and qualitative data from teachers and students. It highlights the importance of managing change and ensuring the continuation of education during the pandemic as well as it emphasizes the importance of online education and the need for effective implementation. Mukhtar et al. (2020) conducted a qualitative case study in Pakistani medical and dental institutes and found that online learning during the COVID-19 pandemic offers advantages like remote learning, comfort, and accessibility as well as limitations like inefficiency and academic integrity issues [54]. The study recommended continuous faculty development, reduced cognitive load, increased nteractivities, case-based learning, and investing in premium software to improve online learning. Al-Fraihet et al. (2020) developed a comprehensive model to evaluate e-learning systems, identifying success determinants and perceived satisfaction [55]. Data from 563 UK university students validated the model, focusing on technical system quality, information quality, service quality, support system quality, and perceived usefulness.

Document Co-citation. Co-citation analysis is a bibliometric method that involves examining the frequency with which two documents are cited together by other documents, providing insights into the intellectual connections and influences within a research

Table 8
Top ten most cited works in E-learning from 2020 to 2022.

Authors	Title	Cites	Year
Bao (2020) [52]	Covid-19 and online teaching in higher education: A case study of Peking University, human behavior and emerging technologies	917	2020
Mishra et al. (2020) [53]	Online teaching-learning in higher education during lockdown period of COVID-19 pandemic	756	2020
Mukhtar et al. (2020) [54]	Advantages, limitations and recommendations for online learning during covid-19 pandemic era	512	2020
Al-Fraihat et al. (2020) [55]	Evaluating e-learning systems success: An empirical study	434	2020
Rasheed et al. (2020) [56]	Challenges in the online component of blended learning: A systematic review	405	2020
Carrillo and Flores (2020) [57]	COVID-19 and teacher education: A literature review of online teaching and learning practices	397	2020
Coman et al. (2020) [58]	Online teaching and learning in higher education during the coronavirus pandemic: Students' perspective	386	2020
Khalil et al. (2020) [59]	The sudden transition to synchronized online learning during the COVID-19 pandemic in Saudi Arabia: A qualitative study exploring medical students' perspectives	351	2020
MacIntyre et al. (2020) [60]	Language teachers' coping strategies during the Covid-19 conversion to online teaching: Correlations with stress, wellbeing and negative emotions	341	2020

field [61]. This concept is crucial in understanding the intellectual structure of a field, as it reveals the relationships between different works based on their co-citation patterns.

With the purpose of retrieving the list of most co-cited documents in e-learning from 2020 to 2022, we analyzed the data in VOSviewer. In this study, a minimum threshold of 10 citations was established for source analysis. Out of the total of 315,080 sources, 561 sources met this threshold. All 561 sources with the highest TLS are visualized in VOSviewer in Fig. 7. A line linking two sources signifies that both sources have been referenced in the same publication.

The results were later reduced to the most co-cited documents, as shown in Table 9. "Dhawan s.," has topped the list [62]. The study focused on e-learning as a necessity during the COVID-19 crisis, forcing educational institutions to shift to online teaching. The article discusses the importance of online learning, the growth of EdTech startups, and the challenges associated with online education. According to the author, online learning is seen as a solution in times of crisis. Further on, Braun and Clarke (2006) delved into the topic of thematic analysis - a qualitative analytic method frequently utilized but rarely demarcated in psychology [63]. The paper asserts that it provides a user-friendly and adaptable method for analyzing qualitative data. The authors provided a concise definition of thematic analysis, situating it within the context of other qualitative analytical methodologies that aim to identify recurring themes or patterns, and examined possible challenges in the process of doing thematic analysis. Ultimately, they delineated the drawbacks and benefits of thematic analysis. UNESCO report (2020) emphasized the importance of communication, support for parents and care-takers, and dealing with prejudice and stigma during the COVID-19 crisis [64]. It also highlighted the need for academic support, teacher coordination, professional development, monitoring student returns, and addressing inequalities as well as highlighting the need to document lessons learned and develop risk-reduction plans. Fornell and Larcker (1981) examined chi square tests for structural equation models with unobservable variables and measurement error, addressing the drawbacks, sample size, and explanatory power issues, developing a system for shared variance measures [65]. The book "Statistical Power Analysis for the Behavioral Sciences" by Jacob Cohen provided a comprehensive guide to understanding and applying statistical power analysis in behavioral research. The work emphasized the importance of statistical power in research design and interpretation, addressing the ongoing neglect of statistical power analysis in behavioral sciences [66]. Hodges et al. (2020) shed light on the essential differences between the two terms: emergency remote teaching and online learning [67]. The authors also provided online learning design options as well as CIPP (context, input, process, and product) evaluation terms. Fred D. Davis's work on the Technology Acceptance Model has significantly influenced the study of technology acceptance, emphasizing the critical roles of perceived usefulness and perceived ease of use in shaping user acceptance of information technology [68]. The work "Self-efficacy: The exercise of control" by Albert Bandura, published in 1997, delves into the concept of self-efficacy, which refers to an individual's belief in their ability to achieve specific outcomes and exercise control over their actions. Bandura's work explores how self-efficacy influences individuals' motivation, cognitive resources,
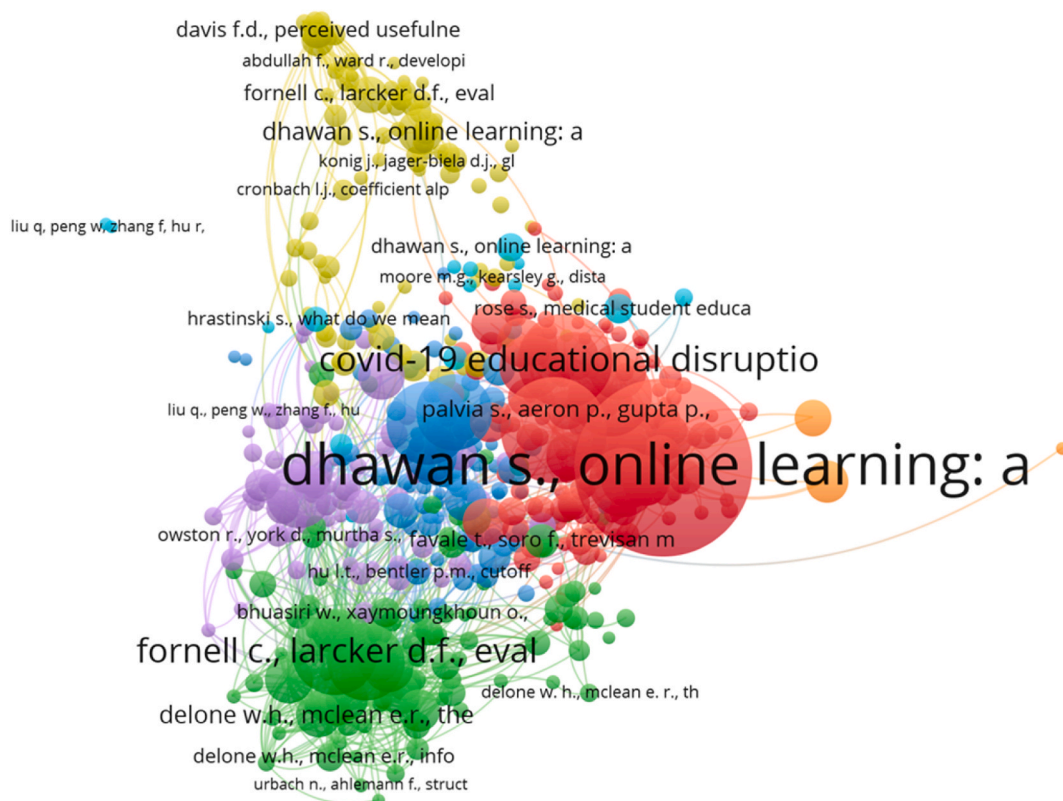

Fig. 7. Document Co-citation analysis in VOSviewer.

Table 9
Top 10 documents with the highest co-citation and total link strength.

Documents (as they appear in VOSviewer)	TLS	Citations
dhawan s., online learning: a panacea in the time of covid-19 crisis, journal of educational technology systems, 49, 1, pp. 5–22, (2020)	611	209
braun v., clarke v., using thematic analysis in psychology, qualitative research in psychology, 3, 2, pp. 77–101, (2006)	340	113
covid-19 educational disruption and response, (2020)	263	100
fornell c., larcker d.f., evaluating structural equation models with unobservable variables and measurement error, journal of marketing statistical power analysis for the behavioral sciences research, 18, 1, pp. 39–50, (1981)	573	88
cohen j., statistical power analysis for the behavioral sciences, (1988)	303	86
hodges c., moore s., lockee b., trust t., bond a., the difference between emergency remote teaching and online learning, educause review, (2020)	212	86
davis f.d., perceived usefulness, perceived ease of use, and user acceptance of information technology, mis quarterly, 13, 3, pp. 319–340, (1989)	464	78
bandura a., self-efficacy: the exercise of control, (1997)	263	77
bao w., covid-19 and online teaching in higher education: a case study of peking university, human behavior and emerging technologies, 2, 2, pp. 113–115, (2020)	253	68
garrison d.r., blended learning: uncovering its transformative potential in higher education, the internet and higher education, 7, 2, pp. 95–105, (2004)	297	63

and ability to regulate their thoughts, emotions, and physiological states. The book provides insights into the origins of self-efficacy within Bandura's Social Cognitive Theory and its role in determining behavior initiation, effort expenditure, and persistence in the face of obstacles and failures [69]. Garrison et al. (2004) discussed the transformative potential of blended learning in higher education, focusing on its ability to support deep and meaningful learning [70]. Online learning is pervasive, forcing educators to confront existing assumptions and meet the demands of prospective students. Blended learning is an effective and low-risk strategy that positions universities for technological developments in the coming years. The convergence of text-based asynchronous Internet-based learning with face-to-face approaches is having a volatile impact on traditional campus-based institutions. Blended learning is about rethinking and redesigning the teaching and learning relationship, resulting in deeper understandings and communities of inquiry. Administration and development issues pertaining to blended learning include policy, planning, resources, scheduling, and support. Organizational and leadership issues include drafting policy to guide technological innovation and developing prototypes that preserve traditional values. The conclusion is that blended learning is consistent with the values of traditional higher education institutions and has the proven potential to enhance both the effectiveness and efficiency of meaningful learning experiences.

It is important to mention that the majority of the above-listed documents in Table 9 are sources that offer guidance and a basis for dealing with obstacles associated to the COVID-19 crisis, including psychological and behavioral issues.

4. Discussion

In this study, an analysis of 10,881 papers has been conducted to provide insights into the focal areas and emerging patterns in studies related to e-learning between 2020 and 2022. The dataset was obtained from Scopus as it is recognized for its broader coverage of conference proceedings and international journals. The data analysis showed a significant increase in research output on e-learning, starting in 2020. Without a doubt, it can be attributed to COVID 19 outbreak. In 2021, there were 1,530 more scientific publications than in 2020. More than 50 % of the research conducted on e-learning consists of journal publications. The above-listed characteristics of the research body served as the basis for investigating research question 1.

To address research questions 1, 2, and 4, document citation analysis was conducted to expose some significant trends. It revealed that the top ten most cited works in e-learning share a common focus on the impact of the COVID-19 pandemic on online teaching and learning in higher education. They address various aspects of online education during the pandemic, including case studies, advantages, limitations, recommendations, empirical studies, and systematic reviews. The works collectively highlight the significant shift towards online education in response to the challenges posed by the pandemic, reflecting the growing importance of understanding and improving online teaching and learning practices, especially in higher education, during this unprecedented time. In addition, country analysis revealed that the USA, China, Indonesia, Saudi Arabia, the UK, India, Malaysia, Australia, Spain, Pakistan were the most influential countries in producing research output on e-learning from 2020 to 2022.

The data analysis also revealed a range of notable research topics in the field of e-learning based on the top keywords identified by both VOSviewer and Citespace. The "hottest" keywords such as "higher education" and "education" encompass various aspects of learning, teaching, and student engagement. Moreover, the integration of "technology", "gamification", and "artificial intelligence" in "higher education" is increasingly prevalent. In addition, "student satisfaction" and "motivation" play crucial roles in educational settings. The challenges posed by the COVID-19 pandemic have prompted the adoption of new technologies and teaching methods, such as "flipped classrooms" and "learning analytics" [71]. Additionally, the perception and pedagogy of university students, along with the use of "learning management systems", have become essential components of modern educational practices [72]. The above-listed areas represent the key areas of focus in response to COVID-19 pandemic (research question 2).

In order to further investigate research questions 2 and 4, the author analyzed document impact that revealed that all the top cited documents address aspects such as challenges and opportunities presented by the pandemic, the advantages, limitations, and recommendations for online learning, and the evaluation of e-learning systems' success. Additionally, the systematic review of challenges in the online component of blended learning contributes to understanding the complexities of transitioning to online education during

the pandemic. These works collectively provide insights into the experiences, strategies, and critical factors influencing the adoption and effectiveness of online teaching and learning in the context of the COVID-19 pandemic.

Most prolific authors, as measured by the CPP index, made significant contributions to the progress of research in e-learning. It is noteworthy that Tawafak, R.M. is the author who is among the most prolific authors with the highest number of citations and CPP index on this list, specializing in assessment practices in online language teaching and student perception of online learning. On the other hand, Garrison, D.R., the author with the highest total number of citations across 10881 papers (660 citations with centrality at 0.21), played a pivotal role in investigating e-learning environments and the associated challenges. Finally, the study of author co-citation indicated that "Wang Y.", with a significant number of 955 co-citations, played a substantial role in defining the research landscape of e-learning. These authors, along with the others listed in the paper, made major contributions to the research body on e-learning from 2020 to 2022 (research question 3).

Document co-citation analysis showed that the most co-cited documents revolve around the use of online learning as a response to the crisis posed by COVID-19, and the implications for psychological research and statistical analysis. The themes of crisis response, online learning as a panacea, and the need for methodological rigor in psychological research emerge across these works, reflecting the profound impact of the pandemic on educational and research practices. This particular form of analysis provided more insight into the fourth research question.

According to the data analysis, the countries with the greatest impact on research production on e-learning were the USA, China, Indonesia, Saudi Arabia, the UK, India, Malaysia, Australia, Spain, Pakistan (research question 3). It is noteworthy that the examination of co-authorship and cluster analysis across countries (research question 5) yielded a nearly identical compilation of countries as the majority of collaborating states (the USA, China, Indonesia, Saudi Arabia, the UK, India, Malaysia, Australia, Spain, Germany). The prominence of these countries in these areas may be ascribed to several factors. To begin with, it can be attributed to government support and funding. Countries like the UK, Australia, and Spain have robust government support and funding for research initiatives. This enabled universities and research institutions within these countries to conduct extensive studies on online teaching during the pandemic. Further on, technological infrastructure can be considered another factor. Countries like Saudi Arabia, the UK, Australia, and Malaysia have well-developed technological infrastructure, including high-speed internet and widespread access to digital devices. This infrastructure facilitates both the implementation of online teaching methods and research on their efficacy. Additionally, educational policies and priorities can make a big difference. India and Pakistan have been focusing on improving their educational systems, especially in the wake of the pandemic. This emphasis has led to increased research efforts to understand the impact of online teaching and to develop strategies for effective implementation. In addition to the aforementioned endeavors, there is a notable presence of international collaboration: many of these countries actively engage in international collaboration and partnerships with other institutions and researchers worldwide, as the analysis revealed. This collaboration enhances the scope and impact of research in e-learning. Last but not least, it is important to acknowledge the significant impact of cultural and linguistic variety. Countries like India, Malaysia, and Pakistan have diverse cultural and linguistic backgrounds, which influence educational practices and necessitate research tailored to specific cultural contexts and language requirements. This analytical approach offered valuable insights into the third research question.

5. Conclusion

The current study aimed to present the status quo of research body on the topic of e-learning during COVID-19 pandemic. The bibliometric analysis conducted revealed a significant increase in the volume of publications, reflecting the rapid adoption and adaptation of e-learning technologies in response to global educational disruptions. The study also identified key thematic areas, influential authors, institutions, and countries contributing to the field. Finally, the researcher identified the most influential and frequently cited publications and the primary contributors to the field of e-learning research.

Notably, the findings indicate that interdisciplinary collaborations have become more prevalent, with contributions from education, computer science, psychology, and other fields converging to address the challenges and opportunities presented by e-learning. Additionally, the analysis revealed emerging trends such as the integration of gamification and adaptive learning systems in e-learning platforms. Last but not least, there is a prominent focus on technological innovations, pedagogical strategies, and the psychological impact of e-learning on students and educators.

In conclusion, the COVID-19 pandemic has acted as a catalyst for e-learning research, accelerating innovation and collaboration across disciplines This unprecedented global crisis has compelled educators, technologists, and researchers to rapidly develop and implement novel solutions to maintain educational continuity. As a result, we have witnessed a surge in creative pedagogical approaches, the integration of cutting-edge technologies, and enhanced cross-disciplinary partnerships. These efforts have not only addressed immediate challenges but also paved the way for a more dynamic and resilient educational landscape.

5.1. Limitations

It is important to acknowledge that the current study has its limitations. To analyze a category such as affiliation names, the author resorted to Scopus analytics (rather than analyzing it through any other software) due to the reason that Scopus export files may lack harmonization (e.g. a consistent format) in this search category. Additionally, the data could have been obtained from Web of Science as well which would have facilitated a more extensive study of the research output. However, it is improbable that these restrictions impacted the findings in this research. Furthermore, this analysis exclusively indexed publications in English. Studies published in other languages may be overlooked, resulting in a limited representation of global research output on e-learning during the pandemic.

This can affect the generalizability of the analysis. Finally, bibliometric analysis may not capture contextual factors that influence research output on e-learning during the pandemic, such as funding priorities, policy changes, or societal trends. Addressing these gaps may potentially become the topic of future research projects.

5.2. Recommendations

The study's findings are valuable for various stakeholders in the e-learning field. To begin with, researchers seeking to understand the global landscape of e-learning research can identify key players and collaborative networks in the field. Besides, bibliometric analysis allows researchers to identify gaps in the existing literature on e-learning during the pandemic. By analyzing publication trends and citation patterns, researchers can pinpoint areas that have received limited attention or where further investigation is needed, guiding the development of future research projects. This analysis can be also used to explore emerging trends and research topics in the field of e-learning during the pandemic. Specifically, by identifying clusters of related publications and analyzing keyword trends, researchers can stay informed about new developments and areas of interest, shaping the direction of their research agendas.

Second, the study can provide insights for educational institutions and policy makers to understand the key research trends and plan for future developments in virtual learning. Specifically, policy makers can utilize the findings of bibliometric analysis to guide the evidence-based policies. By understanding the current state of research on e-learning during the pandemic, they can develop policies that are grounded in empirical evidence and tailored to address specific challenges and needs. Additionally, bibliometric analysis can help policymakers identify priority areas for investment and intervention in e-learning, understanding global perspectives, and supporting resource allocation.

Next, by analyzing research output, educators can identify effective teaching strategies and methodologies for e-learning during the pandemic. Insights from bibliometric analysis can help them adapt their teaching practices to better engage students in online environments and improve learning outcomes. Also, educators can identify relevant resources, tools, and technologies that have been studied and validated in the context of e-learning during the pandemic. In other words, this information can support them in selecting appropriate educational materials and digital tools to enhance their online teaching practices.

Finally, the study may as well benefit decision makers in universities as it can help them overcome the issue of low usage of e-learning systems after becoming familiar with challenges and factors influencing the e-learning system usage during the COVID-19 pandemic.

5.3. Future research

This research holds the possibility of being continued and improved in the future. The author refrained from doing a temporal analysis in the current study since it would have overextended the scope of the research paper. Subsequently, a temporal analysis can be carried out, particularly focusing on various periods which could possibly uncover some significant findings. Thus, the study has the potential to evolve into a juxtaposition of two temporal epochs - the preceding phase prior to the start of 2020 (pre-COVID-19 pandemic) and the subsequent period after the start of 2020 (post-COVID-19 pandemic). This could reveal past and emerging trends and hotspots in the research field. Finally, the search theme could be further narrowed down to gain a deeper insight into the dynamics of a specific research field.

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Data availability statement

The data have been included in the article and supplementary material.

CRediT authorship contribution statement

Marine Levidze: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The author declared that she has no known competing financial interests or personal relationships that could have appeared to influence the work reported in this article.

Appendix A

Scopus Database Keyword Search String.
TITLE ("ONLINE TEACHING" OR "ONLINE INSTRUCTION" OR "ONLINE EDUCATION" OR "ONLINE LEARNING" OR "ONLINE LEARNING ALGORITHMS" OR "DISTANCE EDUCATION" OR "DISTANCE LEARNING" OR "COMPUTER-AIDED INSTRUCTION" OR

"COMPUTER-AIDED LEARNING" OR "COMPUTER-AIDED TEACHING" OR "BLENDED LEARNING" OR "BLENDED TEACHING" OR "HYBRID LEARNING" OR "HYBRID TEACHING" OR "E-LEARNING" OR "E-LEARNING SYSTEMS" OR "E-LEARNING PLATFORMS" OR "VIRTUAL LEARNING" OR "REMOTE TEACHING" OR "EMERGENCY REMOTE LEARNING" OR "EMERGENCY REMOTE TEACHING" OR "COMPUTER-ASSISTED LEARNING" OR "COMPUTER-ASSISTED TEACHING" OR "COMPUTER-ASSISTED INSTRUCTION") AND PUBYEAR >2019 AND PUBYEAR <2023 AND (LIMIT-TO (DOCTYPE, "cp") OR LIMIT-TO (DOCTYPE, "ar") OR LIMIT-TO (DOCTYPE, "re") OR LIMIT-TO (DOCTYPE, "ch") OR LIMIT-TO (DOCTYPE, "no") OR LIMIT-TO (DOCTYPE, "ed") OR LIMIT-TO (DOCTYPE, "bk") OR LIMIT-TO (DOCTYPE, "sh") OR LIMIT-TO (DOCTYPE, "cr") OR LIMIT-TO (DOCTYPE, "rp")) AND (LIMIT-TO (LANGUAGE, "English")) AND (LIMIT-TO (EXACTKEYWORD, "E-learning") OR LIMIT-TO (EXACTKEYWORD, "Online Learning") OR LIMIT-TO (EXACTKEYWORD, "Distance Education") OR LIMIT-TO (EXACTKEYWORD, "Computer Aided Instruction") OR LIMIT-TO (EXACTKEYWORD, "Blended Learning") OR LIMIT-TO (EXACTKEYWORD, "Distance Learning") OR LIMIT-TO (EXACTKEYWORD, "E-Learning") OR LIMIT-TO (EXACTKEYWORD, "Computer-Assisted Instruction") OR LIMIT-TO (EXACTKEYWORD, "Online Teaching") OR LIMIT-TO (EXACTKEYWORD, "Online Education") OR LIMIT-TO (EXACTKEYWORD, "Virtual Learning Environments") OR LIMIT-TO (EXACTKEYWORD, "On-line Education") OR LIMIT-TO (EXACTKEYWORD, "E-learning Environment") OR LIMIT-TO (EXACTKEYWORD, "E − Learning") OR LIMIT-TO (EXACTKEYWORD, "E-learning Systems") OR LIMIT-TO (EXACTKEYWORD, "E-learning Platforms") OR LIMIT-TO (EXACTKEYWORD, "Hybrid Learning") OR LIMIT-TO (EXACTKEYWORD, "Virtual Learning Environment") OR LIMIT-TO (EXACTKEYWORD, "Virtual Learning") OR LIMIT-TO (EXACTKEYWORD, "Online Learning Environment") OR LIMIT-TO (EXACTKEYWORD, "Distance-learning")).

Appendix B

Appendix B
Co-occurrences of keywords in VOSviewer.

Rank	Keyword	Cluster	TLS
1	higher education	1	269
2	education	1	167
3	pandemic	5	162
4	covid-19 pandemic	2	140
5	students	2	121
6	learning	1	107
7	technology	1	100
8	teaching	1	89
9	gamification	4	72
10	medical education	5	70
11	satisfaction	2	65
12	motivation	4	63
13	machine learning	3	58
14	student engagement	4	57
15	challenges	2	53
16	teachers	2	48
17	learning management system	3	48
18	coronavirus	5	48
19	assessment	3	47
20	interaction	4	46
21	perception	2	44
22	pedagogy	1	43
23	university	2	43
24	artificial intelligence	3	43
25	engagement	4	43
26	ict	1	41
27	student	2	37
28	active learning	1	36
29	flipped classroom	1	35
30	learning analytics	3	35
31	student satisfaction	4	34
32	educational technology	5	32
33	moodle	3	30
34	medical students	5	30
35	engineering education	1	28
36	self-efficacy	4	25
37	deep learning	3	22
38	university students	2	17

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