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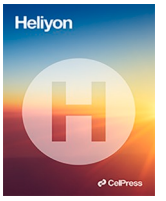

Review article

Technology-enhanced higher education: Text mining and bibliometrics

Xieling Chen [a], Di Zou [b,*], Haoran Xie [c], Fu Lee Wang [d]

[a] School of Education, Guangzhou University, Guangzhou, China
[b] Centre for English and Additional Languages, Lingnan University, Hong Kong SAR, China
[c] Department of Computing and Decision Sciences, Lingnan University, Hong Kong SAR, China
[d] School of Science and Technology, Hong Kong Metropolitan University, Hong Kong SAR, China

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ABSTRACT

Objectives: Research on technology-enhanced higher education (TEHE) has been active and influential in educational technology. The study had three objectives: (1) to recognize the tendencies in the field and the contributing countries/regions/institutions, (2) to visualize scientific collaborations, and (3) to reveal important research topics, their developmental tendencies, correlations, and distributions across contributing countries/regions/institutions.
Methods: We collected 609 papers in relation to TEHE from 2004 to 2022 and analyzed them using text mining and bibliometric methods. Specifically, we focused on determining article trends, identifying contributing institutions/countries/regions, visualizing scientific collaborations through social network analysis, and revealing the important topics and their conceptual evolutions over time using topic models, Mann-Kendall trend test, hierarchical clustering, and Sankey visualization.
Results: Regarding the first objective, TEHE articles have grown consistently and will continue to expand. This growth was due to the contributions of Spanish universities and institutions from other countries/regions such as the USA, the UK, Australia, Germany, China, and Turkey. Regarding the second objective, the exploration of regional and institutional collaborations through social networks revealed that geographically adjacent institutions tended to foster close collaborations, particularly among those sharing similar research interests. Nevertheless, more cross-regional collaborations are needed to advance TEHE research. Regarding the third objective, the analysis of topics highlighted research hotspots and emerging themes such as *Massive Online Open Courses*, *AI and big data in education*, *Gamification and engagement*, *Learning effectiveness and strategies*, *Social networks and discussion forums*, *COVID-19 and online learning*, and *Plagiarism detection and learning analytics*.
Conclusions: This bibliometric study comprehensively analyzed the research landscape of TEHE research regarding contributors, collaborations, and research topics, and offers a glimpse into what the future may hold. It can be used as a guide for contributors to the field to identify the current research hotspots and emerging themes.

* Corresponding author.
E-mail address: dizoudaisy@gmail.com (D. Zou).

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1. Introduction

Technology-enhanced learning (TEL), defined as "any online facility or system that directly supports learning and teaching" ([1], p. 447), is increasingly adopted in higher education [2] to fulfill the needs for innovative instruction and learning. Research on TEL gradually develops into an active field since about 2004 [3]. For example, computer- or web-powered applications bring rich chances for collaborative learning and knowledge-construction practices [4]. Learning analytics powered by artificial intelligence (AI) satisfy individuals' needs and requirements by allowing instructors to perform personalized instruction and track learners' progress [5]. Chatbots facilitate learning through the provision of learning materials, assignments, rehearsal questions, human-like interaction opportunities to promote collaborative learning [6]. As a result, interest in exploiting and promoting higher education quality using information communication technologies (ICTs) is increasing constantly in academia and among instructors in educational institutions and governmental agencies.

According to West [7], there is "practical value to understanding where we are right now, and where we have been in the very recent past. To understand this, it can be helpful to review some of the journals in our field to see what conversations are being held, research being conducted, tools being developed, and theories being accepted (p. 60)". Thus, in academia, it is common that researchers analyze publications of a or several journals in a particular field to comprehend its development, including educational technology research. Wilson [8] collected 440 research papers from the Journal of Research on Technology in Education (JRTE) from 2001 to 2020 and utilized bibliometric approaches to investigate trends in JRTE, offering a complete overview of papers concerning practitioner-centered educational technologies in instruction and learning. Tatnall and Fluck [9] identified topics in 1511 articles on Education and Information Technologies (EAIT) published between 1996 and 2020 to provide direction for future studies in the field of educational technologies. Goksu et al. [10] used bibliometric mapping to examine 469 articles on Computer Assisted Language Learning (CALL) to highlight keyword patterns and learn contributing countries, colleges, and researchers from 2008 to 2019. The most prevalent terms used in the research were "English as a foreign language", "communication", "motivation", "telecollaboration", "mobile learning", "writing", and "blended learning". Taiwan, the USA, and China donated the most to the CALL journal.

While bibliometric analyses provide a comprehensive overview of existing literature, they do not provide in-depth insights into semantic content [11]. To conduct extensive analysis, bibliometric studies must be supplemented with text-data mining approaches such as topic models [12]. Topic modeling analysis extends bibliometric analyses by allowing for more thorough analyses and is considered a more flexible approach for discovering hidden themes within large-scale data sets [13,14]. Chen et al. [15], for instance, performed a structural topic modeling study of 3963 papers in Computers & Education from 1976 to 2018 to detect the recurrently studied topics, tools or applications, and widely recognized theories, and to understand the thematic and conceptual features regarding educational technologies. They specifically focused on queries like "What research topics were the academic community of Computers & Education interested in" and "How have such research topics evolved". The findings gave a thorough picture of the educational technology field and assisted educational institutions and governmental agencies in making scientific policy decisions. Chen et al. [16] examined 3710 articles of the British Journal of Educational Technology from 1971 to 2018 using bibliometrics, word clouds, and topic modeling to uncover publication and citation developments, contributing sources and countries/institutions/authors, and thematic features to provide understandings of educational technology domains. Meanwhile, Ozyurt and Ayaz [17] conducted bibliometric analysis and topic modeling to understand contributors, thematic features, and research trends of EAIT studies to determine research interests and tendencies regarding educational technology. Results identified 21 areas, with the top five most researched being "technology acceptance", "social network-based learning", "teacher education", "satisfaction with e-learning", and "e-learning".

TEL's increasing adoption in higher education settings has received attention in academia, with numeric TEHE-focused publications available to discover themes and developments concerning the field. Shen and Ho [3] used hybrid bibliometric approaches for examining relevant publications indexed in the Web of Science to understand TEHE's developments. They identified five major research areas of TEHE, including implementation, critique, social media, podcasts, and blended learning. Ng'ambi et al. [18] focused on TEHE in South Africa, revealing that "South Africa's higher education institutions have moved from being solely responsible for both their own relatively poor ICT infrastructure and education provision to cloud-based ICT infrastructure with unlimited educational resources that are freely, openly and easily available within and beyond the institution" (p. 843). These studies help understand TEHE research content and recognize gaps and important directions for future research. According to Chen et al. [15], it is also useful to explore the perspectives, voices, and theoretical interpretations, findings/practices in a specific journal. In line with this, regarding TEHE, it would be useful to analyze publications of such journals as the International Journal of Educational Technology in Higher Education. The journal was established in 2004 when research on TEL in higher education started to flourish [3], and has since offered a platform for technology-assisted learning for scholars, professionals, and practitioners to share the latest research work and exchange information from diverse cultural/background perspectives. The journal aspires to advance scientific knowledge on technology use in higher education by informing readers of the most recent breakthroughs concerning digital technologies' adoption in higher education. The present work sought to offer a topic modeling analysis of the journal's articles to understand the thematic characteristics and priorities for the future of TEHE.

Specifically, the present study had several objectives, including determining article trends, identifying contributing institutions/countries/regions, and visualizing scientific collaboration through social network analysis (SNA). Additionally, the study focused on revealing the important topics and their conceptual evolutions over time using topic modeling analysis. The distributions and correlations of these topics across contributing countries/regions/institutions were also analyzed. To achieve these objectives, the present study addressed three research questions (RQs):

RQ1. What were the annual trends of articles and the contributing countries/regions/institutions?

RQ2. What were the scientific collaborations among contributing countries/regions/institutions?

RQ3. What were the research topics, their developmental tendencies, correlations, and distributions across contributing countries/regions/institutions?

The importance of this study in answering these RQs is described in the following. Firstly, examining trends in scientific papers within a specific field reveals changes in production and interest as well as the global advancements and developmental patterns in that field. In general, an increase in publications typically indicates that the field's worldwide science system is growing [19]. Analyzing contributing actors allows pinpointing prominent contributors in the field who have the greatest potential for developing and sharing knowledge [20]. Thus, answers to RQ1 help researchers and educators 1) comprehend the global advancements in science and the developmental directions of the TEHE field and 2) become aware of essential contributors in the field from whom they can learn [21]. Secondly, "research collaborations, by sharing competencies and data, can improve labor efficiency and research quality, and support scientific production and knowledge creation" ([22], p. 2). Governmental organizations have increasingly emphasized scientific collaborations to "facilitate the creation, diffusion, and utilization of scientific knowledge and, ultimately, to boost technology development" ([23], p. 1295). Thus, answers to RQ2 facilitate an intuitive grasp of the social partners and prominent figures in the TEHE field, identify prospective research partners, and assist government entities in formulating policies aimed at fostering the generation of TEHE-related knowledge [22]. Thirdly, Responses to RQ3 shed light on historical and contemporary advancements in research, technical applications, and motivations for upcoming initiatives to promote TEHE. As a result, TEHE researchers/practitioners are kept up to date on crucial problems and new areas of research requiring consideration before acting scientifically or technologically [11,24].

2. Data and methods

2.1. Data collection

The study collected papers published in the International Journal of Educational Technology in Higher Education from 2004 to 2022. Papers published between 2015 and 2022 were obtained from the Web of Science. Papers published between 2004 and 2014 were collected from the Universities and Knowledge Society Journal website[1]. To ensure consistency, only original research articles with English abstracts were included for analysis, and documents of monograph, editorial, introduction, and review types were excluded. A total of 609 research articles with English abstracts were included.

2.2. Data analysis

Regarding RQ1, we counted the number of annual articles and used polynomial regression methods to describe the non-linear connection between the year and the number of articles. We utilized the article count approach [25] to calculate the articles contributed by each country/region/institution.

Concerning RQ2, we used Gephi [26] to show scientific interactions among institutions/countries/regions based on SNA. We saw institutions, countries/regions, and collaborations as nodes with lines connecting them. The breadth of lines related to the degree and frequency of scientific collaboration, while the sizes and colors of nodes showed productivity and geographical information, respectively.

To answer RQ3, we employed structural topic models (STMs) using three phases. We began by extracting terms from titles, keywords, and abstracts and preprocessing them based on tokenization, lemmatization, and stop-word removal. Second, we used the word frequency-inverse document frequency model to choose terms. Third, based on representative words and articles, two experts independently examined 26 models by setting different numbers of topics and picked the 12-topic model with higher semantic consistency within and exclusivity values (see Fig. 1).

We determined the popularity of each topic by calculating $P_k = \left(\sum_d \theta_{d,k}\right) \Big/ D$, with $\boldsymbol{\theta}_{d,k}$ being the percentage of *kth* topic in the d*th* article and D is 609. The Mann-Kendall (M-K) trend test was developed to investigate the developmental tendencies of topics based on yearly proportions. We investigated topic connections using hierarchical clustering analysis and a document-level cosine similarity matrix. Considering D articles, the assignment of *kth* topic is $V_D = (\boldsymbol{\theta}_{k,1}, \boldsymbol{\theta}_{k,2}, \ldots, \boldsymbol{\theta}_{k,d})$, where $\boldsymbol{\theta}_{k,i}$ represented the likelihood of *kth* topic being assigned to d*th* article. The document-level similarity of *kth* and *l th* topics was determined using $\cos_{document}(k,l) = (\sum_{i=1}^{D} \theta_{k,i} \times \theta_{l,i}) / (\sqrt{\sum_{i=1}^{D} (\theta_{k,i})^2} \times \sqrt{\sum_{i=1}^{D} (\theta_{l,i})^2})$ and a complete-linkage agglomerative technique.

We also estimated the proportion of each topic for countries/regions/institutions and used Sankey visualization to display and compare their research focuses.

[1] https://rusc.uoc.edu/rusc/en/index.php/rusc/issue/archive.html.

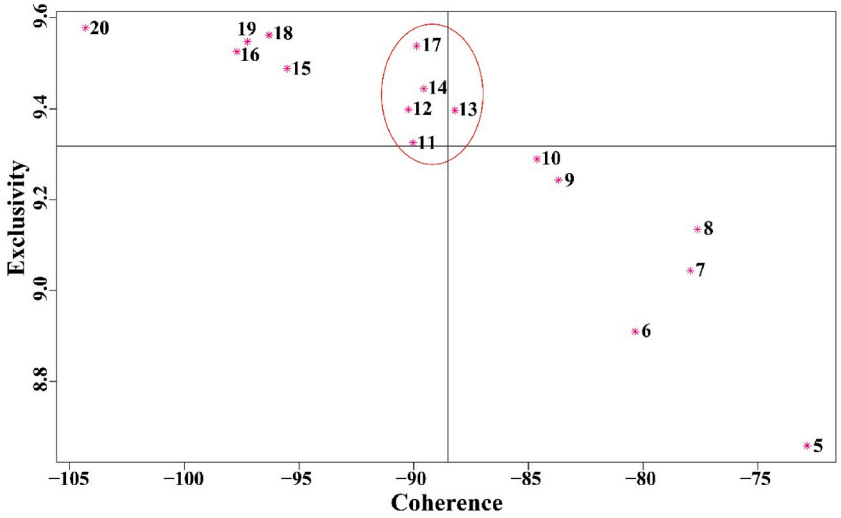


Fig. 1. Graph of coherence and exclusivity values of different topic models.

3. Results

3.1. Analysis of the trend of articles and contributing countries/regions/institutions

From 2005 to 2022, a total of 609 articles with English abstracts were examined. Fig. 2 depicts the articles and trend line from 2005 to 2022. The number of articles between 2005 and 2012 ranged between 19 and 21. In 2013, Springer started to publish the journal, which broadened the influence of the articles. The number of articles has grown considerably since 2016. A significant increase was observed, particularly in 2019 and 2021.

The 609 articles were contributed by 76 countries/regions in total. Fig. 3 depicts the 12 most prolific countries/regions in terms of article count. Despite the wide geographic spread of the authors, the top 12 countries/regions sorted by the number of articles contributed to over 88 %. Spain was the top one with 220 articles, followed by the USA (64) and the UK (43). Fig. 3 also integrates the number of articles and the ranking of countries/regions for the two time periods: 2005–2013 and 2014–2022. The data suggests that the USA, the UK, Australia, Germany, China, and Turkey improved significantly in rank between the two periods, showing increased efforts and interest in TEHE research.

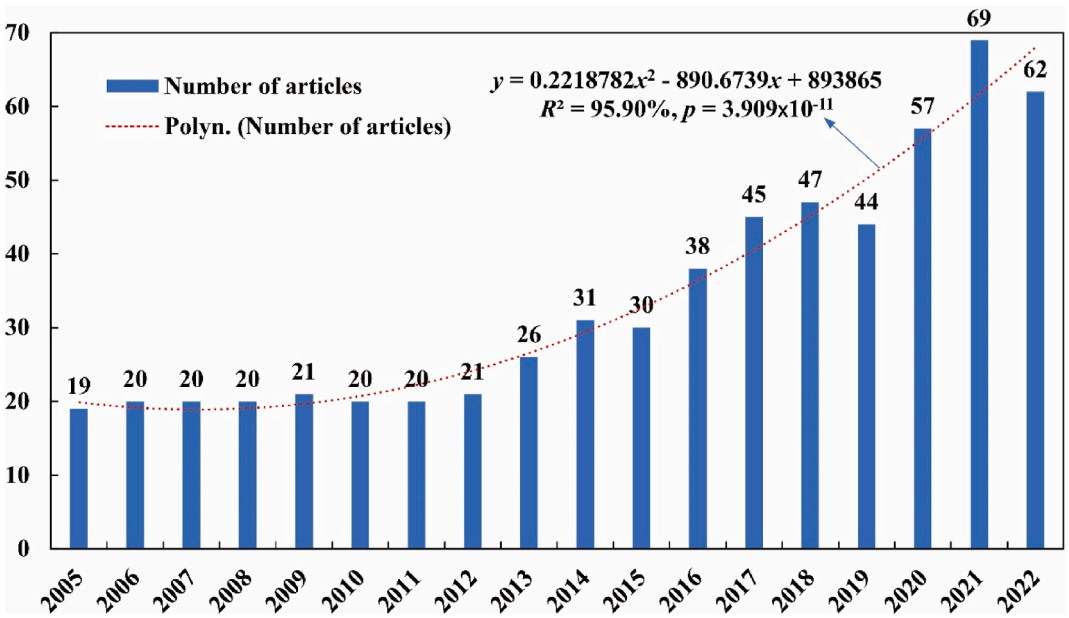
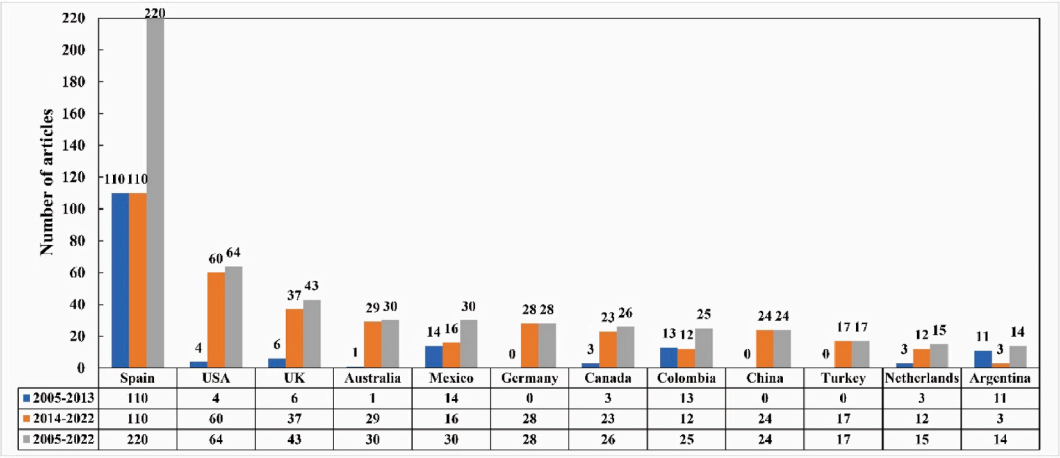


Fig. 2. Analysis of the annual number of articles.



	Spain	USA	UK	Australia	Mexico	Germany	Canada	Colombia	China	Turkey	Netherlands	Argentina
2005-2013	110	4	6	1	14	0	3	13	0	0	3	11
2014-2022	110	60	37	29	16	28	23	12	24	17	12	3
2005-2022	220	64	43	30	30	28	26	25	24	17	15	14

Fig. 3. Top prolific countries/regions.

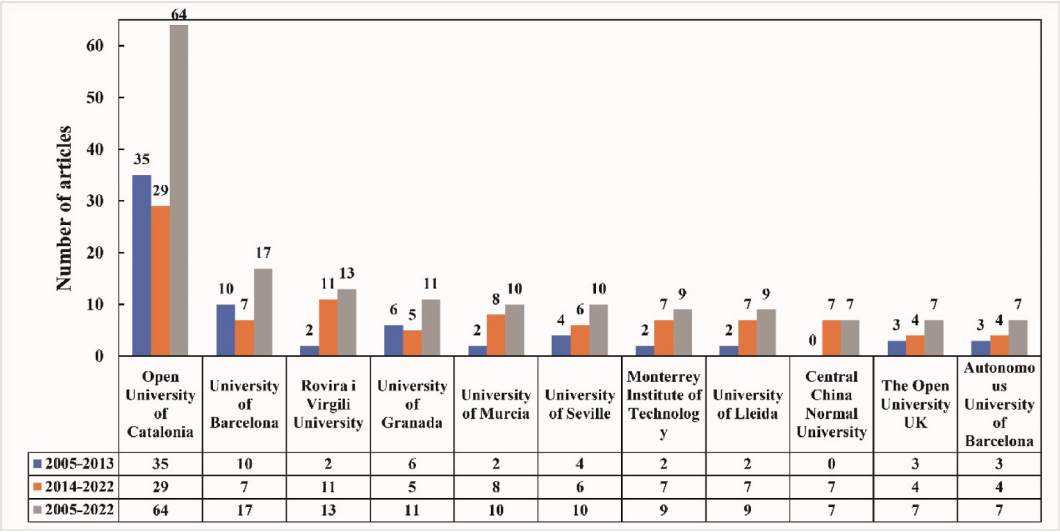
The 609 articles were contributed by 586 institutions in total. Fig. 4 depicts the 11 most prolific institutions in terms of article count. These institutions contributed to around 30 % of the 609 papers. The Open University of Catalonia (UOC) came in the first place, with 64 articles. Other institutions that contributed the most included the University of Barcelona (17) and Rovira i Virgili University (13). Fig. 4 also integrates the number of articles and the ranking of institutions for the two time periods: 2005–2013 and 2014–2022. The data suggest that Rovira i Virgili University and Central China Normal University improved significantly in rank between the two periods, demonstrating increasing efforts and interest in TEHE research.

3.2. Analysis of the scientific collaborations

Among the 609 articles, 24.13 % had a single author, and authors of 19.67 % and 41.00 % of the articles came from a single country/region and institution, respectively. Compared to the period of 2005–2013, the ratio of articles with over one author had decreased from 46.45 % to 14.46 % from 2014 to 2022.

Fig. 5 (a) displays collaboration across countries/regions with a collaborative frequency between 2 and 7. Colombia and Spain were the closest collaborators, followed by the USA and Spain and Mexico and Spain. Fig. 5 (b) depicts collaboration across countries/regions having a collaborative frequency of 2. There are 4 clusters: (1) Canada, the UK, Brazil, South Africa, and Saudi Arabia; (2) Spain, Netherlands, Israel, and Portugal; (3) Colombia, the USA, Mexico, Hong Kong, Ukraine, and Taiwan; and (4) China and Australia.

Collaborations among 4 institutions with a collaborative frequency between 3 and 5 are depicted in Fig. 6. The closest partners were UOC and the University of Barcelona, followed by UOC and Autonomous University of Barcelona and UOC and Pompeu Fabra



	Open University of Catalonia	University of Barcelona	Rovira i Virgili University	University of Granada	University of Murcia	University of Seville	Monterrey Institute of Technology	University of Lleida	Central China Normal University	The Open University UK	Autonomous University of Barcelona
2005-2013	35	10	2	6	2	4	2	2	0	3	3
2014-2022	29	7	11	5	8	6	7	7	7	4	4
2005-2022	64	17	13	11	10	10	9	9	7	7	7

Fig. 4. Top prolific institutions.

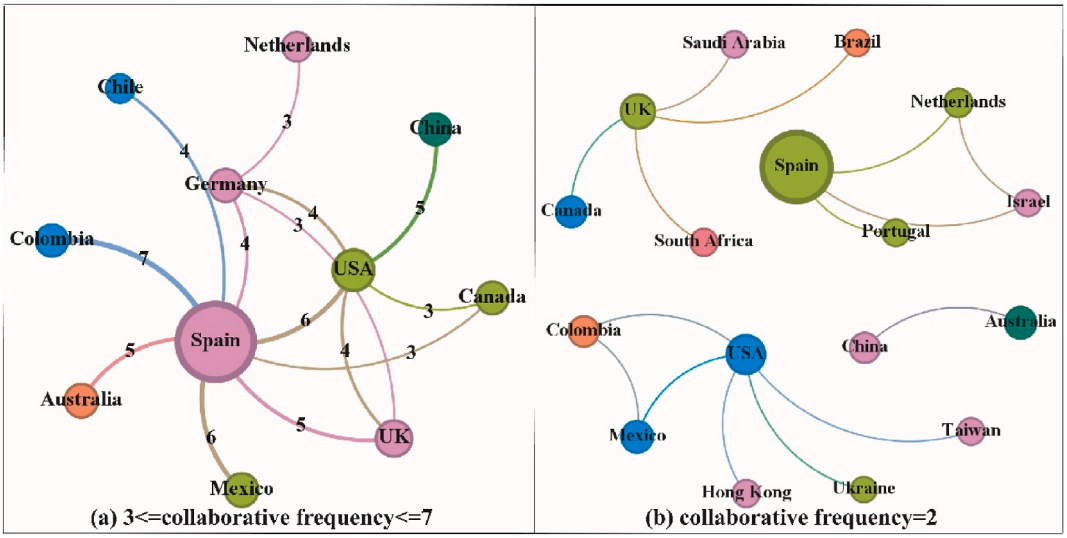


Fig. 5. Regional collaborations with a collaborative frequency between 2 and 7.

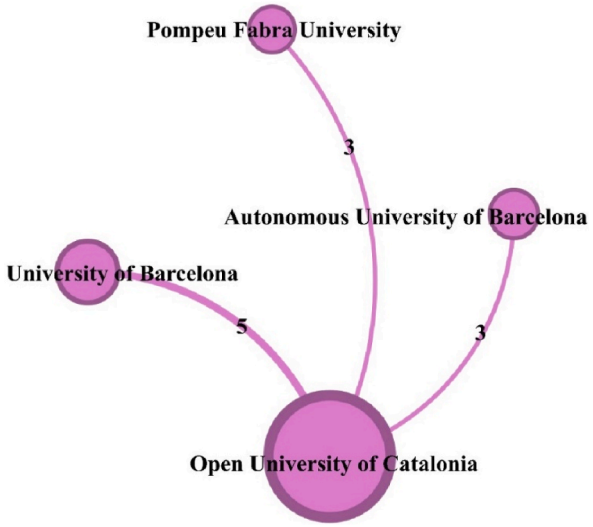


Fig. 6. Institutional collaborations with a collaborative frequency between 3 and 5.

University. Institutional collaborations with a collaborative frequency of 2 are depicted in Figs. 7 and 8. There are 8 clusters, most of which involved institutions from the same regions, for instance, (1) the University of A Coruna and University of Santiago Compostela; (2) the National University of Litoral and National Technological University; (3) TESCHA and Monterrey Institute of Technology; and (4) Pablo de Olavide University and National University of Distance Education.

3.3. Analysis of topics, trends, correlations, and distributions

This section introduces the topic modeling analysis results, resulting in 12 themes. Table 1 shows the proportions of themes, recommended topic labels, and topic developmental tendencies determined by the MK trend test. Furthermore, Table 1 is organized by the intensity with which the topics are investigated (topic proportion).

The most researched topic was *Organizational change and transformation* (12.82 %), followed by *Learning effectiveness and strategies* (12.70 %) and *OERs* (11.00 %). On the other hand, *AI and big data in education* (5.07 %), *Social networks and discussion forums* (4.75 %), and *Plagiarism detection and learning analytics* (3.89 %) were the three least studied topics.

According to the trend test results, 7 topics, *MOOCs* (↑↑), *AI and big data in education* (↑↑↑), *Gamification and engagement* (↑↑↑), *Learning effectiveness and strategies* (↑↑↑), *Social networks and discussion forums* (↑↑↑), *COVID-19 and online learning* (↑↑↑↑), and *Plagiarism detection and learning analytics* (↑↑↑↑), expressed significantly increasing tendencies. On the other hand, 3 topics, *Diversity and digital*

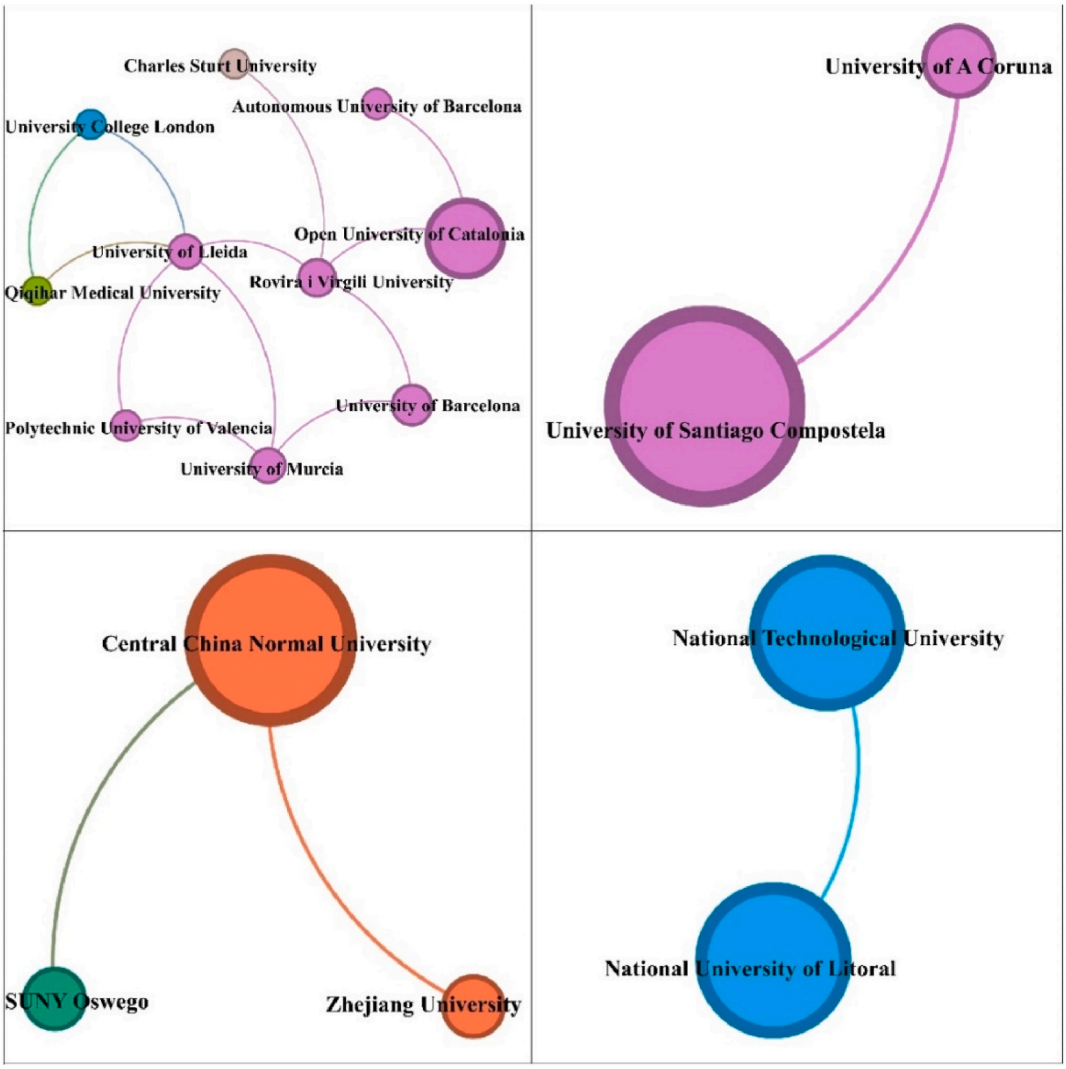


Fig. 7. Institutional collaborations with a collaborative frequency of 2.

equality (↓↓), *Teacher education* (↓↓↓), and *OERs* (↓↓↓↓), expressed significantly decreasing tendencies. The remaining two topics, *Organizational change and transformation* and *Assessment*, showed no significant trends. The year-by-year trends of the 12 topics are depicted in Fig. 9 by exhibiting their varied prevalence in the data corpus, showing how each topic evolves in terms of proportion in each year. For example, some topics such as *Social networks and discussion forums* and *Plagiarism detection and learning analytics* had shown continuously increasing tendencies. Some topics such as *Teacher education* and *OERs* had shown continuously decreasing tendencies. For topics such as *AI and big data in education*, *Gamification and engagement*, and *COVID-19 and online learning*, they had experienced a low growth rate in previous years while sudden and continuing increase thereafter. For topics such as *Diversity and digital equality*, they had experienced increasing tendency in previous years but sudden and continuing decrease thereafter.

We also produced periods for trend analysis of the journal articles. A total of four time periods have been generated: 2005–2009, 2010–2014, 2015–2019, and 2020–2022. Fig. 10 depicts the distribution of topics and the proportion of articles on each topic throughout the four periods. During the periods of 2005–2009 and 2010–2014, the top studied topics included *OERs*, *Diversity and digital equality*, *Organizational change and transformation*, and *Teacher education*. During the period of 2015–2019, the top studied topics included *Organizational change and transformation* and *Learning effectiveness and strategies*. During the period of 2020–2022, the top studied topics included *Learning effectiveness and strategies*, and *COVID-19 and online learning*.

Fig. 11 depicts the outcomes of cluster analysis, providing information about the interactive structures of themes, comparable to an interdisciplinary examination [27]. If topics A and B are frequently referenced in the same article, an interdisciplinary research theme can be formed. According to the results, four interesting clusters are noted: (1) *Teacher education* and *OERs*, (2) *Organizational change and transformation* and *Diversity and digital equality*, (3) *AI and big data in education* and *Plagiarism detection and learning analytics*, and (4) *Learning effectiveness and strategies*, *COVID-19 and online learning*, *MOOCs*, and *Gamification and engagement*.

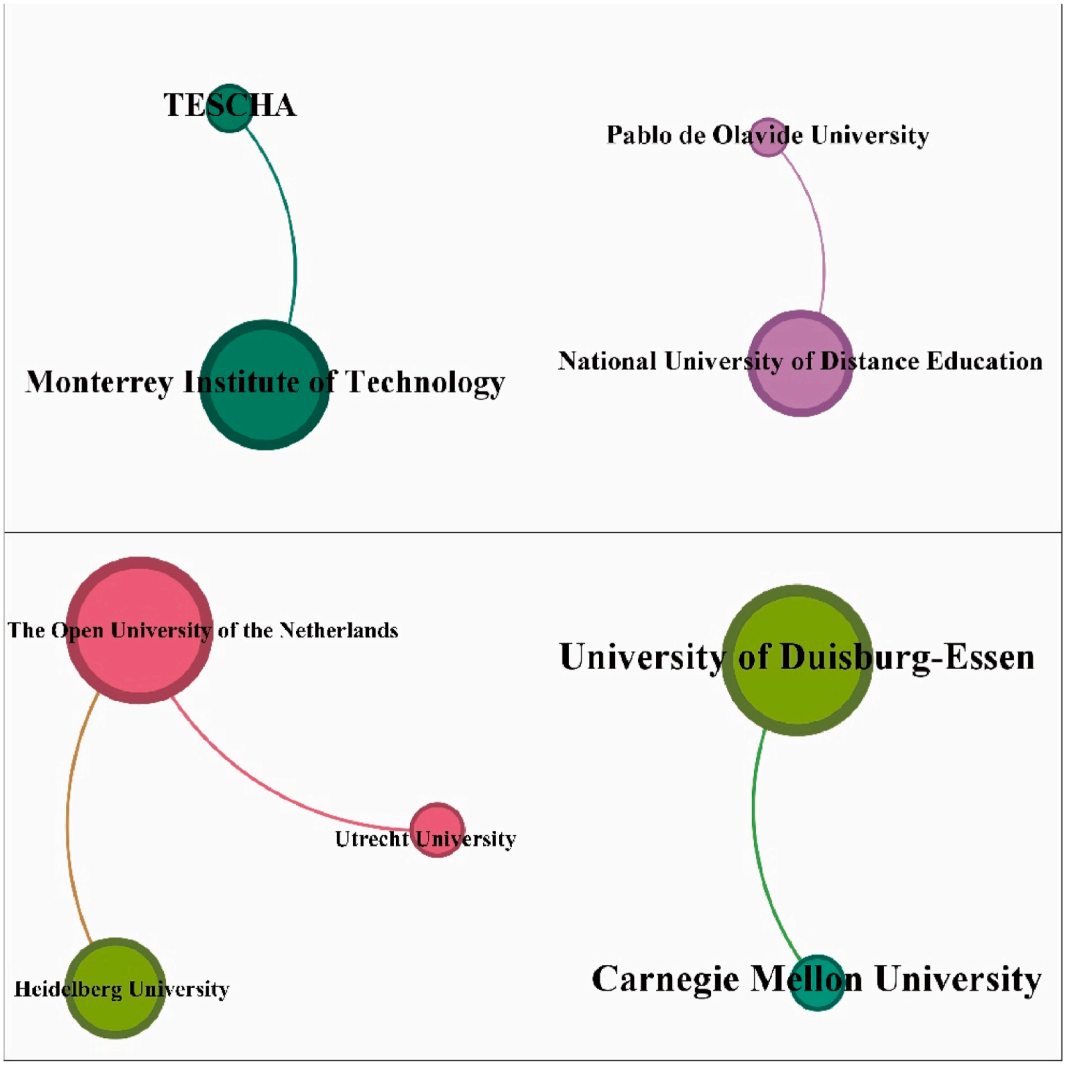


Fig. 8. Institutional collaborations with a collaborative frequency of 2.

Table 1
Topic proportions across the corpus, recommended topic labels, and developmental trends.

Labels	%	*p*	S	trend
Organizational change and transformation	12.82	0.0956	−45	↓
Learning effectiveness and strategies	12.70	0.0019	83	↑↑↑
Open educational resources (OERs)	11.00	0.0000	−125	↓↓↓↓
Diversity and digital equality	10.58	0.0124	−67	↓↓
Teacher education	10.48	0.0080	−71	↓↓↓
COVID-19 and online learning	10.03	0.0002	99	↑↑↑↑
Assessment	7.16	0.5445	−17	↓
Gamification and engagement	5.98	0.0100	69	↑↑↑
Massive online open courses (MOOCs)	5.55	0.0231	61	↑↑
AI and big data in education	5.07	0.0064	73	↑↑↑
Social networks and discussion forums	4.75	0.0100	69	↑↑↑
Plagiarism detection and learning analytics	3.89	0.0004	95	↑↑↑↑

Note: Topics are listed in descending order by proportion. ↑(↓): significantly rising (decreasing) trend ($p > 0.05$); ↑↑(↓↓), ↑↑↑(↓↓↓), ↑↑↑↑(↓↓↓↓): significantly increasing (decreasing) trend ($p < 0.05$, 0.01, and 0.001, respectively).

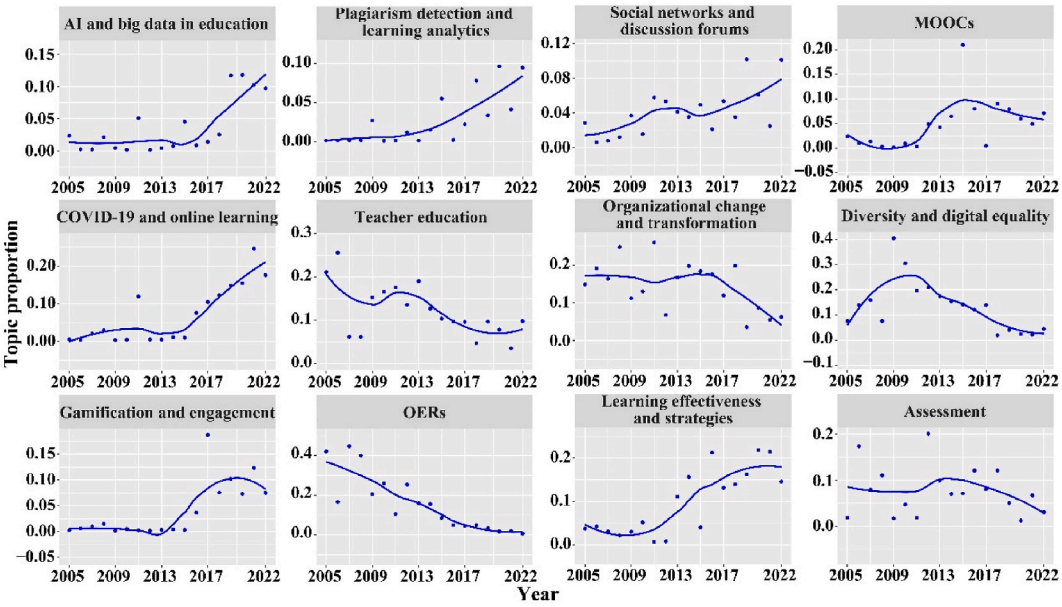
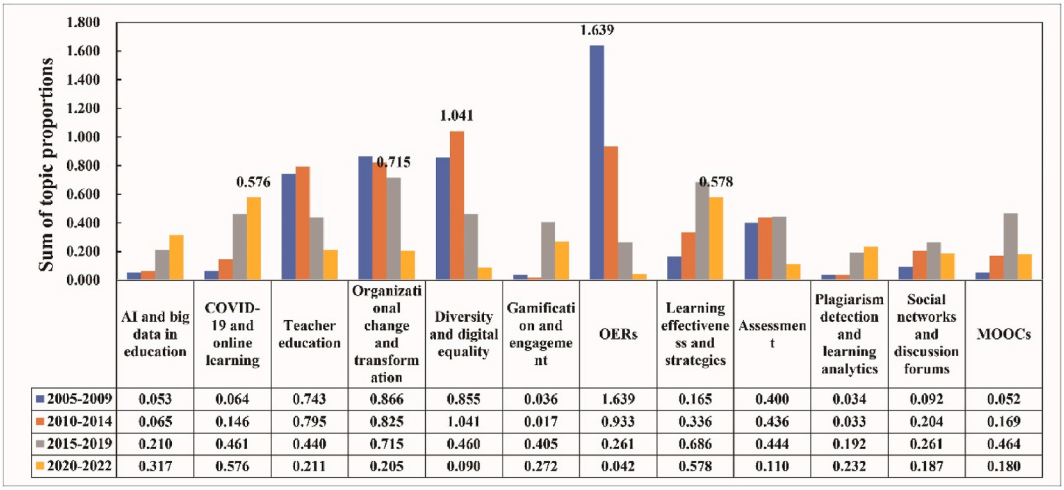


Fig. 9. Annual topic proportions.



	AI and big data in education	COVID-19 and online learning	Teacher education	Organizational change and transformation	Diversity and digital equality	Gamification and engagement	OERs	Learning effectiveness and strategies	Assessment	Plagiarism detection and learning analytics	Social networks and discussion forums	MOOCs
2005-2009	0.053	0.064	0.743	0.866	0.855	0.036	1.639	0.165	0.400	0.034	0.092	0.052
2010-2014	0.065	0.146	0.795	0.825	1.041	0.017	0.933	0.336	0.436	0.033	0.204	0.169
2015-2019	0.210	0.461	0.440	0.715	0.460	0.405	0.261	0.686	0.444	0.192	0.261	0.464
2020-2022	0.317	0.576	0.211	0.205	0.090	0.272	0.042	0.578	0.110	0.232	0.187	0.180

Fig. 10. Distributions of topics in four periods.

Figs. 12–15 depict the distributions of topics across productive countries/regions/institutions described in Figs. 3 and 4, providing insight into which countries/regions/institutions were committed to certain topics. In terms of countries/regions, Canada showed the most interest in *COVID-19 and online learning*; China devoted the most effort to *Learning effectiveness and strategies*; Germany published many studies about *Organizational change and transformation*; the UK was enthusiastic about *Gamification and engagement*; Colombia was more active in *OERs*.

The topic distributions of institutions appeared to be less balanced when compared to the countries/regions, particularly for UOC and Central China Normal University. The UOC showed the most interest in *OERs*; Central China Normal University devoted the most effort to *Learning effectiveness and strategies*; University of Granada published many studies about *Diversity and digital equality*; Rovira i Virgili University and Open University UK were enthusiastic about *Organizational change and transformation*; University of Murcia was more active in *MOOCs*. We also uploaded the dynamic graphs online to allow readers to download them to interactively explore the distributions of topics across productive countries/regions/institutions.

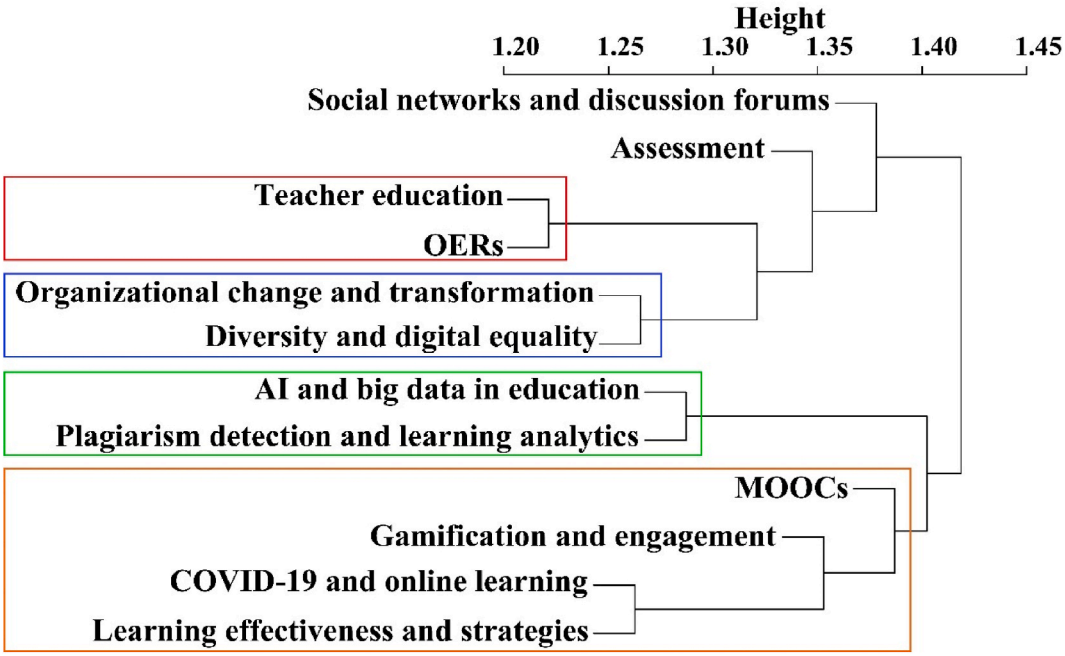


Fig. 11. Clustering analysis between the 12 topics.

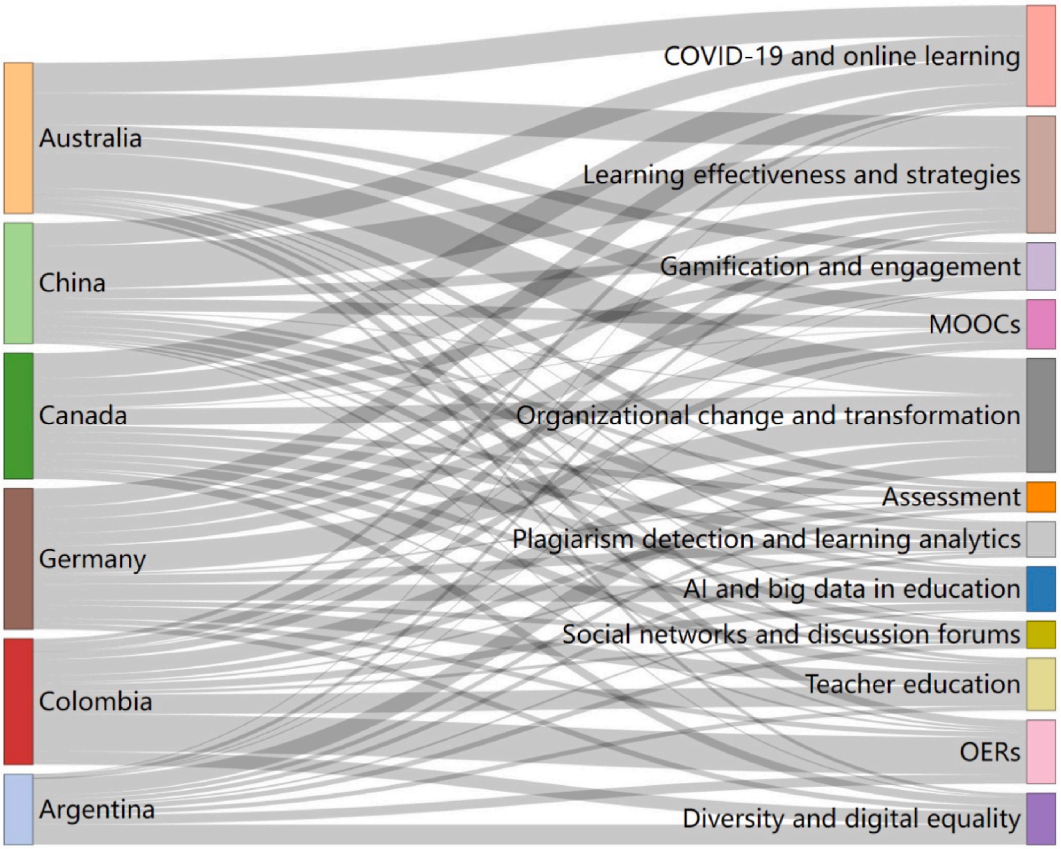


Fig. 12. Distributions of topics across Australia, China, Canada, Germany, Colombia, and Argentina (access via https://drive.google.com/file/d/18wKHnS3EP2cIVhxdcnZhMDOMwCpgUTRO/view?usp=sharing).

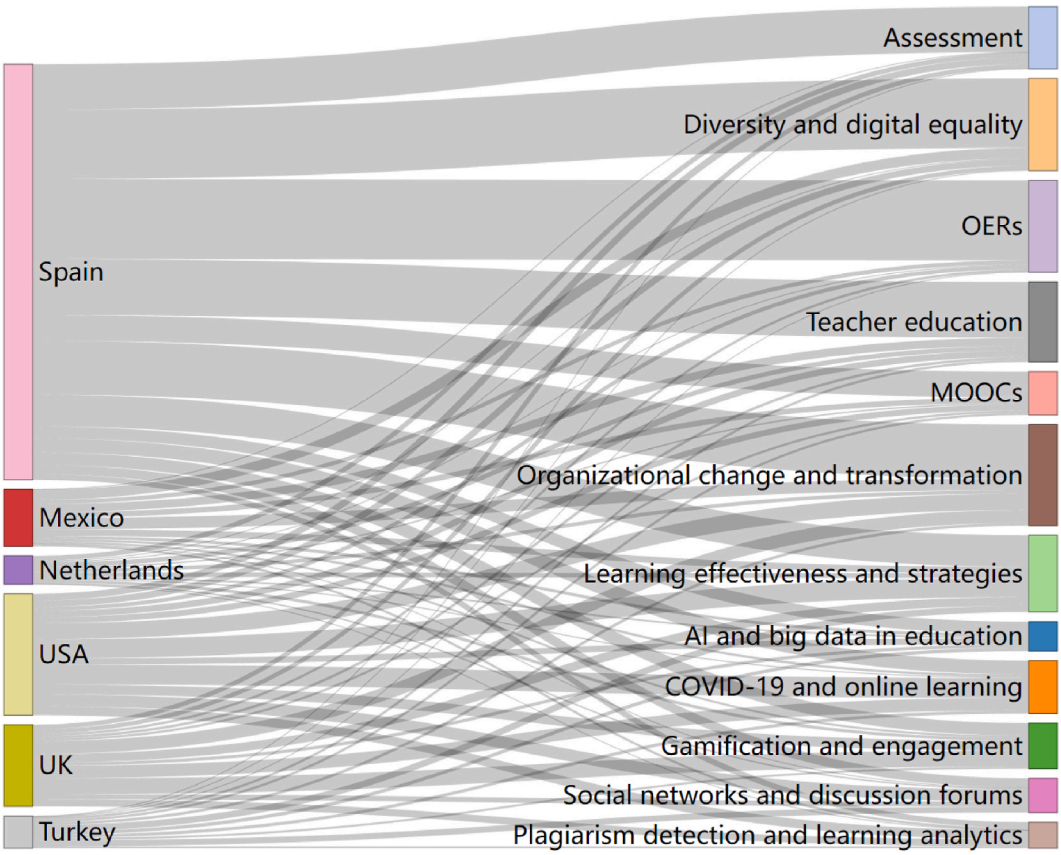


Fig. 13. Distributions of topics across Spain, Mexico, Netherlands, the USA, the UK, and Turkey (access via https://drive.google.com/file/d/1KNP53sBq_u9HoTuGgUdptVaflhjUfGuC/view?usp=sharing).

4. Discussion

4.1. *In response to RQ1 and RQ2*

The trend analysis results presented in Fig. 2 reveal important insights into the growing influence of the research field of TEHE. Throughout the analyzed period, the impact and influence of TEHE research have consistently grown, indicating a promising future with a growing community and scientific output. Based on Fig. 3, Spain is the leading contributor to the community. Since 2010, English has become the journal's official language, and most articles are published in both English and Spanish. According to Zych and Buela-Casal [28], journals with a higher internationality score tend to publish in more languages. Therefore, compared to earlier years, the journal has attracted authors from not only Spain but also other countries, particularly the USA and the UK, resulting in more international impact. Scientific output has no bounds, and research findings can have a huge impact on the worldwide scientific community. English-language articles are more likely to receive international citations, contributing to the journal's international impact. The comparative results of articles from 2005 to 2013 and 2014–2022 further confirm the journal's distinct international character, with increasing interest from countries such as Australia, Germany, China, and Turkey to publish their TEHE research works.

The findings in Fig. 4 identify the UOC as the top contributing institution to the community. Apart from UOC, other Spanish institutions such as University of Barcelona and University of Granada are among the top 4 institutions in the research, which corresponds to Sánchez et al. and highlights the academic influence of Spanish authors. Collaborations among authors have become more prevalent from 2014 to 2022, as indicated by the decrease in the percentage of articles with single authors from 46.45 % to 14.46 % compared to the previous period of 2005–2013. The international character of the journal is also reflected in the regional and institutional collaborations, as presented in Figs. 5–8. The results indicate that countries/regions that have more international collaborations are developing rapidly, as evidenced by Spain and the USA. They are both rated as the most productive according to Fig. 3. Figs. 6–8 suggests that institutions in the same countries/regions tend to collaborate, which is consistent with other important educational technology journals [15,16]. This could be because of the ease and convenience of research exchange and resource sharing. However, Guerrero Bote et al. [29] recommend reducing adverse neighborhood impacts through partnerships with distant countries or regions to promote influence. Therefore, we expect to see more cross-regional collaborations in the TEHE community.

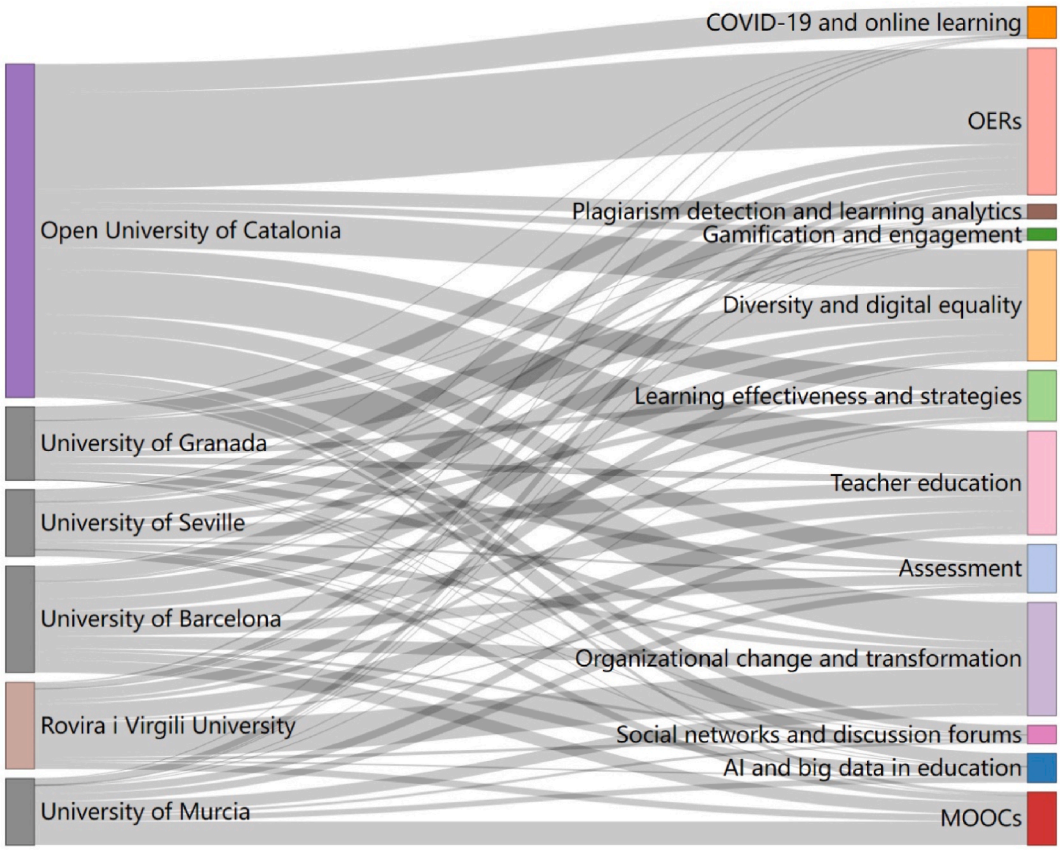


Fig. 14. Distributions of topics across Open University of Catalonia, University of Granada, University of Seville, University of Barcelona, Rovira i Virgili University, and University of Murcia (access via https://drive.google.com/file/d/1BwqG6s4l7UYel79ZrbIoFCIelrrXexpM/view?usp=sharing).

To summarize, TEHE research has grown in importance within the educational technology area, as evidenced by the increasing number of articles. This growth is not solely due to the contributions of Spanish universities but also due to the increasing preference for TEHE research by researchers from other countries and institutions. The journal is encouraged to maintain its focus on internationalization to continue to develop and progress. Additionally, the international collaborations among countries and regions have further contributed to the international character of the journal, particularly in the inter-regional form. However, to advance TEHE research, it is necessary to have more cross-regional collaborations.

4.2. *In response to RQ3*

Drawing on the topic analysis results (Table 1 and Figs. 9–15), this section discusses the prevalence, trends, and correlations of the identified topics and their geographic distributions across contributing countries/regions/institutions.

4.2.1. *Five most studied topics*

The topic modeling results shed light on the research interest in the TEHE research. The articles were grouped under 12 topics, with *Organizational change and transformation*, *Learning effectiveness and strategies*, *OERs*, *Diversity and digital equality*, and *Teacher education* being the most studied topics.

The topic of *Organizational change and transformation* was the most prevalent, accounting for 12.82 %. Organizational change and transformation are critical in educational institutions as they ought to adapt to changing circumstances, including new technologies, societal needs, and pedagogical practices. Technology has revolutionized the way we teach and learn [30]. Thus, educational institutions should leverage technologies to promote learning experiences and educational outcomes [31].

The second most studied topic, *Learning effectiveness and strategies*, accounted for 12.70 %. Effective learning strategies are crucial for students to achieve their academic goals, and the rapid development of technology and changes in educational practices have made research on this topic increasingly important. TEL strategies such as online learning platforms, multimedia resources, and educational games have been identified as key factors that can influence learning outcomes [32].

The third most studied topic, *OERs*, accounted for 11.00 %. OERs are digital materials that are freely accessible, openly licensed,

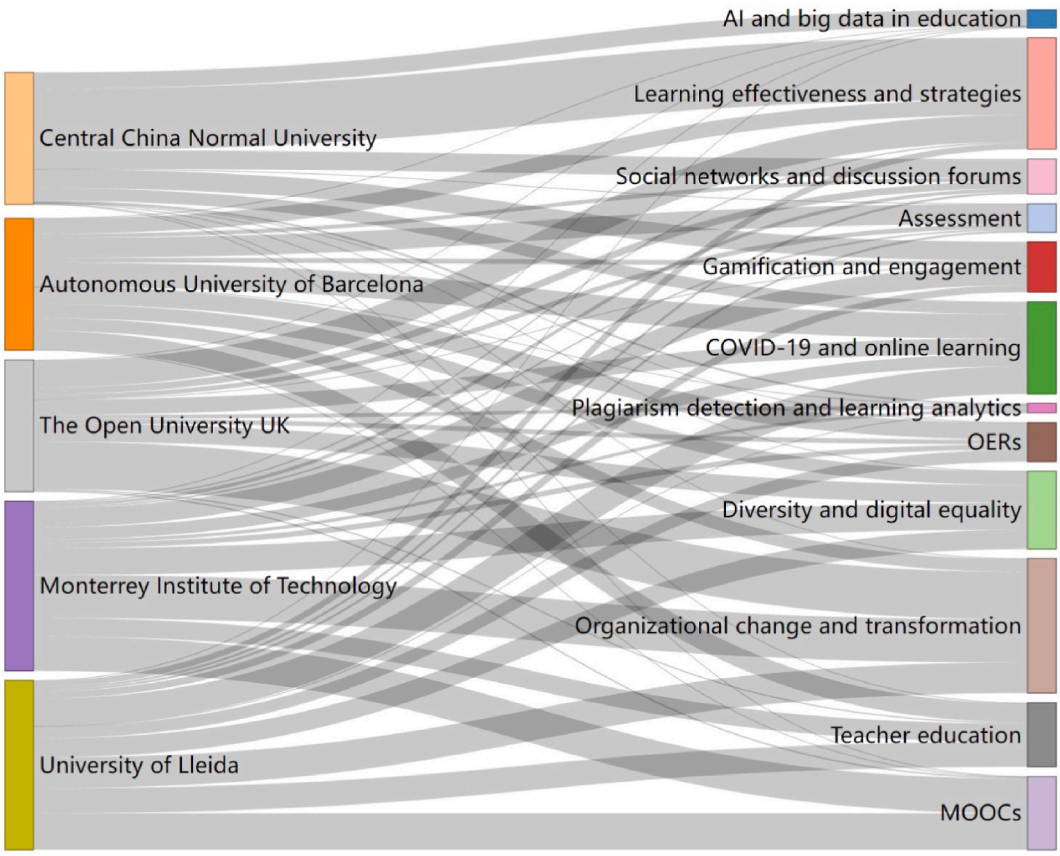


Fig. 15. Distributions of topics across Central China Normal University, Autonomous University of Barcelona, The Open University UK, Monterrey Institute of Technology, and University of Lleida (access via https://drive.google.com/file/d/13I-oUSULSp9mRFVhvqal3odhZTH0gxOy/view?usp=sharing).

and can be modified or adapted to meet individual needs. They have gained widespread use as they address the issue of limited access to educational materials and can be tailored to suit individual learning requirements. OER also facilitates collaborative learning and knowledge-sharing among educators and learners.

The topic of *Diversity and digital equality* was the fourth most studied, accounting for 10.58 %. In the contemporary era, access to technology and digital resources is critical for education. However, not all individuals have the same opportunities to use technology and digital resources, which results in a digital divide and intensifies extant disparities. According to Guo and Wan [33], digital inequality can harm student learning outcomes, particularly for those from low-income backgrounds. By studying diversity and digital equality, educators can aid in the creation of inclusive technologies that meet the needs of diverse populations, improve access to technology and digital resources for individuals with disabilities, and result in more equitable outcomes.

Lastly, the topic of *Teacher education* was the fifth most studied, accounting for 10.48 %. Teachers are essential in shaping the lives of young individuals, and research has shown that high-quality teacher education programs are associated with improved teaching effectiveness and student achievement [34]. These programs equip instructors with the knowledge and skills required to instruct students effectively, which is particularly important in the constantly evolving education landscape. According to Çetin [35], teacher education is essential for developing digital literacy skills among teachers. Furthermore, Harris and De Bruin [36] emphasize the importance of teacher education in promoting teacher reflection and creativity, which results in the development of new and innovative teaching practices.

4.2.2. Seven most accelerated topics

The results of the trend test and analysis (Table 1 and Fig. 9) indicate that 7 topics are currently experiencing accelerated developmental tendencies. These topics include *Learning effectiveness and strategies*, *COVID-19 and online learning*, *Gamification and engagement*, *MOOCs*, *AI and big data in education*, *Social networks and discussion forums*, and *Plagiarism detection and learning analytics*. *Learning effectiveness and strategies* and *COVID-19 and online learning* are the most prevalent, with a prevalence rate of above 10 %. Although the remaining five accelerated topics have a prevalence rate of below 6 %, they have an abundance of articles available in recent years.

4.2.2.1. Learning effectiveness and strategies and COVID-19 and online learning. Since around 2015, e-learning has become a fast-growing educational modality due to the widespread use of handheld applications and global Internet access [37]. As a result, *Learning effectiveness and strategies* and *COVID-19 and online learning* have become important topics in the TEHE research field. An increasing number of colleges have provided online courses that cater to the diverse requirements of today's learners, but online education is commonly criticized for lacking support, feedback, and interaction, which causes a sense of isolation among learners. Moreover, the landscape of e-learning pedagogy allows for passivity and fails to maintain learners' attention, motivation, and learning effectiveness over the long term [38]. These limitations were highlighted during the COVID-19 pandemic when conventional face-to-face classrooms rapidly transitioned to complete online education.

Online course instructors and researchers are investigating instructional tactics that support learning and engage students in online learning classes to make e-learning more successful. These strategies include presenting content through resources and activities, promoting active content exploration, offering learners time to deliberate on information and feedback, engaging them in interactive activities with classmates, and providing content catering to various learning styles/interests [39]. E-learning may become a more effective and interesting medium of education by applying such tactics.

4.2.2.2. Gamification and engagement. The topic of *Gamification and engagement* has emerged to be prominent since 2015. Research has shown that learners tend to engage in learning activities, persist in their academic pursuits, and take pleasure in accomplishing tasks if they find them enjoyable and/or valuable [40,41]. Gamification is a strategy that integrates game-like basics, for example, points, and badges, into non-game contexts, without the need for complex narratives or visual settings [42]. This technique has gained popularity in various learning activities to motivate learners to participate and enhance learning outcomes [43], especially for Generation Y with an expectation of interactive and gamified learning [44].

4.2.2.3. MOOCs. Consistent with Liu et al. [45], researchers' interest in *MOOCs* has been steadily increasing since 2010, coinciding with the rise of smartphones and tablets as essential tools for distance learning. Despite calls to incorporate online learning as a supplement to traditional education for many years, progress has been slow as a result of the strong inertia of face-to-face teaching methods [46]. Nevertheless, the closure of schools during the COVID-19 pandemic accelerated the decolonization of curricula and increased the positive perceptions of learners, instructors, and parents towards online learning, particularly MOOCs, which are a typical form of online education and a powerful alternative to traditional classroom instruction. Before the pandemic, learners generally preferred traditional face-to-face classes over online education [47]. Since the outbreak of COVID-19, MOOCs have become more widely accepted by learners.

4.2.2.4. AI and big data in education. Researchers' interest in using *AI and big data in education* is growing rapidly. The age of AI and big data has heralded a new age in education [48]. In the mid-2000s, the arrival of "big data" in education, alongside the development of educational data mining and learning analytics technologies, was followed by a powerful discourse centered on adaptive systems and individualized learning [49]. This debate is currently being utilized to defend, promote, and advertise AI-based educational solutions. Furthermore, policy-influencing bodies have advocated for using AI to monitor and enhance learning. For instance, an OECD report calls for utilizing "big data, artificial intelligence algorithms, education data mining, and learning analytics … to improve learning and education" by converting scientific evidence into "real-world education practice and policy" ([50], p. 13–14). These examples demonstrate how data-led governance through algorithms has replaced governance by numbers in education, and this shift is increasingly being justified through discourses of scientific and AI-focused policy-making. Therefore, research on big data and AI has become progressively significant within educational areas.

4.2.2.5. Social networks and discussion forums. Academics have been increasingly interested in the topic of *Social networks and discussion forums* over time. Vygotsky's social constructivist theory emphasizes the significance of social interaction and language in knowledge construction [51]. The rise of Web 2.0 has provided new opportunities for authentic interaction and communication through social networking sites and blogs, promoting collaborative learning, reducing anxiety, and improving motivation and learning autonomy [52]. In MOOCs, social factors are also essential in promoting learners' engagement and performance by stimulating higher-order thinking skills [53]. Discussion forums, as a unique form of social technology, have been important in engaging learners in computer-supported collaborative learning, allowing for peer and independent learning and feedback, and promoting interaction and negotiation dynamics [54]. Consequently, researchers have been interested in exploring social technologies for collaborative and interactive learning among learners.

4.2.2.6. Plagiarism detection and learning analytics. The topic of *Plagiarism detection and learning analytics* have piqued the interest of researchers. Academic dishonesty is a widespread occurrence in traditional learning contexts, but it is much more common in online education. The absence of in-person contact between students and professors, combined with learner dispersal, increases the chances of academic dishonesty in online courses [55]. As a result, educators and instructors are worried about students' unethical behaviors in online learning contexts and are working to reduce academic dishonesty. Some research has concentrated on the development of new, robust cheating detection algorithms and techniques. In an attempt to combat plagiarism in academic writing, Alvi et al. [56] developed a three-step strategy that employed context matching and pre-trained word embeddings to discover synonymous replacements and word reordering in plagiarized phrase pairs. Another technique offered by Al-Thwaib et al. [57] was to create a reference corpus for detecting plagiarism in student submissions while simultaneously offering a knowledge foundation for language

education and learning to write without plagiarism. Instructors also use learning analytics and data mining technologies to discover academic dishonesty-related behaviors in students utilizing digital record information in online learning settings. For example, using submission time and exam reply data, a learning analytics system was built to recognize dishonest learners [58]. To prevent plagiarism in online assignments, learners were provided automatic feedback based on text mining [59].

4.2.3. Topics' distributions across contributors and topics' correlations

Figs. 12–15 depicting topic distributions indicate countries/regions/institutions' research strengths in one/more theme(s). This topic-wise view of partnerships across countries/regions/institutions, combined with Figs. 5–8 demonstrates that countries/regions/institutions with comparable interests are more likely to collaborate. This partnership brings together academic capabilities to solve difficulties and advance the field. For instance, the UOC and the University of Barcelona were discovered to be the closest partners, with a shared interest in *OERs*, *Diversity and digital equality*, *Teacher education*, and *Organizational change and transformation*. Colombia and Spain were the closest collaborators, with a special interest in *OERs*. Thus, scholars are encouraged to engage with possible partners, especially those with comparable research capabilities/interests, to collaboratively exploit the feasibility of using instructional and learning technologies.

The hierarchical clustering analysis results in Fig. 11 suggest four groups of topics of interest to researchers.

4.2.3.1. Teacher education and OERs. Researchers have been drawn to the combination of teacher education with OERs, with an emphasis on two aspects: 1) educating teachers on how to utilize OERs and 2) using OERs to educate instructors. Training teachers to use OERs benefits students in various ways, involving offering access to high-quality educational resources for learners who may not have access to expensive textbooks and other learning materials, saving money for both teachers and students, encouraging collaboration and knowledge-sharing among educators, and allowing resources to be customized to satisfy learners' specific needs [60,61]. Resources like OER Commons, OpenStax, and UNESCO's OER Toolkit can be used to offer instructors the skills and knowledge to properly use OERs in their classrooms. Furthermore, OERs include a wide range of materials like lesson plans, textbooks, multimedia, and exams for instructors to improve their knowledge and abilities in instruction. OERs also provide a flexible learning environment that allows instructors to study at their speed and on their schedule, resulting in better teaching practices and learning outcomes through collaborative learning [62,63]. OERs can also be tailored to meet unique cultural or language demands, as well as different levels of competence. As a result, OERs have gained prominence in lowering educational expenses, advancing educational fairness, and enhancing teaching methods and student learning results.

4.2.3.2. Diversity and digital equality and Organizational change and transformation. Diversity and digital equality are critical for organizational development and transformation in educational environments. Organizational change and transformation involve altering an organization's structure, culture, systems, and procedures to achieve a desired outcome. Diversity in educational environments pertains to the presence of multiple social identities, including race, gender, ethnicity, and socioeconomic level. Diverse viewpoints, ideas, and techniques can enhance decision-making and problem-solving, and a diverse student population can also help educational institutions better understand students' various needs and preferences, resulting in improved educational outcomes [64]. Digital equality, on the other hand, refers to equal access to and adoption of digital technology by learners and instructors regardless of their social identity. Digital technology has become an essential component of education, capable of improving learning experiences, generating new educational possibilities, and increasing efficiency. However, digital tools are not equally accessible to all students and professors, resulting in a digital divide that may hinder certain students' engagement in the educational process.

Promoting diversity and digital equality is crucial to achieving organizational change and transformation in education, leading to better educational outcomes, more innovation and creativity, and new educational possibilities. Educational institutions can promote diversity by implementing policies and practices that foster inclusivity and diversity in the learning environment, such as recruiting from a diverse student pool, creating an inclusive learning environment, and providing diversity and inclusion training. Educational institutions can also promote digital equality by providing all students and faculty with equal access to digital tools and training in underserved communities, educating students and teachers in digital skills, and advocating for adopting accessible digital technologies.

4.2.3.3. AI and big data in education and Plagiarism detection and learning analytics. In the realm of plagiarism detection and learning analytics, AI and big data are crucial tools. Implementing these technologies can improve the accuracy of plagiarism detection and provide personalized feedback to enhance learning outcomes [65]. AI and big data offer significant advantages over traditional methods of plagiarism detection, as AI-based systems utilize machine learning algorithms to compare texts and identify similarities. These systems can quickly analyze vast amounts of data and provide detailed plagiarism reports, facilitating educators' assessment of the originality of student work [66]. Additionally, AI and big data play a vital role in developing learning analytics systems that can help educators understand student behaviors and provide personalized feedback [67]. By analyzing student data, such as grades, attendance, and participation, learning analytics systems can identify patterns and predict future performance. This information can assist educators in recognizing areas that need improvement and adjusting their teaching strategies to better meet student needs.

4.2.3.4. 4) Learning effectiveness and strategies, COVID-19 and online learning, MOOCs, and Gamification and engagement. Gamification's integration into online education has garnered significant attention because of its potential to enhance engagement and improve learning outcomes. The hasty shift to online education has created a pressing need for innovative approaches to counter the absence of

in-person teaching [68]. Unlike conventional online courses, gamification has the potential to cultivate a sense of community and social interaction, which are typically absent in online learning environments [69]. By incorporating game-like elements into online courses, educators can stimulate interest, motivation, and retention while also fostering a sense of community and social interaction. Gamification can address some of the difficulties that students face when learning online, including disengagement, lack of motivation, and isolation.

4.3. Current status and future directions

Based on the topic modeling results, it can be inferred that scholars need to pay attention to the frequently researched topics, namely, *Organizational change and transformation*, *Learning effectiveness and strategies*, *OERs*, *Diversity and digital equality*, *Teacher education*, and *COVID-19 and online learning*. Among these, *Learning effectiveness and strategies* and *COVID-19 and online learning* are the topics that have gained the most acceleration over time, and their volumes have increased significantly. Therefore, they should be given particular attention in the future. Although the volumes of the other five most frequently studied topics have decreased over time, they still have the potential to be co-studied with other topics according to topic clustering analysis results (Fig. 11). For instance, the democratization of education through the availability of OERs and other open educational practices can be further enhanced by leveraging large language models like ChatGPT to support effective instruction and learners' learning outcomes [70]. However, it is vital to utilize these models with caution and to thoroughly assess their limits and potential biases [71]. In addition, it is crucial to promote diversity and digital equality to achieve better decision-making, enhanced innovation, and creativity, and create new business opportunities.

Five topics, namely *Gamification and engagement*, *MOOCs*, *AI and big data in education*, *Social networks and discussion forums*, and *Plagiarism detection and learning analytics*, have shown high acceleration rates despite their low volumes. This suggests that these topics have recently gained importance and are likely to be explored in future studies. While gamification has gained immense popularity in promoting active learning and engagement, researchers are expected to further exploit its effective use depending on its strategic application concerning the problem, educational content, and targeted population [72]. This study also proposes some recommendations based on topic clusters. For instance, researchers are advised to continue exploring the potential of AI and big data in addressing educational challenges such as plagiarism detection. However, ethical considerations like data privacy and preventing bias should be considered when implementing AI-based systems in education. The post-COVID-19 era presents several opportunities and challenges for gamification in online learning. Although gamification can enhance learning effectiveness in online learning by promoting engagement, motivation, and personalization, it needs to be tailored to students' needs and preferences and address the challenges posed by the post-COVID-19 era. Additionally, inter-departmental collaborations among system developers, educational experts, and practitioners are encouraged to offer highly effective and personalized learning systems that integrate pedagogy, practice, and technology. Finally, scholars need to focus on addressing the various problems related to AI and big data application-empowered long-distance education.

4.4. Limitations and future work

The current study investigates the research topics, contributors, and collaborations of TEHE research using bibliometrics and topic models. To allow a more comprehensive understanding of the educational technology research field, it is suggested that additional research be performed with the inclusion of comparable journals like The Internet and Higher Education and diverse resources like books, dissertations, and conference proceedings. Incorporating metadata into modeling processes to analyze how it influences topic prevalence can also give new insights. While topic modeling-based bibliometrics has the benefit of providing speedy and automatic large-scale literature data analysis, it may not give the same level of information as human coding and meta-analysis research. Future studies might provide viable ways for doing in-depth analyses of large TEHE articles that combine the benefits of machine learning with systematic analysis methodologies.

5. Conclusion

Based on articles in the International Journal of Educational Technology in Higher Education, we did bibliometric and topic modeling analyses to understand the present status and developments in TEHE research. The journal was chosen because of its growing relevance and activity in the field of TEHE. We got a thorough picture of research topics, their dynamics, correlations, and distributions, which can give insights to researchers, funding agencies, and decision-makers. Our research also identified the primary contributors to TEHE research and illustrated their scientific partnerships. Findings help research governors and funding agencies optimize strategies, develop competitive topics, and improve scientific communication with potential countries/regions/institutions to boost scientific activity and guide research efforts to the most promising and important areas. Furthermore, the findings of our study are useful to potential contributors to TEHE research. For example, by identifying the most popular research topics, administrators may make educated judgments regarding the content and breadth, attracting more submissions and reading. Overall, our research adds to a better knowledge of the current status and future orientations of educational technology research, as well as essential information for field decision-makers, researchers, and funding agencies.

Data availability statement

The data will be available upon reasonable request from the corresponding author.

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Ethics approval statement

This research was conducted following relevant ethical guideline.

CRediT authorship contribution statement

Xieling Chen: Writing – original draft, Visualization, Methodology, Formal analysis, Data curation, Conceptualization. **Di Zou:** Writing – review & editing, Supervision, Investigation, Formal analysis, Conceptualization. **Haoran Xie:** Writing – review & editing, Resources, Project administration, Formal analysis, Conceptualization. **Fu Lee Wang:** Supervision, Resources, Project administration, Funding acquisition, Conceptualization.

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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