Evolution and current state of research into E-learning

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A B S T R A C T

This article aims to undertake a bibliometric review along with a conceptual and intellectual analysis of research on distance learning and e-learning. The purpose of this study is to focus on several academic fields and offer a comprehensive approach on how research on distance learning and e-learning has been approached since 1970. This work applies several bibliometric techniques to assess the research evolution of topics addressed, the most productive authors and the most influential journals. The findings revealed an exponential increase of publications over the last 20 years, highlighting the evolution of topics. The research themes include four main groups: the first relates to pedagogical processes in terms of effectiveness, outcomes, learning strategies, interaction, and self-regulation; the second group includes aspects associated with ICT applied in distance education; the third group focuses on the perceived value, usefulness, acceptance, and satisfaction of e-learning; and the last group portrays the forced application of distance learning strategies to deal with the consequences of the pandemic. This work contributes to expanding the existing literature devoted to study the structure of research on e-learning. It analyses the most representative authors, institutions, and documents, and gathers the growing literature on e-learning, from distance learning in the seventies until the implementation of online learning in the COVID-19 era.

1. Introduction

As stated by Rodrigues et al. [1], there has been much debate regarding the concept of e-learning. These authors have defined it as 'an innovative web-based system based on digital technologies and other forms of educational materials whose primary goal is to provide students with a personalized, learner-centered, open, enjoyable, and interactive learning environment supporting and enhancing the learning processes.' Other related concepts include distance education, online learning, and web-based education, which have been extensively used in research. The term distance education or learning, usually used in the 20th century, evolved with the disruption of the Internet and innovative technologies, giving way to other forms of distance learning, such as web-based, virtual, online, and e-learning [2].

The main aspects to be considered for effective e-learning education are those related to the appropriate design and usability, fulfillment of the desirable learning outcomes, proper interaction with the instructor and other students, importance of the students' self-regulation and their learning styles, the redefinition of the educational roles, and the organizational investment in infrastructure, technology, and human resources. These requirements may boost the engagement, motivation and satisfaction of learners with the

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educational process. According to Rodrigues et al. [1], these characteristics have been addressed in e-learning research over the last decade.

The purpose of our study is to present a comprehensive approach using bibliometric methods of the evolution of e-learning in various research areas since 1970.

Bibliometrics serves as a quantitative tool employed for the systematic examination of the intellectual scene within a specific scientific domain. Its utility lies in the facilitation of a comprehensive portrayal of the outcomes derived from such an analysis, wherein it elucidates the interrelationships among primary publications, authors, academic institutions, and subject matter themes [3]. The most applied methods include evaluative and relational techniques to analyze productivity, impact, co-citation and co-authorship patterns, co-occurrence of keywords, and bibliographic coupling.

Some bibliometric studies have addressed the analysis of how research has evolved, the current state, and the foreseeable trends of e-learning. The most recent ones are those of Djeki et al. [4], which covers the period 2015–2020; Vaicondam et al. [5], which analyzed 1371 papers on digital learning published between 2002 and 2021; Bai et al. [6] studied 7214 documents published between 1999 and 2018 in 10 top journals; Chen et al. [7], focusing on 555 papers on smart learning; Marín, Gabarda & Vidal [8], which covers 219 papers published between 2010 and 2020; Tibaná-Herrera, Fernández-Bajón & De Moya-Anegón [9] for the period 2012–2014.

Other studies have focused on specific applications of e-learning such as gamification [10], virtual reality, artificial intelligence [11,12], mobile learning [13] and augmented reality [14].

Most recently, the challenges of education in the COVID-19 era have been addressed through bibliometric studies since 2020, especially covering the topics analyzed and the most critical areas [15–17].

Although these works offer a review of e-learning, the periods and documents covered do not include the overall range of existing studies. No previous bibliometric study has addressed our analysis of the comprehensive approach to e-learning from 1970 to 2022, including 25,632 documents in all journals indexed in several research categories. Therefore, the purpose of our study is to close the gap, presenting the research progress since 1970 until the present days, and the possible future trends of e-learning, especially after the pandemic, which has led to a new scenario of implementation strategies for distance education. Thus, our study aims to answer the following Research Questions (RQ).

RQ1. What are the main topics addressed in e-learning research and their evolution?

RQ2. What are the most prolific journals publishing e-learning studies?

RQ3. What are the main co-citation patterns of these journals?

RQ4. What are the main authors, journals where they publish, and topics they have addressed?

RQ5. What are the most cited articles on e-learning?

Our work aims to gain a better understanding of the several purposes of e-learning investigation, encouraging researchers to conduct diverse research.
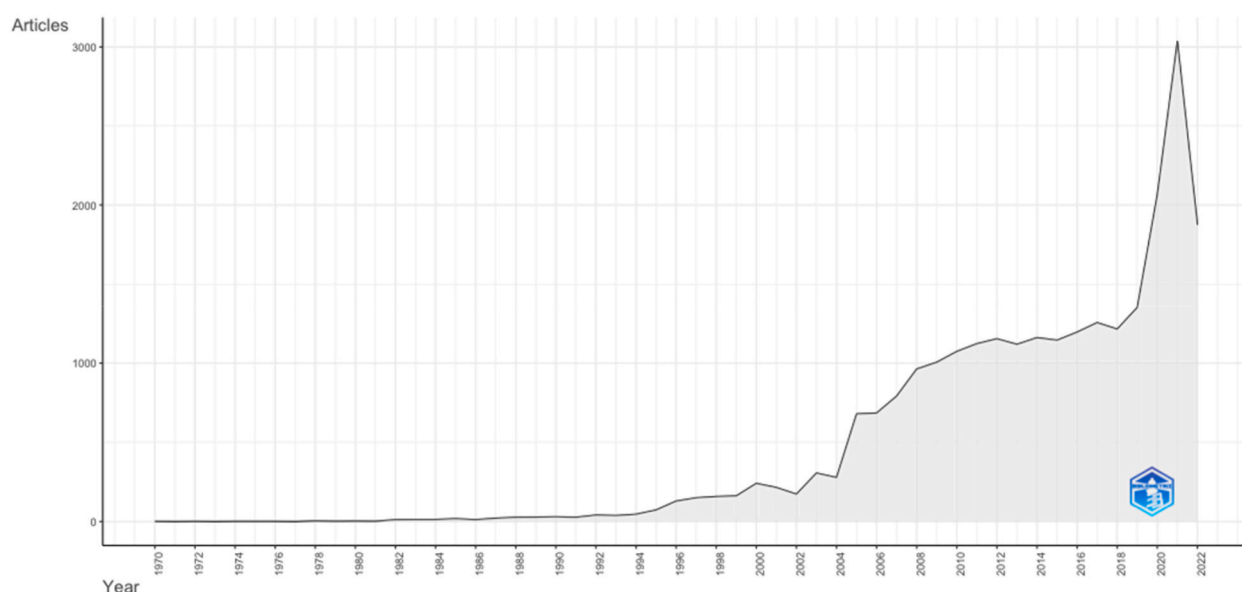

Fig. 1. Scientific production of papers on distance and e-learning (1970–2022). **Source:** Web of Science (WoS) and RStudio.

2. Literature review

The scientific production of distance and e-learning papers has increased exponentially since 1970, with an annual growth rate of 15.59 %, as shown in Fig. 1.

2.1. First period: the 70's and the 80's

The term distance learning was a recurrent research topic in the second half of the 20th century, especially in the fields of education and computer science. Studies such as those of Hofstetter [18] and Harden [19], offer some insights into the concept, and the characteristics that it must fulfill, using the terms distance and computer-based learning. The 70s and the 80s research on distance, computer-based and electronic learning focused on the instructional process [20,21]; the uses of computer-assisted learning for people with disabilities [22,23], the role of libraries in distance education [24], distance learning in medical education [25–28], and the design of effective courseware [29–33].

2.2. Second period: the 90's

In the 90s, some of the topics remained significant in research, such as the use of virtual laboratories and simulators in health education [34–36], engineering [37], linguistics [38], and geography [39]; the learning process using computers by people with disabilities [40]; and the role of libraries [41]. Obviously, the development of the Internet in that decade led to its use in e-learning, and some research has addressed the instructional design and usability of courses [42,43]. However, the focus of e-learning research was related to its pedagogical approach and its critical factors: the effectiveness of courses in terms of specific outcomes and acquisition of competences [44–46]; the satisfaction, attitudes, and motivation of students [47,48]; learning and teaching strategies [49–52]; the importance of the interaction with the tutor and peers [53–55]; and the relevance of collaborative work in distance education [56,57].

2.3. Third period: 21st century

The 21st century has been prolific in terms of e-learning publications, witnessing the evolution of this topic from a computer-based system in the 20th century to a hypermedia and multimedia environment, until the development of the 'world wide web'. Recently, innovative practices using portable devices, social media, and augmented/virtual reality, have emerged. In addition, recent years have witnessed how the pandemic has reshaped the approach to education, giving way to forced e-learning process adoption all over the world. Research has revealed the evolution from several areas with many approaches, including pedagogical and instrumental aspects.

Students' perceptions are a significant indicator of the quality of the learning experience and its outcomes [1]. Thus, one of the main topics of research is student satisfaction. For instance, Paechter et al. [58] refer to the achievement of academic goals, tutors' roles, self-regulation, and collaboration with peers as critical aspects and predictors of success.

Satisfaction is also closely linked to terms such as perceived usefulness. Thus, acceptance and intention to use e-learning have been addressed by applying the Technology Acceptance Model (TAM), usually explained by factors related to perceived usefulness, quality, value, or enjoyment, such as the works of Lee et al. [59], Saadé and Bahli [60], Chiu et al. [61], Yang et al. [62], Cidral et al. [63], Al-Samarraie et al. [64], Salloum et al. [65], Pham et al. [66], Revythi and Tselios [67].

Another important attribute of e-learning is the social presence and interaction with tutors and peers [68]. It has been shown to have a positive impact on student motivation, participation, perceived learning, and satisfaction [69]. In addition, researchers have addressed self-regulation in e-learning. It refers to the motivation and learning strategies of students to achieve their academic goals, and has been analyzed as a success factor in the learning process [70–72]. According to authors such as Davies and Graff [73] and Pardo et al. [74], both interaction and self-regulation are relevant factors affecting academic performance.

The last five years have witnessed increased attention drawn to new thematic areas: Massive Open Online Courses –MOOCs- [75, 76], mobile learning [77–79], virtual and augmented reality [14,80], social media tools [81], gamification [82–85], data mining and data analytics [86,87], blockchain [88] and the server's capacity and security [89].

2.4. Research in the COVID-19 era

The spread of COVID-19 in 2020 led to the interruption of educational activities, and forced educational institutions to implement distance and electronic learning. Thus, since 2020, much research has been devoted to studying several features of new teaching methods during the pandemic. According to the data extracted from the Web of Science (WoS), 30 % of the documents published over the last three years on e-learning have addressed the consequences of the pandemic.

Hence, some works have dealt with the extent of e-learning use in universities, obstacles encountered, advantages and disadvantages, and motivation and perceptions of students and teachers [90–95]. Other studies have focused on the psychological effects on students, such as stress, depression, anxiety, emotional changes, and resilience skills of university students [96–98]. Access to equipment and the digital divide [99], especially in developing countries, have also been a matter of importance in research, giving way to the necessity of implementing strategies in the future to improve the critical factors in education [100,101]. Thus, some studies have focused on the challenges after COVID in terms of access to equipment, infrastructure improvement, e-learning framework implementation [102], and hybridization or mixed methods applied after confinement [103]. In early and middle education, the analysis pinpointed how students cope with distance learning, the relevance of the lack of equipment, communication with teachers,

parenting style and their implication, academic engagement [104], and even the increase in cyberbullying and the use of electronic devices without parental supervision [105,106].

In recent years, e-learning research has been revolutionized by the forced implementation of distance learning strategies and tools by educational institutions to deal with the consequences of the pandemic. As mentioned, the main issues addressed were the experience of teachers, learners, and educational staff, their perception, acceptance and satisfaction with the implemented processes, the effects on their mental health, the effectiveness of the learning methods and the future strategies of governments and institutions. The bibliometric of Boonroungrut et al. [15], Brika et al. [16] and Fauzi [17] offer a good account of the topics covered, the most productive countries, and the most cited documents. Thus, according to Brika et al. [16], the core topics in e-learning research related to the pandemic have been the technology acceptance model (TAM), stress, special education needs, mental health, student satisfaction, surgical teaching, self-efficacy, and technology adoption. Boonroungrut et al. [15] also refers to two important research issues, mental health, and medical education: the psychological and emotional distress of students and the problems and challenges of medical students that must face hands-on and clinical practices in the COVID era.

3. Methodology

Pritchard [107] defined bibliometrics as 'the application of mathematical and statistical methods to books and other means of communication.' It has been defined in other terms, such as a tool to understand how a scientific discipline has evolved from an intellectual, social, and conceptual perspective [108,109] and to detect patterns in research [110].

This has been commonly applied in the literature, applying evaluative techniques and relational techniques [3,111]. The first technique includes the number of publications, which assess productivity [112], the number of citations, which measures their influence [113], the h-index [114], the g-index [115] and the m-index. Thus, these methods depict the most influential productive authors and journals regarding electronic learning. The methodologies employed in our study also involve the utilization of relational techniques, specifically the examination of keyword co-occurrence and the analysis of journal co-citations. These techniques facilitate the creation of graphical visualizations and the generation of graphical representations of scientific output. The concept of co-citation entails an association between two documents that are commonly cited together by a third document, thus elucidating interrelationships within scholarly literature [116]. The examination of keyword co-occurrence involves the analysis of a document's content by assessing the occurrence of word pairs. This method enables the discernment of connections between concepts within a particular field of study. The strength of the conceptual linkage is directly proportional to the frequency with which the words appear together in the document [117]. The keyword co-occurrence analysis offers a network of topics and their links [118–120]. The
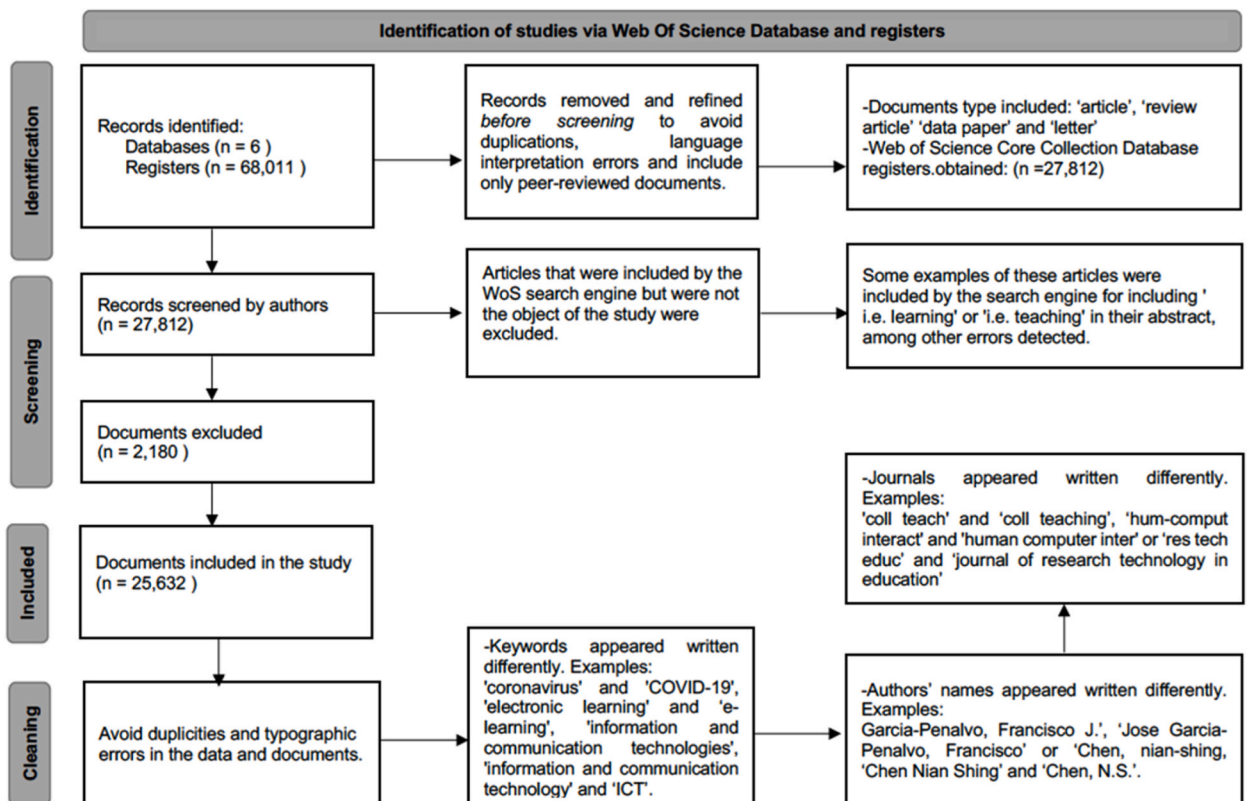
Fig. 2. PRISMA flow diagram applied to our analysis.

software used was VOSviewer [121] and Bibliometrix [122]which combine fractional counting and full counting methods.

According to Martinez-Garcia et al. [109] Merigó et al. [123], WoS is thought to be a leading database worldwide. Our raw data were collected in September 2022. In the search we used the following filters: 'e-learning', 'elearning', 'electronic-learning', 'e-teaching', 'distance-learning', 'courseware' and 'e-class' for all the years available in WoS '1900–2022' within all fields. The search resulted in 68,011 registers, and to assess only relevant literature for the study, we applied Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA flow diagram). Therefore, we selected the WOS Core Collection database and considered articles, review articles, data papers, and letters. We screened all records to exclude those that did not fall within the scope. That gave us 25,632 documents to include in the study. PRISMA flow diagram has been recommended by authors such as Martinez-Garcia et al. [109], Munn et al. [124] and Page et al. [125]. Unlike the original PRISMA application, we adapted the flow including a last phase or section for bibliometrics, consisting of an extra cleaning to correct errors detected in the indexing of publications [109]. Fig. 2 shows the process performed through PRISMA.

4. Results

4.1. E-learning in education: key bibliographic data

We analyzed 25,632 documents published between 1970 and 2022 in several journals. Over 90 % of documents were articles, including 46,032 authors keywords and keywords plus. Out of a total of 58,460 authors, 5933 have published single-authored articles. Hence, multi-authored works correspond to approximately 90 % of the total amount of documents. The collaboration index between authors stands at 3.03 authors per document.

4.2. Keywords analysis

To answer RQ1, in this section, we have analyzed the co-occurrence of keywords on e-learning, the relationship between them, and the hot topics. Fig. 3 illustrates the co-occurrence of the keywords, showing the most cited keywords and providing a network of topics and their connections. According to Mulet-Forteza et al. [3], 'this methodology entails an examination of a document's content by evaluating the prevalence of word pairs, enabling the discernment of associations between concepts within a specified domain. The

Fig. 3. Co-occurrence of keywords. Includes only citations with a threshold of 200 and the 100 most representative links. Source: WoS database; image generated by the VOSviewer software.

degree of conceptual correlation is positively correlated with the frequency of word co-occurrence within the document'. A threshold of 200 keywords and the key 100 connections was applied.

Fig. 3 shows five clusters of different colors, each headed by a central keyword. The size of the nodes indicates the frequency of keywords. 'Education', 'e-learning', 'technology', 'covid-19' and 'system' are the words with the most co-occurrences in each of their clusters. Each node is linked to the words of its own nodes, but also to other nodes.

4.2.1. Outcomes and pedagogical strategies

The first cluster in red has the most keywords, with a total of 35. It is led by 'education', which has relationships with concepts from the same cluster such as 'student', 'online', 'performance', 'impact', 'feedback', 'competence', 'classroom', 'performance', 'achievement', 'motivation' and 'strategy'. Therefore, this cluster relates to educational and pedagogical processes in terms of effectiveness, acquisition of competencies, outcomes, and learning and teaching strategies.

4.2.2. Information and communication technologies in education

The green cluster is led by the keyword with the most co-occurrences in our study, 'e-learning'. 'E-learning' has a high relationship not only with the words in the same node, but also with all the other main keywords in the other clusters. 'Distance learning', 'higher education', 'distance education', 'blended learning', 'internet', 'information and communication technology (ICT)', 'm-learning', 'educational technology', 'multimedia', or 'social media' are some of the main words that form this cluster. These topics showed a strong relationship with the context of new technologies applied in distance education. Most relate to different terms that have evolved over time due to Internet disruption: from distance learning and blended learning to recent topics such as mobile learning and social media.

4.2.3. Attitudes, acceptance, perceived value, and satisfaction

The third cluster in blue is led by the word 'technology' with a total of 17 keywords. The main keywords of this node are related to those of other clusters and to 'acceptance' of the same cluster. In addition, other relevant keywords are 'model', 'perception', 'satisfaction', 'technology acceptance', 'attitude', 'user acceptance', 'quality', 'information', 'self-efficacy', 'adoption', 'behavior', 'e-learning system'. Thus, it includes topics associated with the technological environment of e-learning and electronic systems, their perceived usefulness and value, and therefore the acceptance among users and students' satisfaction.

4.2.4. The pandemic effects on e-learning

The fourth cluster in yellow color is led by the keyword 'covid-19', and it is closely linked to 'e-learning', 'higher education', 'distance learning', 'distance education' and 'student' from other clusters, but also with words from the same cluster such as 'pandemic', 'MOOC', 'online learning', 'university' and 'challenges'. This depicts the forced application of distance learning strategies by universities to deal with the consequences of the pandemic.

The fifth cluster is formed by words such as 'system', 'learning management system', 'Moodle', 'ontology' or 'learning style', which are mainly related to words from other clusters.

Fig. 4 shows graphically the recent trend topics during the years 2010–2022, which can be split in two sub-periods: the first one, between 2010 and 2018, where the most frequent topics were distance and blended learning, e-learning, m-learning, higher education, ICT, assessment and MOOCs; the second one, since 2019, with the prominence of the topic on-line learning and learning analytics in that year, the relevance of covid-19, medical education and artificial intelligence in 2020 and 2021, and the importance of themes such
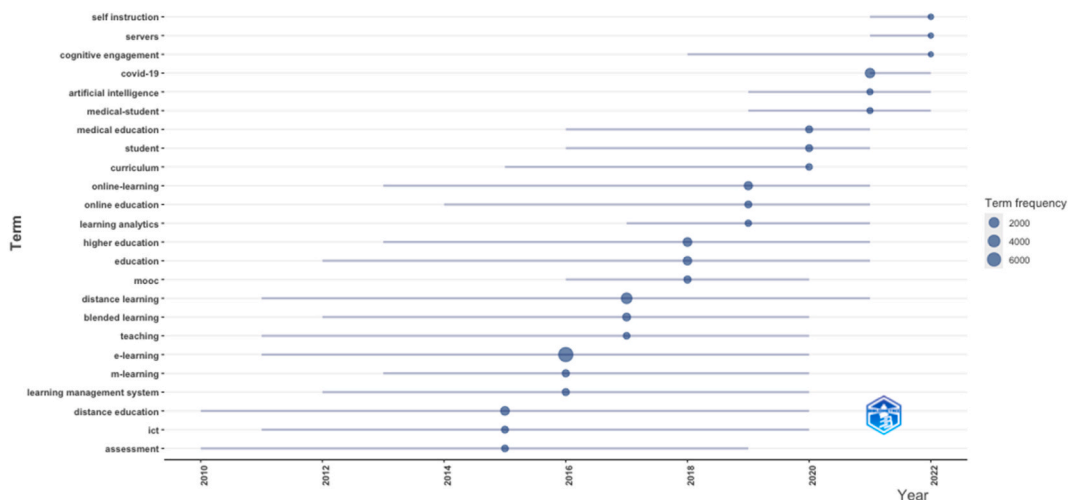

Fig. 4. Leading topics 2010–2022.**Source:** based on Web of Science (WoS) data and RStudio. Timespan: 2010–2022; Word Minimum Frequency: 10; Number of Words per Year: 3.

as servers' capacity and security, the cognitive engagement of students on the tasks and assignments and self-instruction in 2022.

4.3. Most prolific journals

The 25,632 documents gathered were published in 4152 different journals. To answer RQ2, we applied Bradford's Law of Scattering. Garfield [126] indicated that it is a convention by which scientific journals are grouped in decreasing order of article productivity. Fig. 5 graphically represents the frequency of the top five journals in and their accumulated published documents for the period 1970–2022. Table 1 lists the 25 most relevant sources and their clustering, ranking them by the *h*-index [114]. Generally, *H-index* is used as a tool for predicting future research [127]. We have also included impact measures such as *m*-index [128], *g*-index [129], total citations (TC) of the number of publications (NP), and the inception of the journal publication of E-learning topics (PYS).

Among the top five sources that published the most on the analyzed topic, the first journal that started publishing was *Computers and Education* (in green) in 1979. Since then, it has been the journal with most cumulative occurrences until 2022. In 2008, more than 50 articles were published on e-learning. The *International Journal of Emerging Technologies in Learning* (in blue) started publishing papers in 2006 and in this short period it has been placed at the top of the journals that publish the most papers. These are the only two journals that have published more than 500 articles. The third place is occupied by the *British Journal of Educational Technology* (in pink), whose first articles were published in 1983. Fourth, the *Turkish Online Journal of Distance Education* (purple) started publishing its papers on e-learning (21) in 2005. The fifth place is *Education and Information Technologies,* with more than 300 articles published since 2005.

The influence of the journal is quantified through the assessment of the h-index and g-index, which are determined based on citation counts and publication records. To mitigate potential disparities stemming from recently published articles, we have incorporated the preexisting impact indices along with the introduction of the m-index, incorporating the parameter 'PYS'.

Computers & Education is the journal with the highest number of publications and citations received, almost tripling the second-ranked journal with a total of 40,117 in 606 of its 624 articles. It is also the journal with the highest h-index and g-index, almost doubling the following journal in the ranking. The second place is for *Computers in Human Behavior,* with 13,968 citations in 240 out of 243 published documents. The third position, with 11,162 citations received in 367 of the 443 publications, is in the *British Journal of Educational Technology*. If we observe the m-index, the outcome switch, and *Internet and Higher Education*, which was in fifth place, becomes the first in the ranking with the highest impact. The leading three journals have exceeded the publication threshold of 1300 documents on e-learning. The most relevant journal is *Computers & Education* with 624 articles. *Computers in Human Behavior* follows with 243 publications and in the third position is the *British Journal of Educational Technology* with 443 publications. All sources represented in Table 1 are in the core zone 1 of Bradford's law, with a total of 4996 documents published.

Fig. 6 illustrates the co-citation associations among the journals present in the compiled dataset, addressing Research Question 3 (RQ3). Co-citation refers to the frequency at which two documents are jointly cited within the reference lists of other scholarly works [116]. Each journal's citation count is visually depicted through node size, where larger nodes correspond to higher citation counts. Given the substantial interconnectedness between various journals, we have applied a minimum threshold of 1000 citations, thereby directing our attention towards the examination of the most noteworthy interactions among the foremost journals.

Fig. 6 shows the relation of the four clusters. The main one in red gathers 22 journals. The top two journals are the *British Journal of Educational Technology* with 5746 citations and *Internet and Higher Education* with 5411 citations, both are indexed in the first quartile of the 'Education & Educational Research' category of the Web of Science, and are the only two journals in the cluster that exceed 5000 citations. In addition to maintaining relationships with the journals in the same cluster, they also maintained links with the two main journals of the second and third clusters: *Computers & Education* and *Computers in Human Behavior*. Two journals have more than 4000
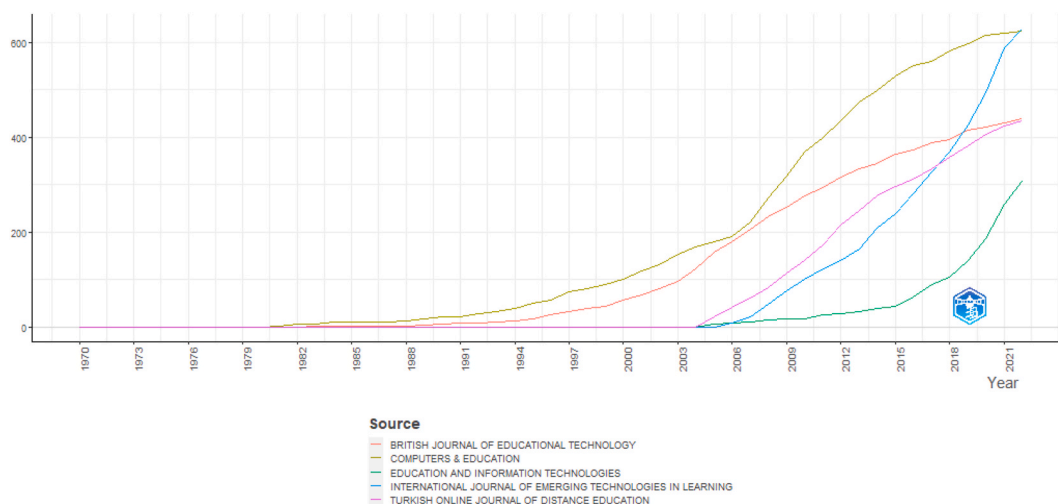

Fig. 5. Journals growth. **Source:** elaboration based on Web of Science (WoS) data and RStudio.

Table 1
Ranking of the 25 top journals.

R	Source	Zone	h_index	g_index	m_index	TC	TP	NP	PYS
1	Computers & Education	1	106	171	2.409	40117	624	606	1979
2	Computers in Human Behavior	1	65	108	2.031	13968	243	240	1991
3	British Journal of Educational Technology	1	53	86	2.789	11162	443	367	2003
4	Educational Technology & Society	1	46	76	2.3	7896	280	266	2003
5	Internet and Higher Education	1	43	74	2.867	5588	83	78	2008
6	Journal of Computer Assisted Learning	1	43	69	1.593	5768	182	180	1995
7	ETR&D-Educational Technology Research and Development	1	36	62	1.59	4329	147	133	1989
8	IEEE Transactions on Education	1	36	63	0.9	4986	168	161	1982
9	International Review of Research in Open and Distributed Learning	1	35	61	2.5	5106	254	231	2009
10	Expert Systems with Applications	1	33	59	1.138	3884	107	105	1994
11	Interactive Learning Environments	1	29	42	1.526	2975	205	184	2003
12	IEEE Transactions on Learning Technologies	1	27	46	1.8	2675	124	112	2008
13	Education and Information Technologies	1	26	38	1.529	3229	331	289	2005
14	Australasian Journal of Educational Technology	1	25	34	1.563	1820	123	115	2007
15	Distance Education	1	25	37	1.667	1561	79	71	2008
16	BMC Medical Education	1	24	40	1.714	1981	128	102	2009
17	Electronic Journal of E-Learning	1	24	37	1.333	2095	220	183	2005
18	Journal of Chemical Education	1	23	35	1	2801	314	267	2000
19	Journal of Educational Computing Research	1	23	38	0.697	1961	122	111	1990
20	Sustainability	1	23	32	2.3	1779	237	170	2013
21	American Journal of Distance Education	1	22	42	1.222	1865	77	58	2005
22	IEEE Access	1	22	35	2.75	1645	177	136	2015
23	International Journal of Engineering Education	1	22	28	0.917	1589	197	171	1999
24	Medical Teacher	1	22	40	0.647	1790	88	81	1988
25	Anatomical Sciences Education	1	21	38	1.5	1503	43	41	2009

Notes: R: Ranking; **TP:** total publications; **CF:** cumulative frequency; **TC:** total citations; **NP:** number of publications with citations; **FPY:** publication year start. **Source:** elaboration based on Web of Science (WoS) data and RStudio.
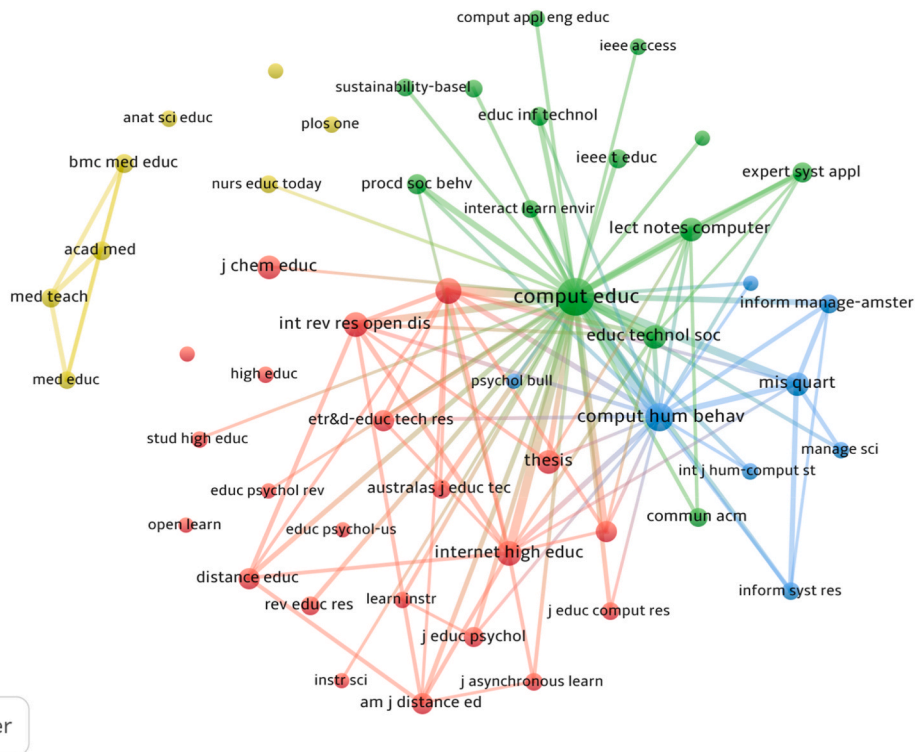

Fig. 6. Co-citation between journals. Threshold of 1000 and the 100 most representative connections. Source: elaboration based on Web of Science (WoS) data; figure formed by the VOSviewer Software.

citations: *Thesis* and *Journal of Chemical Education*, the latter indexed in the second quartile of the WoS category 'Education, Scientific Disciplines'. *ETR&D-Educational Technology Research and Development* with 3111 citations, *Journal of Computer Assisted Learning* with 2820 citations and *Distance Education* with 2769 citations are among the journals indexed in the first quartile of the WoS category 'Education & Educational Research'. The *Journal Of Educational Psychology* is indexed in the first quartile of 'Psychology, Educational', which has received 2294 citations.

The second cluster, in green, consists of 14 journals. The journal *Computers & Education* is the most influential with 19,987 citations received. It is the only journal with more than 9000 citations and is linked to the four clusters. It is indexed in the first decile of the categories 'Education & Educational Research', and 'Computer Science, Interdisciplinary Applications' of the WoS. *Educational Technology & Society* is the second most significant journal in this group with 4189 citations, indexed in the second quartile of the category 'Education & Educational Research' and with relationships with journals in the first and third clusters. Four other journals in this cluster are above 2000 citations: *Lecture Notes in Computer Science* with 3935 citations, *Procedia - Social and Behavioral Sciences* with 2639 citations, *Expert Systems with Applications* with 2300 citations and *Education and Information Technologies* with 2126 citations, the latter indexed in the first quartile of the categories 'Operations Research & Management Science' and 'Education & Educational Research' respectively.

The third cluster in blue comprises eight journals led by *Computers In Human Behavior* with 8394 citations and with many connections to journals in the same cluster, as well as in the first and third clusters. It is indexed in the first quartile of the categories 'Psychology, Experimental', and 'Psychology, Multidisciplinary'. It is followed by *Mis Quarterly* with 4433 citations and *Information & Management* with 2153 citations, both indexed in the first quartile of 'Computer Science, Information Systems'.

The fourth cluster (in yellow) consisted of eight journals that focused on health. *Medical Teacher,* and *Academic Medicine* with 2217 and 2116 citations respectively, are the two leading journals indexed in the first quartile of the WoS category 'Education, Scientific disciplines'. The third journal, *BMC Medical Education,* has 2097 citations and is indexed in the second quartile of the WoS category 'Education & Educational Research'.

4.4. The scientific structure of the relationship among authors, keywords, and journals on e-learning

Sankey's diagram graphically represents flow relationships and has been applied in works such as those of Zarate et al. [130], Glover et al. [131], Lamer et al. [131] and Chong [132]. It represents connectivity and its quantification among different variables. Each is sized according to its relevance. The width of a flow denotes its magnitude. Thus, the magnitude of flow is directly proportional to the thickness of the line.

Fig. 7 reveals the links through Sankey's diagram and the answers to RQ4. The visualization comprises three columns denoting the elements: prominent authors, key topics, and primary journals, along with their interrelations. The width of the connecting lines signifies their frequency; thus, a broader line conveys a heightened occurrence. The utility of this analysis resides in its capacity to
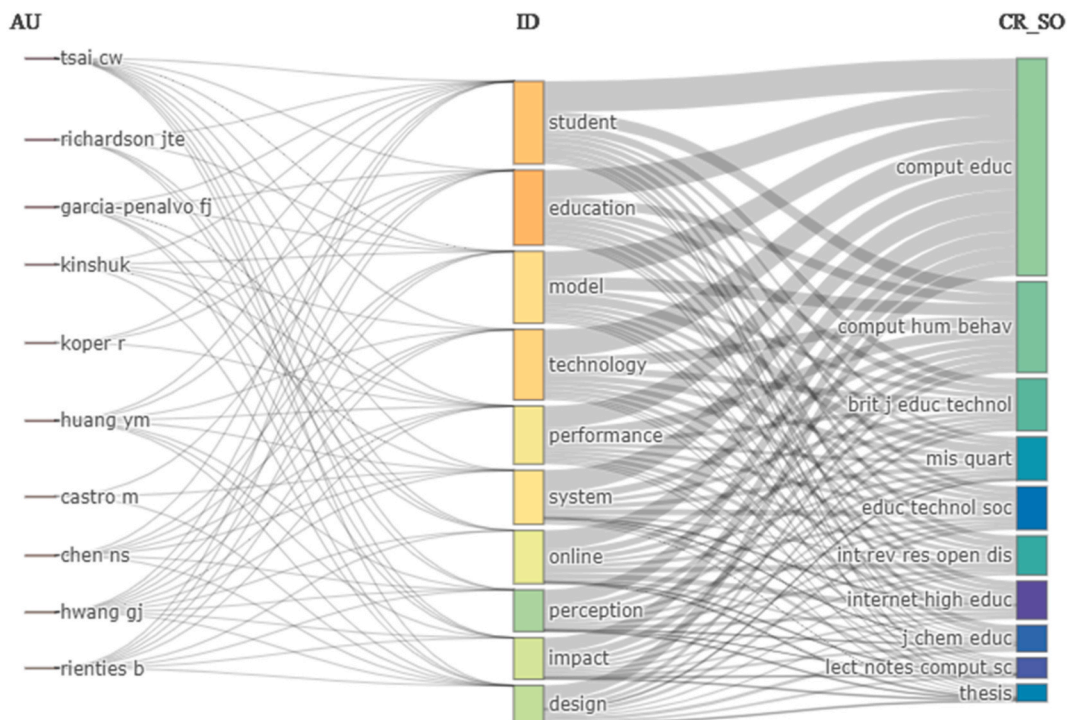

Fig. 7. Three-Fields Plot relating the top-10 authors, keywords, and journals. Source: Web of Science (WoS).

assist researchers in identifying highly productive collaborators among top authors, discerning pertinent journals for publication, and pinpointing focal subjects that warrant exploration.

Figs. 7 and 8 depict the most productive authors in e-learning. The most prolific author with 35 papers published is Chia-Wen Tsai from the Ming Chuan University of Taiwan. The main topics addressed by this author fundamentally relate to self-regulation, team-based learning, learning effectiveness, and computer skills, having published relevant papers in *Computers in Human Behavior, Computers & Education, Educational Technology and Society,* and the *British Journal of Educational Technology* where he has also published papers on research trends in e-learning.

John T.E. Richardson follows in second place, with 30 documents published. He is an emeritus professor at the UK Open University. His main fields of research have been the perception of students of their courses, approaches to studying, adults' learning, and the academic achievement in e-learning of people with disabilities and ethnic minorities. He has published articles on tutors' perspectives, adult learners, and the relevance of interaction in the top journals *British Journal of Educational Technology* and the *International Review of Research in Open and Distributed Learning.*

The third place is occupied by Francisco J. García-Peñalvo, from the University of Salamanca (Spain), with 29 documents. He has published papers on m-learning, acceptance, augmented reality, software and environment design, students' performance and COVID-19, in top journals such as *Computers in Human Behavior* and *Educational Technology and Society.*

The next author in the ranking is Kinshuk from Athabasca University (Canada). He has co-authored several papers with Nian-Shing Chen. Both are prolific publishing in top journals: *Computers in Human Behavior, Computers & Education, Educational Technology and Society,* the *British Journal of Educational Technology,* and the *International Review of Research in Open and Distributed Learning.* Some of his work focuses on systems and algorithms, learning styles, learning analytics and data mining, m-learning, acceptance, satisfaction, perception, and attitudes towards e-learning.

Rob Koper from the Open University of the Netherlands is specialized in e-learning design and environments, and pedagogy. With a total of 24 papers, the relevant papers on the mentioned subjects were published in top journals: *Computers in Human Behavior, Computers & Education, Educational Technology and Society,* and the *British Journal of Educational Technology.*

The following author is Yueh Min Huang from the National Cheng Kung University (Taiwan), who has published 23 papers, some, in top journals such as *Computers in Human Behavior, Computers & Education,* and *Educational Technology and Society.* The main topics were e-learning acceptance, students' behavior and achievement, wiki-based learning, m-learning, and instructional processes, specializing in mathematics, physics, and material sciences.

Among the 10-top authors, stands out Nian-Shing Chen from the National Taiwan Normal University, with 21 papers published. He is one of the most prolific authors in terms of publications in the top journals *Computers in Human Behavior, Computers & Education,* the *British Journal of Educational Technology,* and *Educational Technology and Society,* where he is a member of the journal steering board. The main topics addressed by this author were performance, learning styles, quality and design of environments and materials, acceptance, social interaction, u-learning and augmented reality.

Gwo-Jen Hwang from the National Taiwan University of Science & Technology, with 21 papers, is also one of the most prolific authors in terms of publications in the top journals. In fact, 57 % of his papers were published in *Computers & Education,* the *British Journal of Educational Technology, Educational Technology and Society,* and the *International Review of Research in Open and Distributed Learning,* where he has published a bibliometric study on artificial intelligence. Mobile and ubiquitous learning, learning styles, students' and teacher attitudes, self-efficacy, and interaction are the main topics addressed by this researcher.
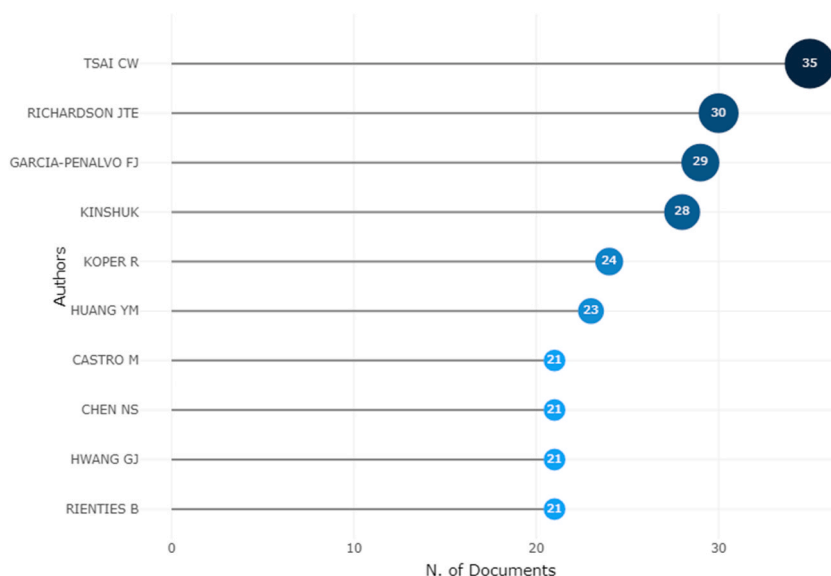

Fig. 8. Top-10 authors publishing on e-learning.

Bart Rienties, from the UK Open University, is an expert on learning analytics, on which he has published relevant papers, especially in top journals such as *Internet and Higher Education*, the *British Journal of Educational Technology,* the *International Review of Research in Open and Distributed Learning,* and *Computers and Human Behavior,* where he has also published on motivation, participation, and performance in e-learning.

Manuel Castro from the National University of Distance Education (UNED-Spain) is the fifth most prolific author, with 21 papers. His expertise lies in engineering, and therefore, in the course's design, especially in remote laboratories. One of his relevant papers, on the reliability of peer assessment in MOOCs was published in *Computers & Education.*

4.5. *Most cited documents*

To answer RQ5, we analyzed the most cited documents on e-learning published between 1970 and 2022 according to the WoS. Table 2 shows the ranking of the ten most cited articles with more than 525 citations.

The main topics of the most cited papers relate to learners' satisfaction, continuance intentions, course effectiveness, acceptance of e-learning, and social interaction. *Computers & Education* is the main journal that publishes the most influential documents. The most cited article with 1130 citations, is 'What drives a successful e-learning? An empirical investigation of the critical factors influencing learner satisfaction' authored by Pei-Chen Sun, Ray J. Tsai, Glenn Finger, Yueh-Yang Chen and Dowming Yeh, and published in the journal *Computers & Education* in 2008. This study considered six dimensions that affect learners' satisfaction: learners (attitude, anxiety, and self-efficacy), instructors (timely responses and attitude), courses (flexibility and quality), technology (technology and Internet quality), design (usefulness and ease of use), and environment (diversity in assessment and social interaction). A total of 295 surveys of university students in Taiwan were conducted to investigate the critical factors affecting their satisfaction with e-learning. The findings reveal that the learner's computer anxiety, attitude of the instructor, course flexibility and quality, perceived usefulness and ease of use, and diversity in assessments are critical factors affecting learners' perceived satisfaction.

The second article in the ranking with 759 citations is titled 'Identifying the pitfalls for social interaction in computer-supported collaborative learning environments: a review of the research' by Karel Kreijns, Paul A. Kirschner and Wim Jochems published in 2003 in *Computers in Human behavior*. The effectiveness of collaborative learning in computer-based courses depends on the size and composition of the group, tasks, and learning styles, all of which are related to social interactions. This work highlights that aside from the functional environment that enables critical thinking and argumentation, the environment should provide casual communication channels to improve social interaction and, thus, learners' satisfaction. Almost 20 years have passed since the publication of this paper,

Table 2
Most cited documents since 1970 published on e-learning.

R	Authors	Tittle	Source	PY	TC	TC/Y	NC
1	Sun, Pei-Chen; Tsai, Ray J.; Finger, Glenn; Chen, Yueh-Yang; Yeh, Dowming	What drives a successful e-Learning? An empirical investigation of the critical factors influencing learner satisfaction	Computers & Education	2008	1130	75,3	58,8
2	Kreijns, K; Kirschner, Pa; Jochems, W	Identifying the pitfalls for social interaction in computer-supported collaborative learning environments: a review of the research	Computers in Human Behavior	2003	759	37,95	27,30
3	Dominguez, Adrian; Saenz-De-Navarrete, Joseba; De-Marcos, Luis; Fernandez-Sanz, Luis; Pages, Carmen; Martinez-Herraiz, Jose-Javier	Gamifying learning experiences: Practical implications and outcomes	Computers & Education	2013	735	73,50	53,95
4	Gwo-Hshiung Tzeng; Cheng-Hsin Chiang; Chung-Wei Li	Evaluating intertwined effects in e-learning programs: A novel hybrid MCDM model based on factor analysis and DEMATEL	Expert Systems with Applications	2007	712	44,50	39,85
5	Roca, Juan Carlos; Chiu, Chao-Min; Martinez, Francisco Jose	Understanding e-learning continuance intention: An extension of the Technology Acceptance Model	International Journal of Human-Computer Studies	2006	656	38,59	41,01
6	Lee, Matthew K.O.; Cheung, Christy M.K.; Chen, Zh	Acceptance of Internet-based learning medium: the role of extrinsic and intrinsic motivation	Information & Management	2005	584	32,44	30,25
7	Wang, Yi-Shun; Wu, Ming-Cheng; Wang, Hsiu-Yuan	Investigating the determinants and age and gender differences in the acceptance of mobile learning	British Journal of Educational Technology	2009	553	39,50	28,07
8	Garrison, D. Randy; Cleveland-Innes, Martha	Facilitating Cognitive Presence in Online Learning: Interaction Is Not Enough	American Journal of Distance Education	2005	535	29,72	27,71
9	Zhang, Ds; Zhou, Ln; Briggs, Ro; Nunamaker, Jf	Instructional video in e-learning: Assessing the impact of interactive video on learning effectiveness	Information & Management	2006	528	31,06	33,01
10	So, Hyo-Jeong; Brush, Thomas A.	Student perceptions of collaborative learning, social presence and satisfaction in a blended learning environment: Relationships and critical factors	Computers & Education	2008	525	35,00	27,29

Notes: R: Ranking; **PY:** publication year; **TC:** total citations; **TC/Y:** total citations per year; **NC:** normalized total citations. **Source:** elaboration based on Web of Science (WoS) data.

and nowadays, the evolution of the environment allows even the assessment of students depending on their social interaction [133], satisfaction of psychological needs [134] and learning analytics [135].

Gamification is the focus of the third most cited document, with 735 citations. Its title is 'Gamifying learning experiences: practical implications and outcomes' published in 2013 in *Computers & Education* by Adrián Domínguez, Joseba Saenz de Navarrete, Luis de Marcos, Luis Fernández Sanz, Carmen Pagés and José Javier Martínez Herráiz. The authors designed a gamified educational experience applied to an e-learning platform in a university ICT course. A plugin provided exercises in a gamified manner to increase competition and, thus, students' motivation. The results revealed that students completing the games showed greater motivation and got better scores on practical assignments, but they performed poorly on written assignments and participated less in class activities.

5. Conclusions

This article provides a bibliometric examination and a conceptual mapping of the intellectual structure within the realm of e-learning, a subject area that has garnered scholarly attention across diverse fields, notably encompassing education, pedagogy, psychology, computer science, engineering, and medical education. This study adopts a comprehensive bibliometric approach to investigate the evolution of e-learning research spanning from 1970 to 2022. The employed methodology includes bibliometric analyses, encompassing measures of productivity, and graphic visualization techniques, enabling the assessment of prolific authors, influential articles, pertinent journals, and the evolutionary trajectory of research themes that have been addressed.

According to the literature review undertaken in the second half of the 20th century the persistent topic in research was 'distance learning', the instructional process, assisted learning for people with disabilities, the role of libraries in distance education, courseware design, and, already in the nineties, the effectiveness of courses, the satisfaction and motivation of students and teachers, learning strategies, and interactions with tutors and peers. The 21st century has witnessed the development of the 'world wide web', so multimedia, hypermedia, and online environments have emerged as a topic of research, without forgetting the pedagogical approach. Innovative practices using portable devices, social media, augmented/virtual reality, and the implementation of e-learning during the pandemic have been key research topics in the last decade.

From a bibliometric perspective, mapping the co-occurrence of keywords has shed light on the subtopics studied by researchers since 1970, to answer RQ1. Thus, the mapping reveals 5 clusters of keywords. The main topics relate to educational and pedagogical processes in terms of effectiveness, acquisition of competencies, outcomes, learning strategies, interaction, and self-regulation. The second group includes aspects associated with new technologies applied in distance education: from the term distance learning and blended learning to recent topics such as mobile learning and social media. The third cluster relates to the technological environment of courses, their perceived usefulness and value, and therefore the acceptance among users and students' satisfaction. The fourth group is led by the keyword 'covid-19', which portrays the forced application of distance learning strategies to address the effects of the pandemic.

Recent trends addressed in research between 2015 and 2022 include distance and blended learning, m-learning, higher education, ICT, assessment, MOOCs, learning analytics, covid-19, medical education, artificial intelligence, servers' capacity and security, cognitive engagement of students, and self-instruction.

Regarding RQ2 and RQ3, the top five journals in terms of impact, publishing on e-learning, are *Computers & Education*, indexed in the first decile of the categories 'Education & Educational Research' and 'Computer Science, Interdisciplinary Applications' of the WoS; *Computers in Human Behavior*, indexed in the first quartile of the categories 'Psychology, Experimental' and 'Psychology, Multidisciplinary'; the *British Journal of Educational Technology*, indexed in the first quartile of the 'Education & Educational Research'; *Educational Technology and Society*, indexed in the second quartile of 'Education & Educational Research'; and *Internet and Higher Education* of the first quartile of the 'Education & Educational Research' *category of the WoS*.

As for RQ4, we analyzed the 10-top authors, their top keywords, top journals, and their common connections via Sankey's diagram. Thus, the most prolific author is Chia-Wen Tsai, from the Ming Chuan University of Taiwan, with relevant research on self-regulation, team-based learning, learning effectiveness, and computer skills. John T.E. Richardson follows in second place, with research on perception of students, learning strategies, adults' learning, and academic achievement of people with disabilities. The third place is occupied by Francisco J. García-Peñalvo, from the University of Salamanca (Spain), who has published documents on m-learning, acceptance, augmented reality, design, performance, and COVID-19. It follows Kinshuk from Athabasca University (Canada), who has co-authored several papers with Nian-Shing Chen. Some of his works focus on systems and algorithms, learning styles, analytics, m-learning, acceptance, satisfaction, perception and attitudes towards e-learning. Rob Koper from the Open University of the Netherlands ranks fifth, with publications on design and pedagogy. The following author is Yueh Min Huang from the National Cheng Kung University (Taiwan), whose research published in top journals focuses on acceptance, behavior, achievement, m-learning, and instructional processes, specializing in mathematics, physics and material sciences. Another relevant and influential author is Nian-Shing Chen from the National Taiwan Normal University, whose topics addressed are performance, learning styles, quality and design, acceptance, social interaction, u-learning, and augmented reality. Gwo-Jen Hwang from the National Taiwan University of Science & Technology is also one of the most prolific authors in terms of publications in the top journals on mobile and ubiquitous learning, learning styles, attitudes, self-efficacy, and interaction. Bart Rienties, from the UK Open University, is an expert on learning analytics on which he has published relevant papers, especially in top journals. Manuel Castro from the National University of Distance Education (UNED-Spain) is an expert on engineering and therefore in course's design and especially in remote laboratories.

Concerning RQ5, the three most cited documents on e-learning with more than 700 citations were published in *Computers & Education* and in *Computers in Human Behavior*. The first in the ranking is 'What drives a successful e-learning? An empirical investigation of the critical factors influencing learner satisfaction' authored by Pei-Chen Sun, Ray J. Tsai, Glenn Finger, Yueh-Yang Chen and

Dowming Yeh, published in 2008 and followed by 'Identifying the pitfalls for social interaction in computer-supported collaborative learning environments: a review of the research' by Karel Kreijns, Paul A. Kirschner and Wim Jochems published in 2003. The third one is 'Gamifying learning experiences: practical implications and outcomes' published in 2013 by Adrián Domínguez, Joseba Saenz de Navarrete, Luis de Marcos, Luis Fernández Sanz, Carmen Pagés and José Javier Martínez Herráiz.

Limitations practical and theoretical implications

This paper has some limitations. The first limitation focuses on data gathered from the WoS database. WoS collects data as a full-count system, where articles with more than one author generally have preference in the analysis over single-authored documents. To overcome this limitation, we used a fractional count in the mapping analysis using VOSViewer software. The results obtained were very similar for the two methods mentioned above, and there was no significant deviation between the two methods. Second, the database comprises a select few journals, each recognized for its impact and pertinence. Notwithstanding the encountered constraints, the conducted research offers a comprehensive examination of predominant and noteworthy developments within the domain of e-learning, as guided by bibliometric measures. Furthermore, this investigation presents an overview spanning the historical, contemporary, and prospective dimensions of research pertaining to this subject matter. It is worth noting that the outcomes remain dynamic, subject to evolution over time.

We highlight three main theoretical implications of this research. Firstly, it provides a broad overview of the status and advances in e-learning research from the beginning to the present. Research in this field has increased exponentially in recent years demonstrating the great importance of the topic in society and in research and how it has been conducted from different perspectives depending on the area of research, from computer applications to pedagogy, and the use of technologies by users. Secondly, this study presents significant prospects for forthcoming researchers to comprehensively advance their understanding of the evolutionary trajectory of e-learning and its multidisciplinary facets. It offers a contemporary overview of this subject, delineating the preeminent journals, influential authors, and key topics. This facilitates the identification of prolific collaborators, pertinent publication outlets, and thematic areas to prioritize, thereby enhancing the prospects of research success and publication in high-impact journals. Thirdly, it elucidates the contemporary focal points of concern within the research community, which are poised to shape forthcoming trends and potentially delineate research agendas across diverse domains encompassing education, pedagogy, and applied software, among others.

Current research trends have addressed challenges due to the pandemic that will require ongoing efforts from educational institutions, policymakers, and technology providers to develop more effective and inclusive e-learning and distance learning solutions. In addition, the integration of Artificial Intelligence (AI) in e-learning and education in general has the potential to transform the way students learn, but it also poses some challenges that should be addressed in research: privacy and security in managing personal data, bias and fairness of data, digital divide in accessing AI, teachers' training to integrate it effectively into their teaching practices, ethical issues, and the impact on employment. Overall, the integration of advances in e-learning and AI in education presents both opportunities and challenges for future research. It is essential to address these challenges to ensure that the benefits are accessible to all students and do not perpetuate social inequality.

Data availability statement

Data will be made available on request.

Additional information

No additional information is available for this paper.

CRediT authorship contribution statement

Aitor Martínez-García: Conceptualization, Data curation, Formal analysis, Methodology, Software, Writing – original draft, Writing – review & editing. **Patricia Horrach-Rosselló:** Conceptualization, Formal analysis, Supervision, Validation, Writing – original draft, Writing – review & editing. **Carles Mulet-Forteza:** Conceptualization, Methodology, Supervision, Validation, Writing – review & editing.

Declaration of competing interest

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

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