IEEE Access
Multidisciplinary ⋮ Rapid Review ⋮ Open Access Journal

Received 9 July 2024, accepted 9 August 2024, date of publication 14 August 2024, date of current version 26 August 2024.

Digital Object Identifier 10.1109/ACCESS.2024.3443313

RESEARCH ARTICLE

Mapping Artificial Intelligence Integration in Education: A Decade of Innovation and Impact (2013–2023)–A Bibliometric Analysis

MUHAMMAD AFZAAL[1], XIAO SHANSHAN[2], DONG YAN[3], AND MUHAMMAD YOUNAS[3]

[1]Institute of Corpus Studies and Applications, Shanghai International Studies University, Shanghai 220033, China
[2]School of English Studies, Shanghai International Studies University, Shanghai 220033, China
[3]School of Educational Technology, Beijing Normal University, Beijing 100875, China

Corresponding author: Muhammad Younas (younaskherani@bnu.edu.cn)

ABSTRACT Artificial Intelligence (AI) has garnered considerable attention from educators, policymakers, and scholars within the realms of education and social sciences, achieving notable historical significance. Employing bibliometric analysis, this paper aims to provide a comprehensive analysis of the most noticeable trend of using AI in education. The corpus comprises a dataset of publications sourced from Web of Science (WoS) and Scopus-indexed journals. It concentrates on contemporary scientific research and innovative methodologies within the education sector, particularly relevant to the intersection of education and technology in the AI era. The results reveal a significant rise in AI-related technological research beginning in 2018, with citations reaching their zenith in 2019. Furthermore, collaborative metrics indicate that the United States and China are leading in publication volume. In addition, the study highlights a rising interest in AI applications within education and healthcare, particularly in the context of the COVID-19 pandemic.

INDEX TERMS Artificial intelligence, education, technology, visualization, bibliometric analysis.

I. INTRODUCTION

The evolution of the global economy and society has significantly impacted by artificial intelligence (AI) and its applications, which have attracted widespread interest throughout the world. In addition, researchers in the field of artificial intelligence have mostly focused on a few key areas such as classical model-based machine learning, intelligence inspired by biology, intelligence gleaned from large amounts of data, intelligence based on simulations of the human mind, language sciences, intelligence based on perception, and even in education [1]. The educational artificial intelligence research may be broken down into four key conceptual domains: technical basis, technological breakthroughs, intelligent applications, and symbiotic integration [2]. Furthermore, there has been a significant rise on the use of sophisticated information and communication technologies, together with computational methodologies, within the domain of education and training. The significance of this was emphasized by the study carried out [3], [4]. Furthermore, it is expected that specialized artificial intelligence in education (AIED) technologies, which are specifically developed to improve learning and teaching, will have a significant impact on the future of education.

Against this backdrop, this study employs bibliometric analysis to present an in-depth assessment of the research trends and important areas of interest within the field of AI during the previous decade [5]. Many studies have shown that the incorporation of artificial intelligence (AI) into educational curricula is now in its nascent stages in several nations. For instance, China is prioritizing the implementation of AI curriculum by means of teacher education programs. In this

The associate editor coordinating the review of this manuscript and approving it for publication was Ka Wai Gary Wong.

particular context, the main subjects of interest in the field of artificial intelligence (AI) have received considerable attention. These subjects include machine learning, data science, big data analysis, deep learning, and ethical issues. These themes have been extensively examined in studies [6], [7]. The importance of the mobile computing and distributed technologies on the development of intelligent educational applications was thoroughly explored at the 10th International Conference on Artificial Intelligence in Education. The authors further propose that 'when considering the future trajectory of research in the domain of artificial intelligence (AI) in education', it becomes apparent that interdisciplinary cooperation among specialists in computer science, statistics, education, cognition, and robotics will be essential.

There has been a noticeable and constant increase in academic interest across a range of fields in recent years. Significantly, some developed countries such as US has assumed a prominent position in scholarly papers pertaining to the Internet of Things (IoT) in the field of education, as shown by the study [8]. Furthermore, China is a significant force in the field of artificial intelligence (AI) research as it pertains to the use of this technology in the context of high school pupils. The integration of artificial intelligence (AI) and robots into the field of Library and Information Science (LIS) is considered crucial in light of the anticipated changes in skill demands and this approach is supported by the findings of these studies [9], [10].

AI has not only gained popularity in education but also made substantial contributions to digital education research through the involvement of highly engaged individual scientists [11]. In addition, it is worth noting that artificial intelligence (AI) shows promise in providing tailored advice, assistance, and evaluation to students and instructors throughout the educational journey. This concept has been examined in the scholarly works [12], [13]. Although there has been a rise in the use of AI in interdisciplinary research, there are still challenges, potential hazards, and obstacles in the field of education. A study highlights their multifaceted and dynamic educational capabilities and significance of e-learning systems in the modern society [14]. The use of Internet of Things (IoT) technology in the field of education has generated significant attention and discussion among scholars and professionals, highlighting the profound impact it may have on the educational environment. Previous study present that 'the advent of innovative computing tools has facilitated the development of more enriched learning experiences, promoted a spirit of discovery, and fostered cooperation among learners [15]. Moreover, the incorporation of artificial intelligence (AI) technology into existing information systems presents significant opportunities for increasing educational results via improvement and innovation. The emphasis on technology and AI in education is evident in the study [16]. They propose that the availability of educational resources online, the automation of tasks to save teacher time, and the provision of learning assistance to enhance student involvement are driving positive changes in education.

Many studies [17], [18] have further explored the use of information technology and computer science in the underdisciplined research in education. Reference [19] mention that 'the field of information technology and computer science has seen significant progress, which has had a lasting impact on our everyday lives. The main research areas within this field focus on the advancement and assessment of the Technological Pedagogical Content Knowledge (TPACK) framework, the enhancement of teachers' technological pedagogical content knowledge in teacher education programs, the utilization of TPACK across various disciplines, digital literacy, online communities, and the complex dynamics of motivation and belief. Zou et al. [20] discuss several dimensions and together enhance our comprehension of the dynamic educational environment.

Therefore, many educators consider the use of AI in education a major contributing factor in achieving excellence. The issue of AI literacy has become a significant concern among educational authorities worldwide as they endeavor to equip the next generation with the essential skills and knowledge of recent technology.

Another significant area of research identified by scholars, involves integrating gamification and e-learning for young learners. This emerging trend has not only heightened interest but also fostered the development of innovative approaches within the realm of educational research.

References [21] and [22] have identified four prominent areas for future research, including customization, game aspects, learner styles, and learner engagement. These themes highlight the dynamic nature of educational approaches and technology, emphasizing the need for more investigation in these domains.

In addition to the ramifications, the trend of AI in education has also turned to interest in the field of digital literacy, particularly in relation to the incorporation of digital technology, ontology research, educational approaches pertaining to digital literacy, and assessments of effectiveness [23]. This interest has been particularly heightened in light of the Covid-19 epidemic. References [24] and [25] gives useful insights to scholars and suggests new directions for future investigations. For instance, technologies-enhanced learning (TEL) has arisen as a notable breakthrough, which has disrupted traditional teaching and learning methods by using information and communication technologies to improve educational results. Reference [26] underscore the significant transformational capacity of Technology-Enhanced Learning (TEL) in the context of higher education.

The studies above mentioned have highlighted that the trend in the usage of AI in education has emerged as a potential solution to solve the increasing issues encountered by contemporary education systems, as shown by many academic works [27], [28]. These aforementioned issues have specifically hindered the ability to obtain education and

engage in effective learning. The integration of artificial intelligence (AI) into the realm of education has led to the emergence and evaluation of novel pedagogical approaches in various settings. Hence, it is worth mentioning that sophisticated information and communication technologies, together with computational approaches, have been used in educational and training environments.

Based on the literature reviewed above, this study focuses on providing a comprehensive analysis of the progression of artificial intelligence (AI) research within the realm of higher education (HE). The study employs bibliometric analysis and topic modeling approaches, as described by [29] to offer insights into the changing dynamics of artificial intelligence in the field of education.

The study aims to examine past trends, as the use of artificial intelligence has become a crucial factor influencing forthcoming strategic choices. According to [30] the augmentation and implementation of artificial intelligence (AI) skills are of utmost importance across many study disciplines. It is worth noting that current research has only offered a limited understanding of the widespread use of artificial intelligence (AI) in various areas of study.

Recently, the domain of artificial intelligence (AI) has seen notable progressions and is positioned to revolutionize diverse facets of human existence. It is worth mentioning that artificial intelligence (AI) technology has begun to penetrate the field of higher education. Many recent studies have contributed to the proliferation of AI in the education sector. The proliferation of academic papers has followed the increasing use of Artificial Intelligence (AI) technology in the field of education. However, there is a gap in the literature as no extensive investigation covering the many aspects of this discipline on a broad scope has been undertaken so far [31]. The latest studies highlight the latest advancements and research requirements, emphasizing the need for future initiatives that include extensive research partnerships and thorough examinations of intelligent educational strategies [32], [33]

Considering recent advancements, the main aim of this study is to analyze patterns in publications and citations, prominent nations and affiliations, authorship status, prevalent themes, thematic features, research interests, and developing trends within the area. In doing so, the study provides a comprehensive understanding of the trajectories and consequences of artificial intelligence (AI) in the context of online learning, offering insights into global trends and identifying potential areas for future research.

II. RESEARCH QUESTIONS

This study endeavors to delineate a holistic understanding of the evolutionary trajectory, and research foci of AI within the field of education technology. Guided by a rigorous academic framework, this study seeks to address the subsequent research questions:

(1) What are the basic statistics concerning the annual production, citation for relevant publication source and authors?

(2) Which collaborative metrices, manifested through nations, institutional affiliations, and scholarly contributions, are discernible in this academic domain?

(3) How are the prevailing research epicenters, concentrated foci and nascent paradigms, as reflected in the keyword co-occurrence networks and temporal keyword clusters?

III. METHODS

A. BIBLIOMETRIC TOOLS AND PARAMETRIC SETTING

Bibliometrics is a widely used and 'fast advancing tool in the field of intelligence research, namely in the evaluation of scientific themes' [34], [35], [36], [37], [38], [39]. It employs quantitative analysis, 'correlation networks, and statistics to examine the bibliographic and content data of papers in a specific topic [40], [41]. Furthermore, a wide reportoire of bibliometric studies across various fields (especially scientometrics) have yielded satisfactory results through conducting similar quantitative analysis [19], [42], [43], [44].

Therefore, this study employs Bibliometrix tool (4.0.0) for the overall quantitative analysis of the bibliometric analysis of AI in education. The Bibliometric tool is based on R language and works on data extracted from Scopus, Clarivate Analytics Web of Science, Cochrane Database of Systematic Reviews (CDSR) and RIS Pubmed/Medline. Additionally, the study uses of Bilblioshiny (4.0) in conjunction with Bibliometrix for the visualization of ''Authors'' ''Sources'' ''Documents'' ''Clustering'', etc. Biblioshiny is a web-interface for bibliometrix. It enables users to make a hands-on, code-free bibliometric analysis, including analytics/plots for different metrics, analysis for three structures of knowledge (K-structures). (https://www.bibliometrix.org/home/index.php /layout/biblioshiny). In the workflow of Bibliometrix and Biblioshiny, the data collected are first loaded and converted to R data frame. Based the collected data, descriptive analysis followed by bibliometric mapping are then conducted. Finally, Biblioshiny shows the data visualization including conceptual structure mapping and network mapping [45].

Moreover, the study incorporated [46] VOSViewer for the visualization and mapping. VOSViewer offers open source solution, dedicated to the generation of intricate bibliometric mappings. Owing to VOSviewer's capability to ''illustrate expansive bibliometric maps with intruitive clarity'' [47], [48], [49]. This software offers the crafting of co-occurrence networks and delineating country/ author collaboration metrices. This function ensures that the large dataset is analyzed systematically and structures into lucid and visually compelling graphs. Finally, the study incorporates CiteSpace version 6.1 for the data handling and setting the metrics to analyze the trends and reflected patterns in the domain of AI in education. Citespace (6.1 R6), crafted on a Java-based application, stands as an intricate and robust tool for the bibliometric evaluation. Underpinned by burst detection algorithm [50] for identification of emergent research front, betweenness centrality [51] metric for detection of essential

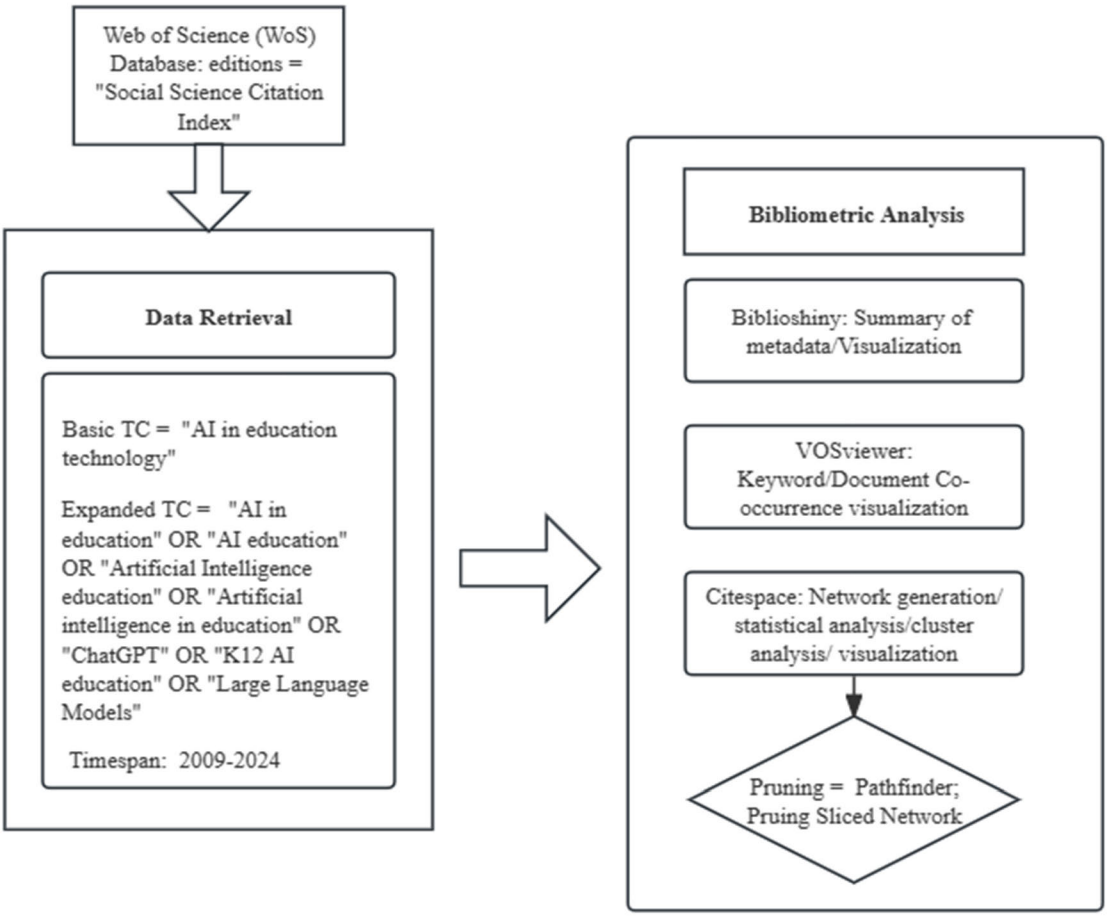


FIGURE 1. Flowchart of bibliometric analysis.

paradigm shift points as well two visualization modes- - cluster views and time zone views, Citespace stands out as a composite bibliometric software well operationalizing the focal points of ''research fronts'' and ''intellectual bases'' in information science [52]. Within its parametric configurations, the three-year time slice and ''pruning'' option in pathfinder are set while the other parameters remain default.

B. DATA SOURCE AND DATA COLLECTION

Web of Science (WOS), an all-encompassing database with more than 15,000 journal indexes and a volume of nearly 50 million articles. Utilizing the WOS database, this study endeavors to retrieve publication metadata pertinent to AI education. The selection criteria are meticulously delimited to encompass solely the ''editions = Social Science Citation Index'' only. The basic theme is articulated as ''AI in education technology''. The expanded theme has been designated, encapsulating terminologies such as ''AI (in) education'' ''Artificial Intelligence (in) education'' ''Artificial Intelligence in Education (AIED) '' ''ChatGPT'' ''Large Language Models'' ''Open AI'' to ensure all possible keywords within this field are included. The chronological boundary for this is demarcated between the years 2009-2024 whereas linguistic parameters remain unbound. Overall, the study found 2216 articles as per the thematic criteria from the dataset. However, the total number of articles are reduced to 2101 as per the setting of article types such as ''Article'', ''Review Article'' and ''Review Article''. The entire process encompassing data collection, parametric settings and data analysis is demonstrated in the flowchart in **Figure 1**.

IV. RESULTS AND DISCUSSIONS

A. BASIC PUBLICATION STATISTICS

This section utilizes Bibliometrix and Bilioshiny to probe into the basic publication statistics within the research field of AI in education technology. Specifically, document type distribution, annual publications/ citations, relevant sources/authors/affiliations are to be examined meticulously in this part. As demonstrated in Table 1, a total of 2101 documents scatter over a time span of 16 years from 2009 to 2024, coming from 963 sources. On average, each document is cited more than six times, and the cumulative number of references reaches up to 78,908.

In figure 2, of the 2,101 documents, 85% are articles and 70% sing-authored individually comprise 70%, while the remainder are integrated into book chapters, proceedings

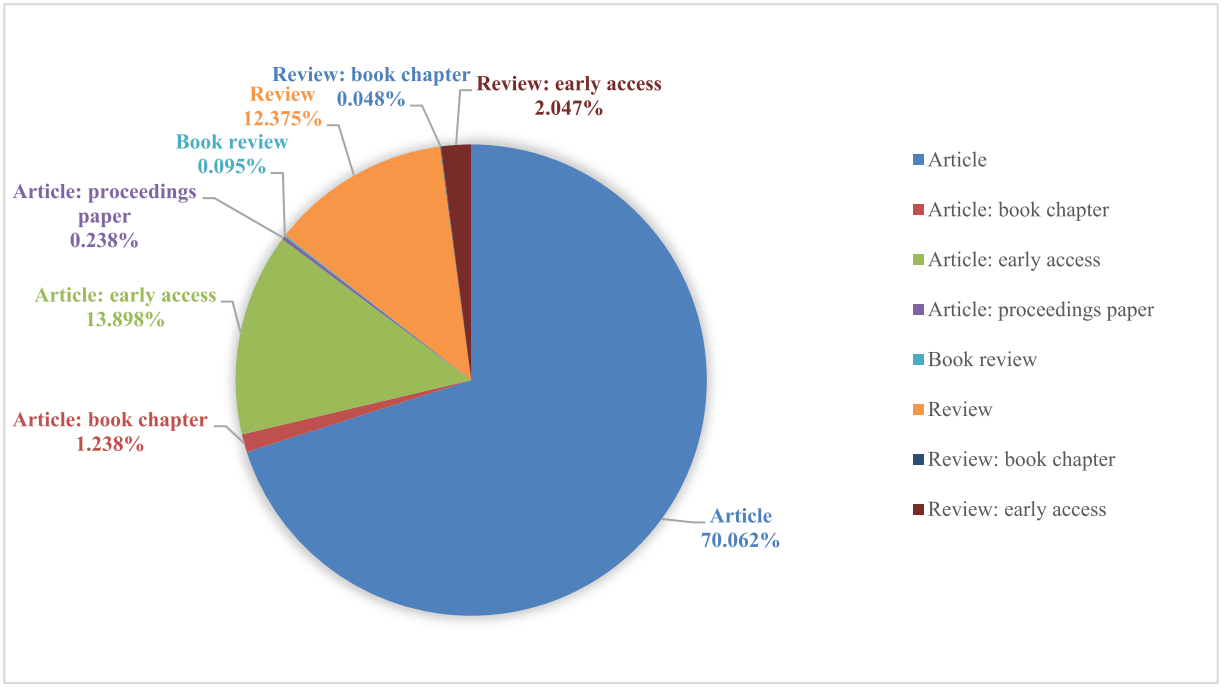


FIGURE 2. Distribution of data type.

papers, and early access collections. In stark contrast, review articles and book reviews make up no more than 15% of the entire collection. **Figure 3** demonstrates yearly based an overall evolving trend from 2009 to 2023. In the first decade starting from 2009 to 2018, the evolving line of publication remains flat, which indicates that research in this field is at the initial stage.

Subsequent years witness a marked ascent of publication from 17 (2018) to 1223 (2023), with an increasing growth rate manifest in steeper lines in the trend plot.

TABLE 1. MData Size.

Timespan	2009:2024
Sources (Journals, Books, etc)	963
Documents	2101
Average citations per doc	6.756
References	78908

Table 2 of the study shows the annual metric in Publications. Results indicate that the initial mean total citations per article is 16.67 times, with a yearly citation of 1.11 times. Moreover, the mean total citations per article peaks at 45.32 times the at year 2016 while the yearly mean total citation is the greatest in 2019 (8.07). To elucidate the change of average annual citation per year, **Figure 4** shows an overall zigzag trend, indicating that "AI in education technology" has garnered an increasing popularity across the years, with the most essential research insights occur in 2019.

V. OVERVIEW OF PUBLICATION SOURCES, AFFILIATION, AUTHORS

As one of the most tangible pattern indicates that sources, affiliations and authors are measured jointly with relevance and local impact. Bibliometrix calculates relevance drawing on frequency measures including number of documents, percentage and fractionalized frequency. Relevance in this study is indicated by the total amount of publications. **Table 3** demonstrates the top 25 most relevant sources, affiliations, and author relevance. The 'Cureus Journal of Medical Science', a Springer Nature journal in the field of Medicine, is the one with the most publications (101) in AI education, followed by 'Sustainability' (63), an open-access journal focusing on environmental, cultural, economic, and social sustainability of human beings The journal that ranks 3rd is Education and Information Technologies (49), the topic of which is congruent with information, communication technologies and education. Moreover, the author-based metrics h-index, g-index and m-index offer a perspective taking into account productivity and citation impact of publication sources, affiliations and authors. **Table 4** demonstrates the top 25 journals with the greatest local impact. International Journal Of Artificial Intelligence In Education, Sustainability, IEEE Access,British Journal Of Educational Technology, Education And Information Technologies are the top 5 journals with the greatest h-index and g-index. Since

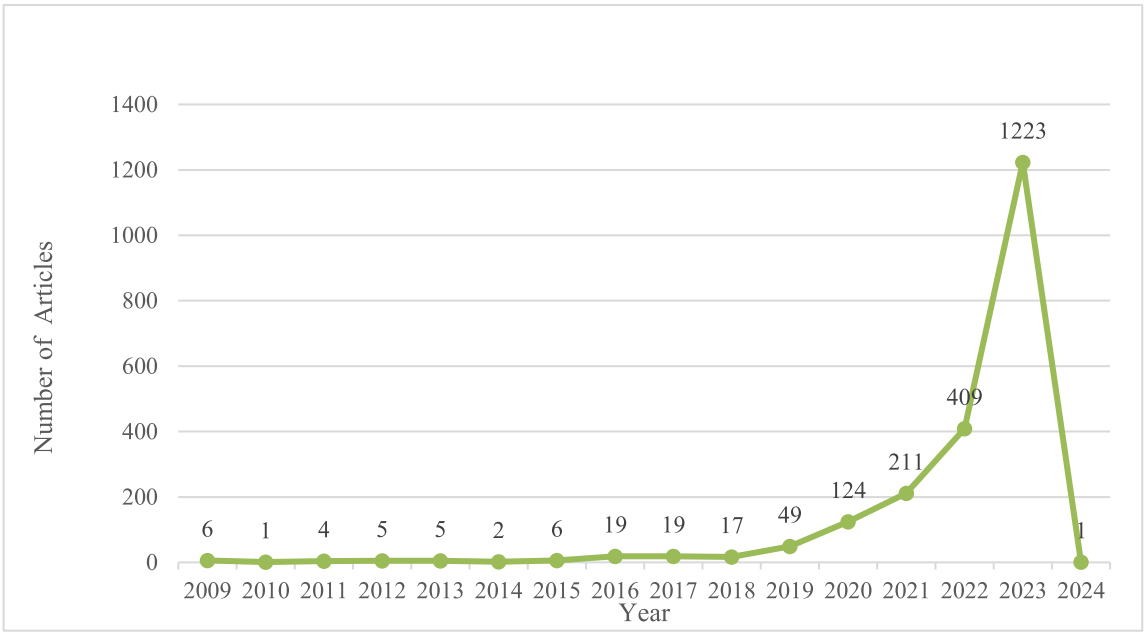


FIGURE 3. Number of annual publications.

TABLE 2. Annual citations per year.

Year	Mean (TC) per Art	Number	Mean (TC) per Year	Citable Years
2009	16.67	6.00	1.11	15
2010	14	1.00	1.00	14
2011	15.25	4.00	1.17	13
2012	23.2	5.00	1.93	12
2013	29	5.00	2.64	11
2014	33	2.00	3.30	10
2015	6.5	6.00	0.72	9
2016	45.32	19.00	5.66	8
2017	23.16	19.00	3.31	7
2018	37.94	17.00	6.32	6
2019	40.35	49.00	8.07	5
2020	23.34	124.00	5.84	4
2021	9.82	211.00	3.27	3
2022	4.28	409.00	2.14	2
2023	2.46	1,223.00	2.46	1

m-index is defined as h/n, where h is defined as h-index while n is the number of years since the first publication of paper, the ranking of m-index differ significantly from that of the other two metrics. Cureus Journal Of Medical Science, Aesthetic Surgery Journal, Journal Of Chemical Education, Sustainability, British Journal of Educational Technology have the greatest local impact if measured by m-index.

From the most productive authors in AI in education perspective, Table 3 shows that Chai CS (14), Chiu TKF (13), Kim J (13), Hwang GJ (12), Wang FY(12) are found the top 5 most relevant authors. Also, **Table 5** shows the top 25 authors with the greatest local impact. G-index and h-index align with each other in taking Chai CS, Chiu TKF, Hwang GJ, Cukurova M are among the top 4 ranking. But in terms of m-index, this ranking is replaced by Wang FY,

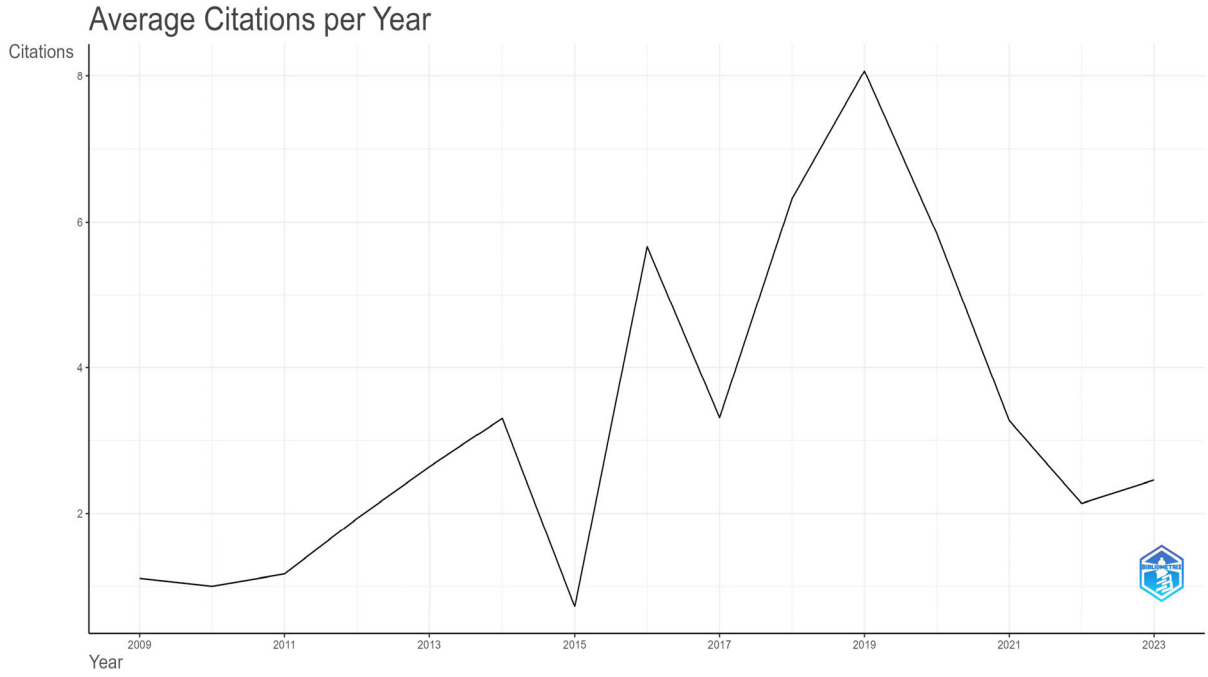


FIGURE 4. Average annual citations of papers.

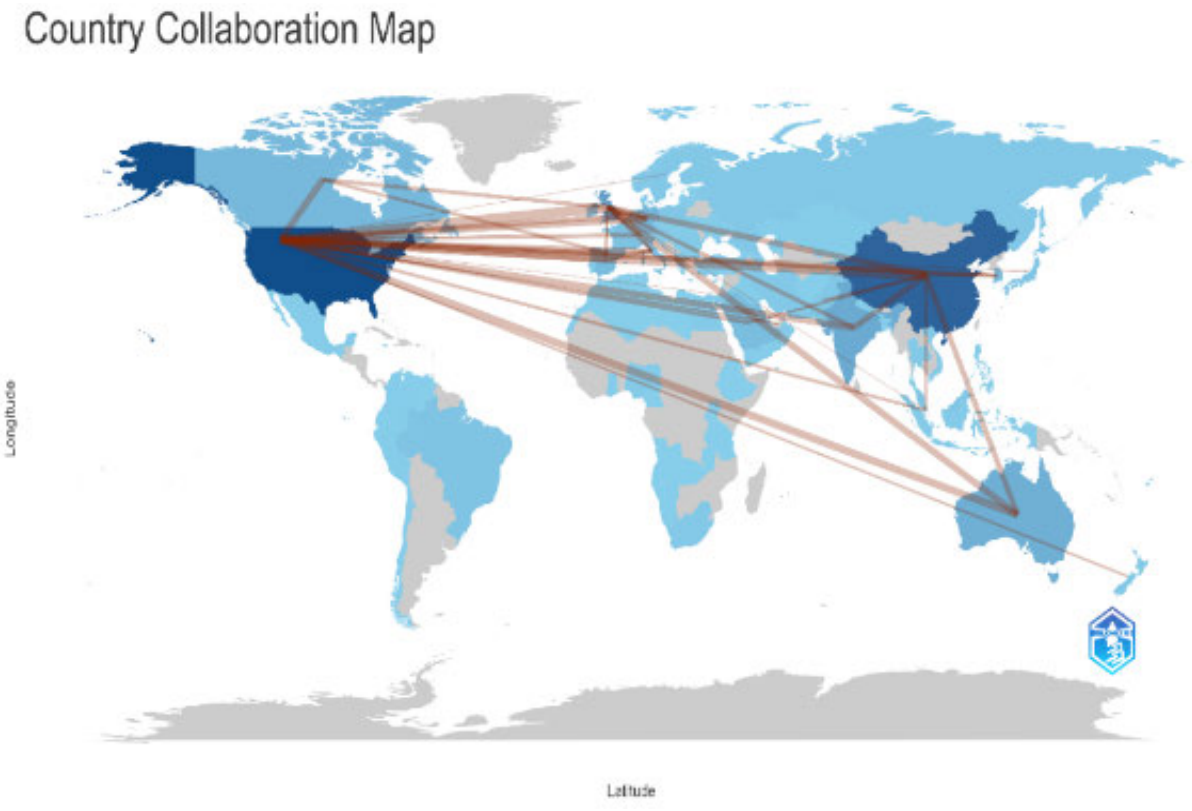


FIGURE 5. Documents distribution/ Country cooperation map.

Alhasan K, Aljamaan F And Al-Eyadhy A. The publication of affiliations is shown in the fifth and sixth column of Table 3. Following the most productive institutions, University of Toronto (51), University of London (46), University College

TABLE 3. Top 25 most relevant sources, affiliations and authors.

Sources	Number of Articles	Authors	Number Of Articles	Affiliation	Number Of Articles
Cureus Journal Of Medical Science	101	Chai Cs	14	University Of Toronto	51
Sustainability	63	Chiu Tkf	13	University Of London	46
Education And Information Technologies	49	Kim J	13	University College London	43
International Journal Of Artificial Intelligence In Education	45	Hwang Gj	12	Harvard University	38
Ieee Access	34	Wang Fy	12	Udice-French Research Universities	37
Frontiers In Psychology	25	Cukurova M	8	Vanderbilt University	37
British Journal Of Educational Technology	22	Dai Y	7	University Of California System	36
Education Sciences	22	Chu Skw	6	State University System Of Florida	35
Interactive Learning Environments	22	Jong Msy	6	Stanford University	33
Annals Of Biomedical Engineering	20	Mondal H	6	King Saud University	31
Applied Sciences-Basel	18	Seth I	6	State University System Of Florida	26
Educational Technology & Society	16	Sharma S	6	Chinese University Of Hong Kong	25
Wireless Communications & Mobile Computing	16	Singh S	6	Universite Paris Cite	25
Frontiers In Artificial Intelligence	15	Tu Yf	6	University of London	25

TABLE 3. *(Continued.)* **Top 25 most relevant sources, affiliations and authors.**

Journal of Medical Internet Research	15	Xie Y	6	Chinese Academy of Sciences	23
Ai & Society	13	Yang Sjh	6	University of Texas System	22
Engineering	13	Chen Y	5	Humboldt University of Berlin	21
Frontiers In Public Health	13	Gupta A	5	Harvard Medical School	19
Jmir Medical Education	13	Ho Mt	5	Mcgill University	19
Soft Computing	13	Hunter-Smith Dj	5	Sichuan University	19
Frontiers In Education	12	Jeon J	5	Chinese University of Hong Kong	19
International Journal of Educational Technology In Higher Education	12	Lee J	5	University of California System	19
Journal Of Chemical Education	11	Lee S	5	University of Hong Kong	19
Techtrends	11	Li B	5	Institute of Automation, Cas	17
Electronics	10	Li J	5	Monash University	17

London(43), Harvard University(38), Udice-French Research Universities(37) are the most productive institutions.

VI. ANNUAL SCIENTIFIC PRODUCTION

A. COOPERATION AND CITATION ANALYSIS

1) COUNTRIES/REGIONS PUBLICATION NETWORK

The map in **figure 5** shows the distribution of publications across the world with number of publications attached. Publications span across 104 countries/regions across the world. The number of publications is indicated by the darkness of the blue color of each region. The regions with more publications are tinted with darker blue while those less are of lighter blue. According to **Figure 5**, China and US have the most publications.

Figure 5 and **Table 6** combined demonstrate the collaboration status among countries. (USA, China), (USA, United Kingdom) and (USA, Australia) have the closest bond according to **Table 6.** Notably, China and USA are also with the most extensive global cooperations.

2) HIGHLY CITED PUBLICATIONS

Table 7 comprises the top 25 papers with the most citations. In bibliometric analytics, global citation score (GCS) is the overall citations of article in WOS database while local citation score (LCS) only measures the citations in the current collected dataset. The normalized local citation (NLCS) in bibliometric (**see Table 7**) is calculated by dividing the actual count of local citing items by the expected citation rate for documents with the same year of publication. It precisely measures the relative citations of various documents published in different years. The paper with largest NLCS is considered the most influential paper within the specified

TABLE 4. Top 25 Sources with the largest local impact.

Journals	H_Index	G_Index	M_Index	TC	NP	PY_Start
International Journal Of Artificial Intelligence In Education	**15**	**30**	1.667	914	45	2015
Sustainability	**13**	**19**	**2.600**	455	63	2019
IEEE Access	**11**	**20**	1.222	423	34	2015
British Journal Of Educational Technology	**10**	**19**	2.000	364	22	2019
Education And Information Technologies	**9**	**16**	1.800	315	49	2019
Engineering	**9**	13	1.125	871	13	2016
Cureus Journal Of Medical Science	**8**	14	**4.000**	286	101	2022
Jmir Medical Education	7	10	1.750	118	13	2020
Applied Sciences-Basel	6	10	1.200	119	18	2019
Education Sciences	6	10	1.200	110	22	2019
Educational Technology & Society	6	11	2.000	144	16	2021
Interactive Learning Environments	6	13	0.500	187	22	2012
Journal Of Medical Internet Research	6	15	1.500	280	15	2020

TABLE 4. *(Continued.)* **Top 25 Sources with the largest local impact.**

Learning Media And Technology	6	10	1.500	190	10	2020
Computers & Education	5	6	0.333	120	6	2009
Computers In Human Behavior	5	7	0.714	261	7	2017
Radiography	5	5	1.667	46	5	2021
Aesthetic Surgery Journal	4	6	**4.000**	42	6	2023
Ai & Society	4	9	0.800	88	13	2019
Frontiers In Public Health	4	7	1.000	56	13	2020
Insights Into Imaging	4	5	1.000	40	5	2020
International Journal Of Educational Technology In Higher Education	4	12	0.800	395	12	2019
Journal Of Chemical Education	4	7	**4.000**	56	11	2023
Journal Of Intelligent & Fuzzy Systems	4	6	0.800	44	6	2019
Journal Of The American Medical Informatics Association	4	5	1.333	61	5	2021

field. In addition, the **table 7** shows that the paper titled ''Opinion Paper: ''So what if ChatGPT wrote it?'' Multidisciplinary perspectives on opportunities, challenges and implications of generative conversational AI for research, practice and policy'', published on the International Journal of Information Management, has the greatest NLCS. The paper with the largest LCS is the review article authored by ZAWACKI-RICHTER et al in International Journal of Education Technology in Higher Education. Most of the documents with high LCS or NLCS were published within the timespan

TABLE 5. Top 25 authors with the largest local impact.

Author	H_Index	G_Index	M_Index	TC	NP	PY_Start
Chai CS	6	14	1.500	223	14	2020
Chiu TKF	6	13	1.500	185	13	2020
Hwang GJ	6	12	2.000	208	12	2021
Cukurova M	5	8	1.000	190	8	2019
Yang SJH	5	6	1.250	110	6	2020
Dai Y	4	7	1.000	84	7	2020
Jong MSY	4	6	1.000	98	6	2020
Kim J	4	8	1.000	65	13	2020
Koedinger KR	4	4	0.500	116	4	2016
Ouyang F	4	4	2.000	51	4	2022
Selwyn N	4	4	1.000	84	4	2020
Singh S	4	6	2.000	52	6	2022
Wang FY	4	6	**4.000**	41	12	2023
Ahmad S	3	3	1.000	12	3	2021
Al-Eyadhy A	3	4	**3.000**	34	4	2023
Alharbi A	3	3	1.500	22	3	2022
Alhasan K	3	4	**3.000**	34	4	2023
Aljamaan F	3	4	**3.000**	34	4	2023
Bozkurt A	3	3	1.000	77	3	2021
Bucea-Manea-Tonis R	3	3	1.000	53	3	2021
Chao J	3	4	1.500	33	4	2022
Chen Y	3	5	1.500	48	5	2022
Edwards C	3	3	0.500	66	3	2018
Guo Q	3	3	1.000	16	3	2021
Gupta A	3	3	1.000	16	5	2021

TABLE 6. Country collaboration statistics.

From	To	Frequency
USA	China	37
USA	United Kingdom	36
USA	Canada	24
USA	Australia	23
United Kingdom	Australia	21
China	Australia	18
USA	India	18
China	India	16
China	United Kingdom	16
USA	Germany	16
United Kingdom	Germany	14
USA	France	14
USA	Netherlands	13
USA	Italy	12
Germany	Netherlands	11
United Kingdom	India	11
USA	Korea	11
USA	Spain	11
United Kingdom	Canada	10
United Kingdom	Italy	10
USA	Saudi Arabia	10
Canada	France	9
China	Singapore	9
United Kingdom	Netherlands	9
United Kingdom	Spain	9

from 2019 to 2023, consistent with the trend of publication demonstrated in **Figure 3**.

3) ANALYSIS OF CITED REFERENCES

Burst detection facilitates the frequency tracking of documents over a specific period of time [50]. **Figure 6** shows the top 25 references with the strongest burst strength. The blue bar indicates the overall timespan from 2009 to 2024. However, upon deleting three documents with unspecified publication information, 81 documents with burst strength are detected out of 626 references. The period in which references appear is shown in red bar. The reference with the strongest citation burst comes from [37] aligning with the result provided in **Figure 6**. The document with the longest citation period and the second largest citation burst is ''Exploring the impact of artificial intelligence on teaching and learning in higher education'' by [53] in which the future directions and challenges of AI in higher education were meticulously investigated.

B. RESEARCH FOCI AND TRENDS

In this section, research foci and emerging trends in the field of AI education are examined through keyword analysis including keyword co-occurrence analysis and cluster analysis.

1) RESEARCH FOCI

Figure 2 shows Knowledge domain map of keyword co-occurrence network (a) network visualization map based on LinLog modularity normalization; (b) density visualization map based on article weights.

Firstly, to observe the keyword co-occurrence network, VOSviewer is utilized to plot two knowledge domain maps—the network visualization map as well as the density visualization map. In **Figure 7a**, the largest node in the green part is artificial intelligence, followed by ChatGPT, representative of a technology-oriented cluster. In the red part of the map, keywords are primarily concerned with education. The largest node in the red part is education. The color of nodes in

TABLE 7. Top 25 most-cited papers.

Document	DOI	Year	Local Citations	Global Citations	LC/GC Ratio (%)	Normalized Local Citations	Normalized Global Citations
Zawacki-Richter O, 2019, Int J Educ Technol H	10.1186/s41239-019-0171-0	2019	130	337	38.58	19.78	8.35
Sallam M, 2023, Healthcare -Basel	10.3390/healthcare11060887	2023	76	125	60.80	57.80	50.76
Dwivedi Yk, 2023, Int J Inform Manage	10.1016/j.ijinfomgt.2023.102642	2023	59	129	45.74	44.87	52.38
Dos Santos Dp, 2019, Eur Radiol	10.1007/s00330-018-5601-1	2019	54	213	25.35	8.22	5.28
Alkaissi H, 2023, Cureus J Med Science	10.7759/cureus.35179	2023	51	79	64.56	38.79	32.08
Roll I, 2016, Int J Artif Intell E	10.1007/s40593-016-0110-3	2016	47	133	35.34	8.19	2.93
Chen Lj, 2020, Ieee Access	10.1109/ACCESS.2020.2988510	2020	45	159	28.30	15.00	6.81
Cotton Dre, 2023, Innov Educ Teach Int	10.1080/14703297.2023.2190148	2023	39	51	76.47	29.66	20.71
Cascella M, 2023, J Med Syst	10.1007/s10916-023-01925-4	2023	39	62	62.90	29.66	25.17
Huh S, 2023, J Educ Eval Health P	10.3352/jeehp.2023.20.1	2023	38	49	77.55	28.90	19.90
Tlili A, 2023, Smart Learn Environ	10.1186/s40561-023-00237-x	2023	36	42	85.71	27.38	17.05
Dowling M, 2023, Financ Res Lett	10.1016/j.frl.2023.103662	2023	36	40	90.00	27.38	16.24
Holmes W, 2022, Int J Artif Intell E	10.1007/s40593-021-00239-1	2022	29	60	48.33	29.65	14.01

TABLE 7. *(Continued.)* **Top 25 most-cited papers.**

Salvagno M, 2023, Crit Care	10.1186/s13054-023-04380-2	2023	28	66	42.42	21.30	26.80
Timms Mj, 2016, Int J Artif Intell E	10.1007/s40593-016-0095-y	2016	26	103	25.24	4.53	2.27
Chiu Tkf, 2020, Sustainability-Basel	**10.3390/su12145568**	**2020**	**25**	**50**	**50.00**	**8.33**	**2.14**
Khan Ra, 2023, Pak J Med Sci	10.12669/pjms.39.2.7653	2023	24	34	70.59	18.25	13.81
Macdonald C, 2023, J Glob Health	10.7189/jogh.13.01003	2023	24	33	72.73	18.25	13.40
Perkins M, 2023, J Univ Teach Learn P	10.53761/1.20.02.07	2023	22	26	84.62	16.73	10.56
Luckin R, 2019, Brit J Educ Technol	10.1111/bjet.12861	2019	21	57	36.84	3.20	1.41
Chatterjee S, 2020, Educ Inf Technol	10.1007/s10639-020-10159-7	2020	21	78	26.92	7.00	3.34
Hwang Gj, 2021, Mathematics-Basel	10.3390/math9060584	2021	19	50	38.00	8.60	5.09
Lo Ck, 2023, Educ Sci	10.3390/educsci13040410	2023	19	26	73.08	14.45	10.56
Schiff D, 2021, Ai Soc	10.1007/s00146-020-01033-8	2021	18	40	45.00	8.15	4.07
Taecharungroj V, 2023, Big Data Cogn Comput	10.3390/bdcc7010035	2023	18	30	60.00	13.69	12.18

density visualization is an indication of their citation weights. Aligning with **Figure 7b**, artificial intelligence and chatgpt are also of the greatest citation weights as manifested in their bright yellow color.

Following the keyword co-occurrence network, this section has conducted a factorial analysis embedded in the "conceptual structure" functional panel in Biblioshiny. Factorial analysis in bibliometrix is underpinned by Multi-correspondance Analysis (MCA), an exploratory multivariate technique for the graphical and numerical analysis of multivariate categorical data [46]. **Figure 8** depicts a keyword cluster based on the commonality of study area of the keywords. The proximity between these keywords indicates the extent to which they are treated together. In this conceptual

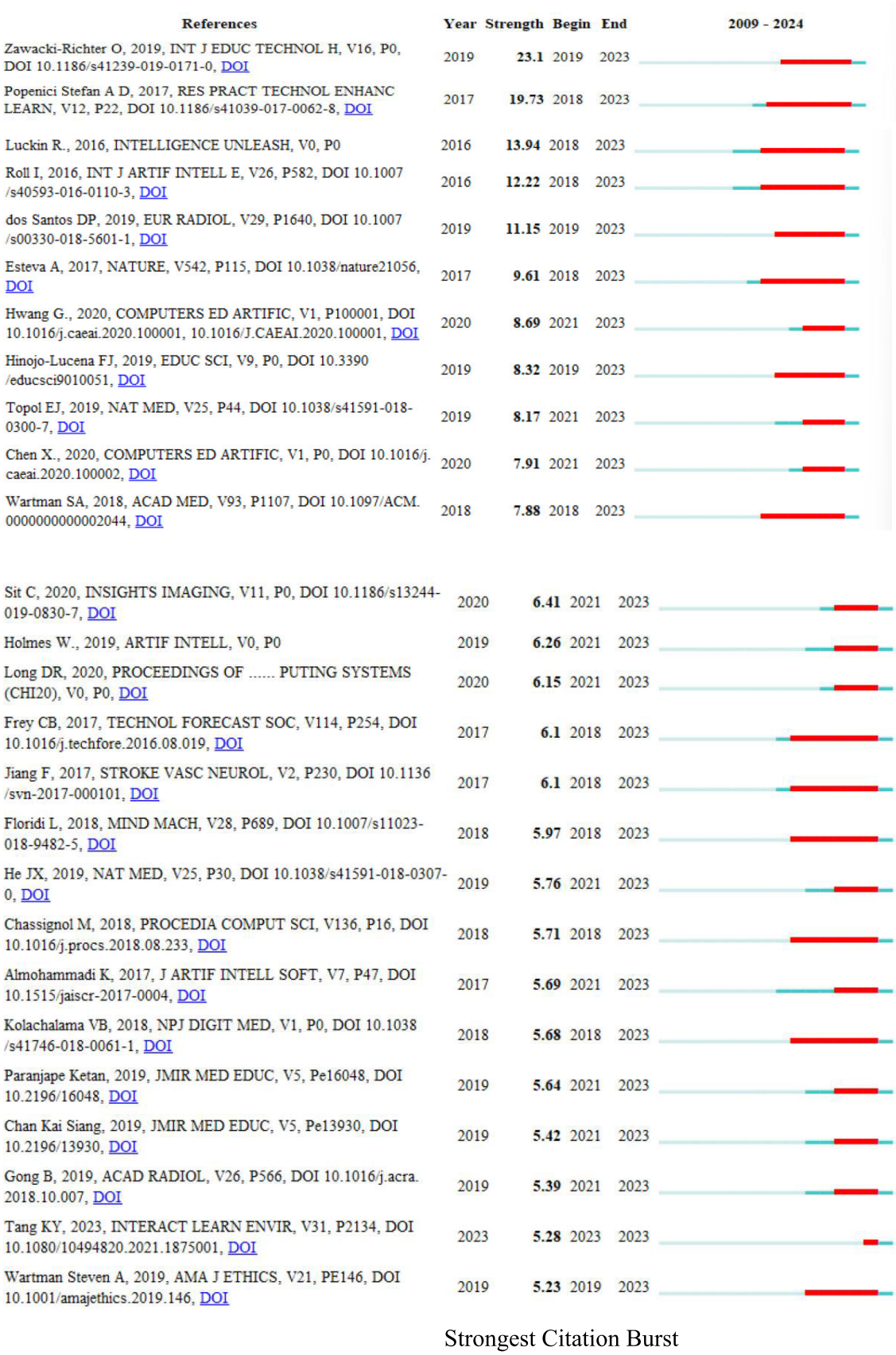
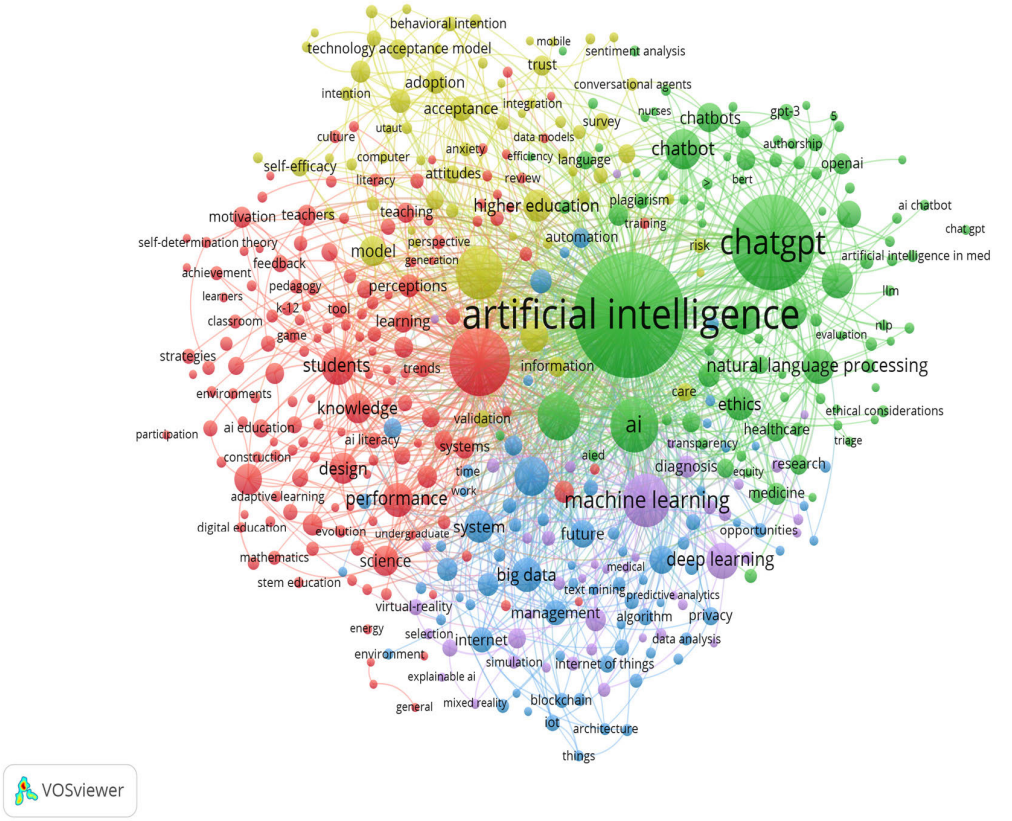
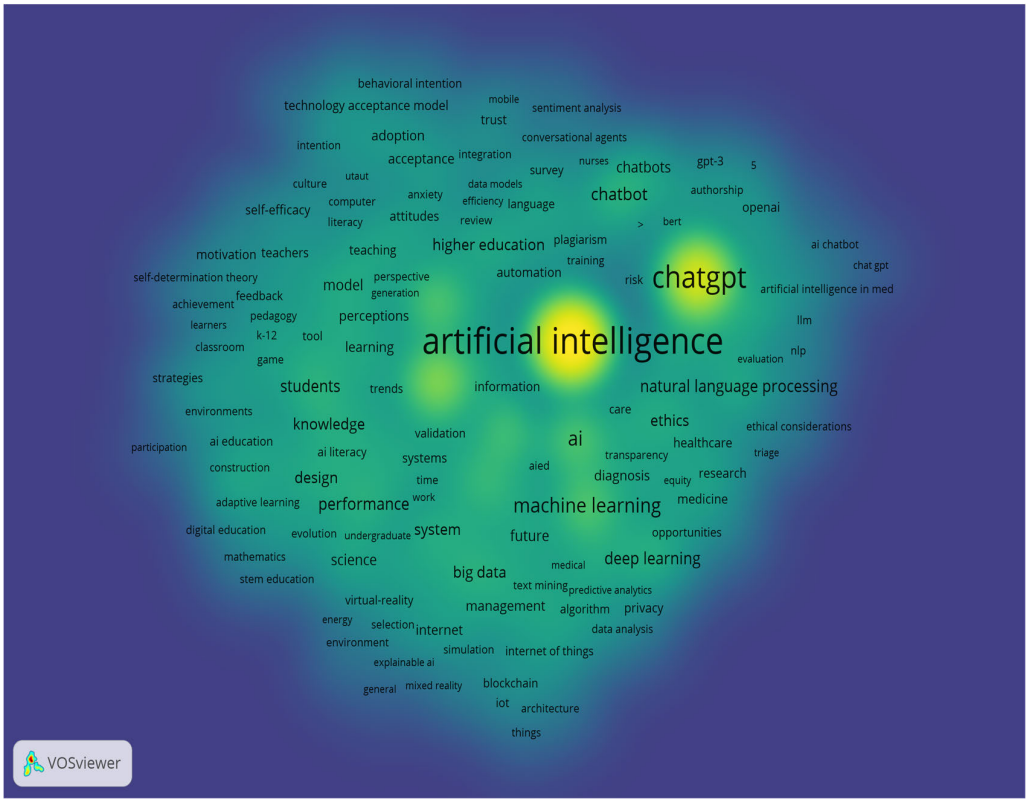


FIGURE 6. Top 25 references with the strongest citation burst.



(a)



(b)

FIGURE 7. a. Reserch Foci b. Reserch Foci.

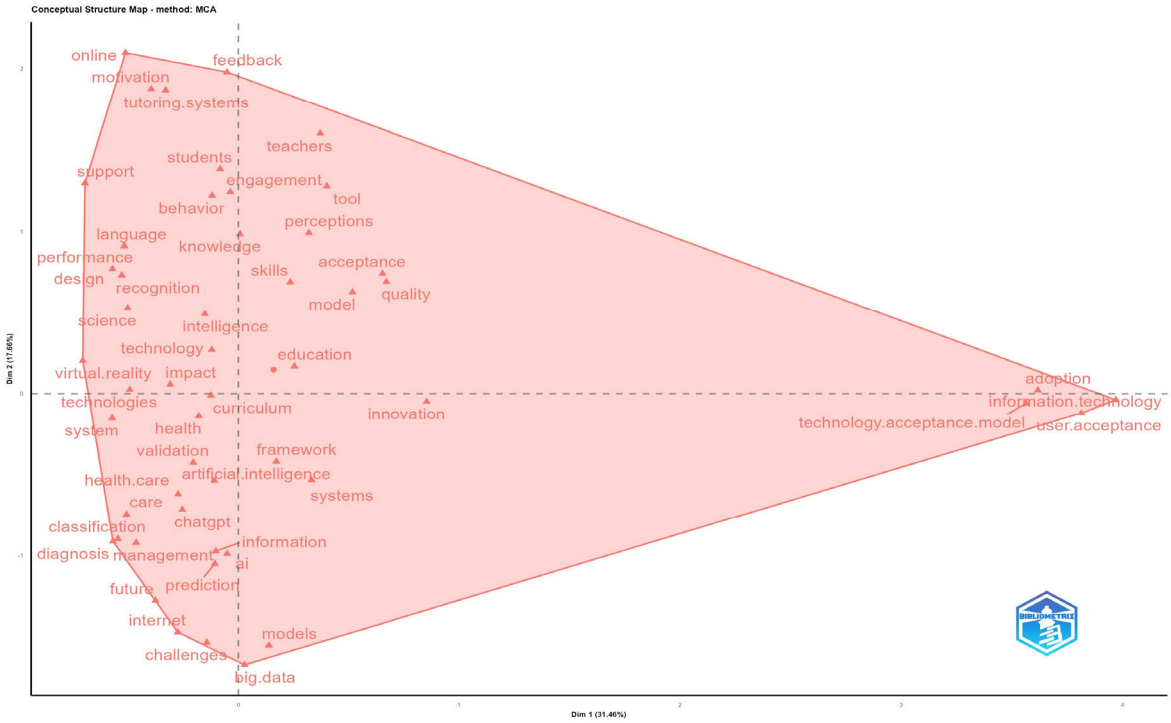


FIGURE 8. Conceptual structure map.

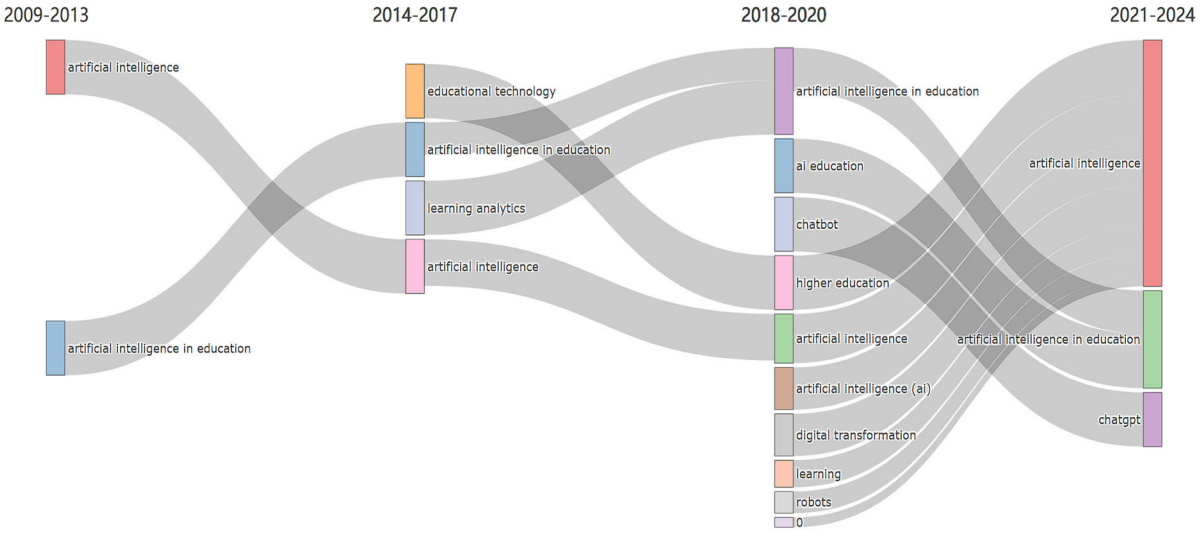


FIGURE 9. Topic evolution process of AI in education technology research.

structure map, keywords such as ''adoption'', ''information technology'' ''technology acceptance model'' and ''user acceptance'' are in the other end of the dimension, away from the rest of keywords such as ''technologies'', ''artificial intelligence'', which lean toward the technology itself and relative application. Divergence shown in the map indicates that technology adoption/acceptance are treated separately from technology/application by most researchers. Following the horizontal axis of the map, keywords from the right end focus more multidimensional measurement and evaluation while those on the left emphasize more one-dimensional studies [42]. Additionally, keywords are distributed at the

Keywords	Year	Strength	Begin	End	2009 - 2024
artificial intelligence in education	2009	3.75	2009	2017	
language-learning	2012	4.79	2012	2014	
human-resource	2012	3.42	2012	2014	
health-care	2015	15.7	2015	2017	
19-pandemic	2015	14.38	2015	2017	
covid-19-pandemic	2015	14.38	2015	2017	
information-technology	2015	13.72	2015	2017	
ai-related	2015	7.82	2015	2017	
regarding-ai	2016	5.9	2016	2017	
ai-ml	2015	4.56	2015	2017	
active-learning	2016	3.27	2016	2017	
mobile-learning	2016	3.27	2016	2017	
technology	2018	8.01	2018	2023	
future	2018	4.59	2018	2023	
deep learning	2019	4.11	2019	2020	
machine learning	2019	3.53	2019	2020	
big data	2016	3.3	2018	2023	

FIGURE 10. Top 17 Topics with the strongest citation burst.

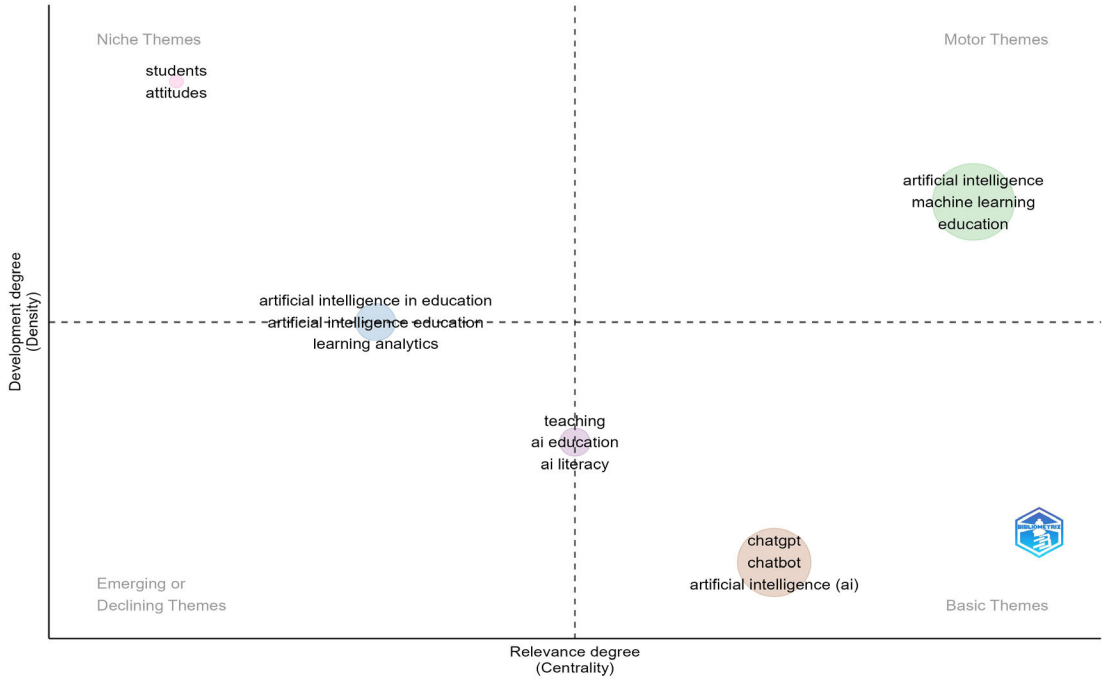


FIGURE 11. Strategic diagrams of AI in education research.

center of the map which represents the research foci since it is the average position of all of the articles. In this context, keywords like ''education'' ''quality'' ''innovation'' constitute the research foci.

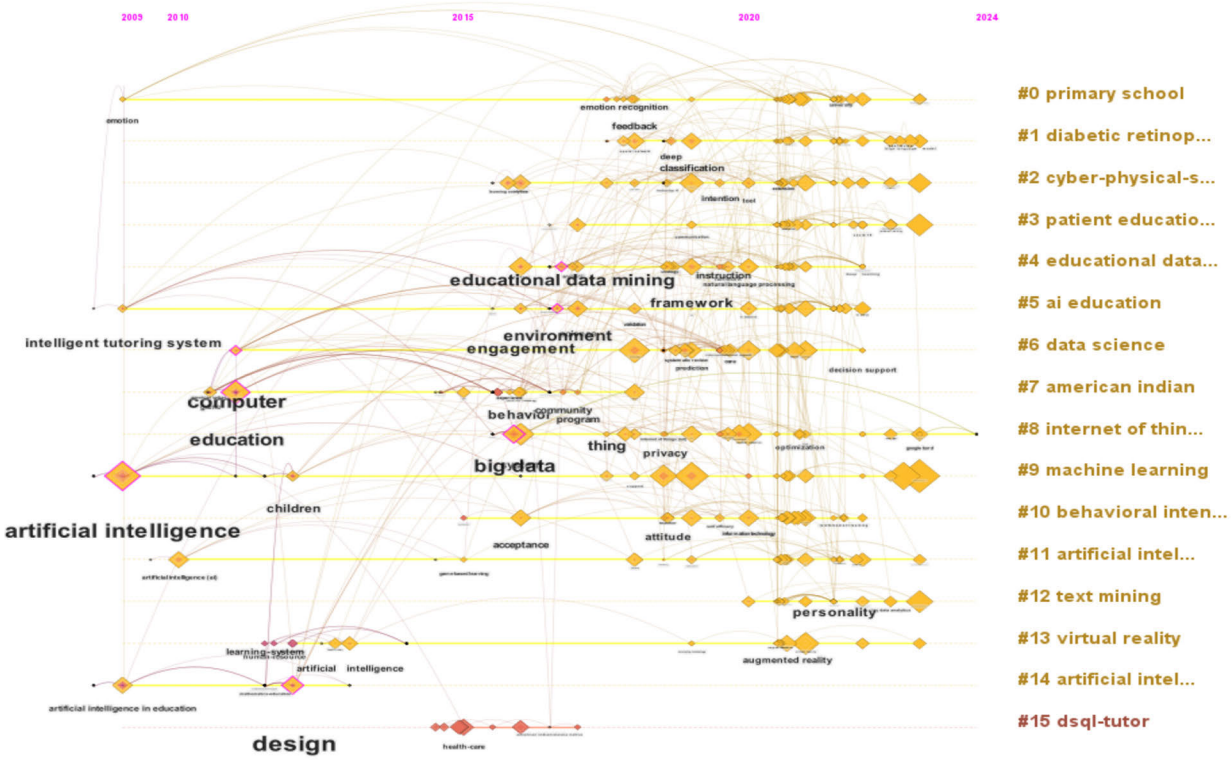


FIGURE 12. Timeline view of keyword clusters.

2) KEY POINTS AND RESEARCH TRENDS

Keywords are the index the research trends and key points. How specific research topic has evolved over time is depicted in **Figure 9**. The thematic evolution process in Figure 9 is originated from [54]. The 15-years span is divided into four periods. Artificial intelligence and artificial intelligence in education occur in the first four-year period and span across the whole period. In the second period, ''learning analytics'' and ''educational technology'' appear as new topic. The year 2018 to 2020 marks the bloom of AI, in which terms such as ''chatbot'' ''robots'' emerge as hot topic. The last period is indexed by ''chatgpt'', the large language model with its ground-breaking impact in the field of AI and every aspect of daily life. Technology-based terms like AI and chatgpt are on the right side while those related to education are on the left side, indicating that more focus on ''AI in education'' research is leaned to technology instead of education. While from the vertical axis, ''student attitudes'' are more established in this field than ''teaching'' and ''AI literacy'' and ''chatgpt'' is under-developed. Since the field under examination is yet to be established, no keyword fall into the third quadrant.

Later, the burst term detection analysis is conducted by Citespace aiming to observe the topics that have undergone rapid changes. A total of 17 burst terms are detected. The strength and the timespan of these burst terms are shown in **Figure 10**. Following a chronological order, the first keyword that has undergone abrupt change is ''artificial intelligence in education'', which has the longest burst range spanning across eight years 2009-2017). The term with the largest burst strength is ''health-care'' from 2015 to 2017, followed by ''covid-19-pandemic'' (2015-2017). The period 2016-2023 is marked by the AI-related technology such as deep learning, machine learning and big data. Notably, the term ''technology'' in general has garnered much attention starting from 2018 until now. Additionally, the strategic diagram demonstrated in **Figure 11,** consisting of four quadrants, graphically illustrates the centrality and density of keywords. The keywords on the right side are of greater centrality or higher degree of connection between clusters. Those on the upper side of the quadrant are of greater density or higher degree of connection between keywords in the cluster. Therefore, the keywords on the first quadrant are called motor themes, which are well-developed and bearing great significance [54].

To further understand research trends, Citespace is used to generate a timeline view.

Figure 12 presents the year-wise trend of research topics from 2009 to 2024 with 477 nodes, 888 links and a density of 0.0078.

The modularity and silhouette of the cluster is 0.6995 and 0.8811 respectively.

Table 8 is the summary of clusters with the attribute Cluster ID, size, silhouette, mean citation year and labels. Items in Table 7 are ordered by cluster size. As per the mean citation

TABLE 8. Summary of clusters.

Cluster ID	Size	Silhouette	Mean (Year)	Label (LLR)
2	24	0.856	2020	cyber-physical-social systems (11.83, 0.001); learning analytics (11.67, 0.001); deep learning (11.2, 0.001); parallel intelligence (10.79, 0.005); taxonomy (10.79, 0.005)
0	22	0.88	2020	primary school (17.36, 1.0E-4); sentiment analysis (17.36, 1.0E-4); digital education (15.76, 1.0E-4); systematic literature review (15.76, 1.0E-4); computational modeling (13.95, 0.001)
6	22	0.878	2019	data science (11.37, 0.001); natural language processing (9.99, 0.005); clinical decision support (8.61, 0.005); attitude (7.19, 0.01); systematic review (6.52, 0.05)
1	21	0.836	2020	diabetic retinopathy (18.27, 1.0E-4); machine learning (16.4, 1.0E-4); artificial neural networks (13.87, 0.001); prompt engineering (12.17, 0.001); primary care (12.17, 0.001)
4	21	0.791	2019	educational data mining (18.03, 1.0E-4); online learning (13.54, 0.001); natural language processing (13.04, 0.001); medical education (11.77, 0.001); medical imaging (10.43, 0.005)
8	21	0.923	2019	internet of things (32.07, 1.0E-4); internet of things (iot) (16.75, 1.0E-4); smart cities (14.85, 0.001); digital health (14.35, 0.001); big data (12.1, 0.001)
9	20	0.903	2016	machine learning (147.76, 1.0E-4); artificial intelligence (132.73, 1.0E-4); chatgpt (77.87, 1.0E-4); large language models (70.18, 1.0E-4); deep learning (65.94, 1.0E-4)
10	20	0.974	2020	behavioral intention (25.96, 1.0E-4); technology acceptance (24.85, 1.0E-4); higher education (12.94, 0.001); data privacy (12.21, 0.001); utaut2 (11.05, 0.001)

TABLE 8. *(Continued.)* **Summary of clusters.**

5	19	0.783	2019	ai education (25.12, 1.0E-4); machine learning (17.91, 1.0E-4); self-determination theory (14.97, 0.001); k-12 education (14.97, 0.001); k-12 ai education (13.76, 0.001)
11	19	0.806	2019	artificial intelligence (ai) (45.37, 1.0E-4); machine learning (ml) (22.98, 1.0E-4); future of work (16.94, 1.0E-4); work (11.29, 0.001); technological change (11.29, 0.001)
7	18	0.937	2015	american indian (17.05, 1.0E-4); educational technology (14.17, 0.001); usa (11.36, 0.001); college students (11.36, 0.001); undergraduate (11.36, 0.001)
3	15	0.878	2021	patient education (17.33, 1.0E-4); problem solving (17.33, 1.0E-4); machine learning (13.95, 0.001); computer science education (12.94, 0.001); general (11.54, 0.001)
13	15	1	2017	virtual reality (46.5, 1.0E-4); augmented reality (38.27, 1.0E-4); artificial intelligence (20.13, 1.0E-4); surgical education (17.42, 1.0E-4); mixed reality (15.76, 1.0E-4)
12	10	0.838	2021	text mining (25.81, 1.0E-4); artificial intelligence (ai) education (25.81, 1.0E-4); higher education (20.89, 1.0E-4); academic integrity (18.82, 1.0E-4); generative artificial intelligence (15.04, 0.001)
15	9	0.98	2015	dsql-tutor (10.73, 0.005); working (10.73, 0.005); teaching querying (10.73, 0.005); labor (10.73, 0.005); student needs (10.73, 0.005)
14	6	0.958	2011	artificial intelligence in education (59.28, 1.0E-4); teachers (10.06, 0.005); artificial intelligence (9.53, 0.005); delphi method (7.75, 0.01); learning tactics (7.75, 0.01)

year in Table 7, cluster #7 (American Indian), cluster # 15 (dsql tutor) are the initial clusters with mean citation year of 2015 Cluster # 3 (patient education) and cluster # 12(text mining) mark the most recent trend in this field. Additionally, cluster #0 is the longest spanning cluster, indicating that cyber-physical-social systems, learning analytics, deep learning, parallel intelligence, taxonomy are hot research topics in the field of AI education.

VII. CONCLUSION

The study offers a bibliometric analysis of the AI in education and aims to highlight the trends, and reflected patterns. In doing so, the study shows the diversity of themes, patterns and novel approaches to education while using AI technology across the world. The study also shows developments in the field of artificial intelligence in education, big data and learning analytics and offers valuable suggestions based on the findings. This study examines the worldwide context of artificial intelligence (AI) research, specifically focusing on the nations, universities, authors, journals, and publications that have shown the highest levels of productivity in the area of AI integrated with online learning between the years 2010 and 2024. The research answers these questions by highlighting and examining a range of challenges related to the utilization of AI in education, along with the opportunities it presents. These challenges encompass the possibility of inappropriate application of AI techniques, the changing roles of teachers and students, and the ethical and social consequences arising from the integration of AI.

Overall, the study highlights that AI is proven to be a helping aid that as focused on studying and creating intelligent machines and software capable of learning, logic, communicating, manipulating, and perceiving objects. To enhance the usefulness, intelligence, and human-like qualities of machines, specific application-oriented intelligent technologies have been developed for particular scenarios. Following a chronological order, the first keyword that has undergone an abrupt change is ''artificial intelligence in education,'' which has the longest burst range spanning eight years (2009-2017). The term with the largest burst strength is ''healthcare'' from 2015 to 2017, followed by ''covid-19-pandemic'' (2015-2017). The period from 2016 to 2023 is marked by AI-related technologies such as deep learning, machine learning, and big data. Notably, the term ''technology'' in general has garnered much attention from 2018 until now.

As per the mean citation year in Table 7, cluster #7 (American Indian) and cluster #15 (dsql tutor) are the initial clusters with a mean citation year of 2015. Cluster #3 (patient education) and cluster #12 (text mining) mark the most recent trends in this field.

The results of this study have provided statistical evidences of topics and themes, diversity in using artificial intelligence (AI) tools and gadgets which have emerged as a highly effective method for extracting meaningful insights in higher education. Nevertheless, the primary objective of using AI in education is not to acquire useable knowledge, but rather to utilize the knowledge to facilitate the teaching and learning process. Recently, there has been a proliferation of using ChatGPT models and other AI tools in education.

Overall, the studies presented in this review showed that the integration of artificial intelligence (AI) in the field of education has achieved notable advancements, particularly in economically advanced nations, as shown by relevant academic research [19], [55]. The influence of AI applications within the realm of education is becoming more evident. The transformative impact of this phenomenon is visible in various aspects, such as the reduction of teacher workloads, the provision of personalized learning experiences, the incorporation of intelligent tutoring systems, the analysis and prediction of learner profiles, the enhancement of precision in education, the facilitation of collaborative learning environments, and the monitoring of individual learners' progress.

Finally, the study identifies that artificial intelligence (AI) has a diverse range of capabilities that extend beyond the establishment of Intelligent Learning Environments (ILEs). Its influence on real-world teaching practices has been extensively discussed [56]. The noticeable increase in scholarly articles related to these fields in recent years indicates the rising significance and pressing nature of these subjects.

REFERENCES

[1] M. Afzaal, M. Imran, X. Du, and N. Almusharraf, *Automated and Human Interaction in Written Discourse: A Contrastive Parallel Corpus-based Investigation of Metadiscourse Features in Machine-Human Translations.* Newbury Park, CA, USA: Sage, 2022.

[2] P. Song and X. Wang, ''A bibliometric analysis of worldwide educational artificial intelligence research development in recent twenty years,'' *Asia Pacific Educ. Rev.*, vol. 21, no. 3, pp. 473–486, Sep. 2020.

[3] M. Chassignol, A. Khoroshavin, A. Klimova, and A. Bilyatdinova, ''Artificial intelligence trends in education: A narrative overview,'' *Proc. Comput. Sci.*, vol. 136, pp. 16–24, Jul. 2018.

[4] X. Chen, G. Yu, G. Cheng, and T. Hao, ''Research topics, author profiles, and collaboration networks in the top-ranked journal on educational technology over the past 40 years: A bibliometric analysis,'' *J. Comput. Educ.*, vol. 6, no. 4, pp. 563–585, Dec. 2019.

[5] F. Gao, X. Jia, Z. Zhao, C.-C. Chen, F. Xu, Z. Geng, and X. Song, ''Bibliometric analysis on tendency and topics of artificial intelligence over last decade,'' *Microsyst. Technol.*, vol. 27, no. 4, pp. 1545–1557, Apr. 2021.

[6] M. J. Timms, ''Letting artificial intelligence in education out of the box: Educational cobots and smart classrooms,'' *Int. J. Artif. Intell. Educ.*, vol. 26, no. 2, pp. 701–712, Jun. 2016.

[7] A. Vazhayil, R. Shetty, R. R. Bhavani, and N. Akshay, ''Focusing on teacher education to introduce AI in schools: Perspectives and illustrative findings,'' presented at the *Proc. IEEE 10th Int. Conf. Technol. Educ. (T4E)*, Dec. 2019.

[8] F. I. Maulana, M. A. Febriantono, D. R. B. Raharja, I. R. Sofiani, and V. Al Hadid Firdaus, ''Two decade mapping the scientific research of Internet of Things on education—A bibliometric analysis,'' presented at the *Proc. Int. Conf. Electr. Inf. Technol. (IEIT)*, Sep. 2021.

[9] E. Tait and C. M. Pierson, ''Artificial intelligence and robots in libraries: Opportunities in LIS curriculum for preparing the librarians of tomorrow,'' *J. Austral. Library Inf. Assoc.*, vol. 71, no. 3, pp. 256–274, Jul. 2022.

[10] F. A. Triansyah, I. Muhammad, A. Rabuandika, K. D. P. Siregar, N. Teapon, and M. S. Assabana, ''Bibliometric analysis: Artificial intelligence (AI) in high school education,'' *Jurnal Imiah Pendidikan Dan Pembelajaran*, vol. 7, no. 1, pp. 112–123, Apr. 2023.

[11] A. Purnomo, A. Septianto, F. Anam, A. Christanti, and G. K. Zamahsari, ''A bibliometric overview and visualization of the digital education publication,'' presented at the *Proc. Int. Conf. Inf. Manage. Technol. (ICIMTech)*, vol. 1, Aug. 2021.

[12] M. Ali and M. K. Abdel-Haq, "Bibliographical analysis of artificial intelligence learning in higher education: Is the role of the human educator and educated a thing of the past?" in *Advances in Educational Technologies and Instructional Design*. Hershey, PA, USA: IGI Global, 2021, pp. 36–52.

[13] L. Chen, P. Chen, and Z. Lin, "Artificial intelligence in education: A review," *IEEE Access*, vol. 8, pp. 75264–75278, 2020.

[14] D. T. K. Ng, J. K. L. Leung, K. W. S. Chu, and M. S. Qiao, "AI literacy: Definition, teaching, evaluation and ethical issues," in *Association for Information Science and Technology*. Hoboken, NJ, USA: Wiley, 2021.

[15] C. Rodríguez Jiménez, M. Sanz Prieto, and S. Alonso García, "Technology and higher education: A bibliometric analysis," *Educ. Sci.*, vol. 9, no. 3, p. 169, Jul. 2019.

[16] D. J. Borgohain, R. K. Bhardwaj, and M. K. Verma, "Mapping the literature on the application of artificial intelligence in libraries (AAIL): A scientometric analysis," *Library Hi Tech.*, vol. 42, no. 1, pp. 149–179, Feb. 2024.

[17] M. Imran and N. Almusharraf, "Analyzing the role of ChatGPT as a writing assistant at higher education level: A systematic review of the literature," *Contemp. Educ. Technol.*, vol. 15, no. 4, p. ep464, Oct. 2023.

[18] T. Z. Shah, M. Imran, and S. M. Ismail, "A diachronic study determining syntactic and semantic features of Urdu-English neural machine translation," *Heliyon*, vol. 10, no. 1, Jan. 2024, Art. no. e22883.

[19] C. Huang, C. Yang, S. Wang, W. Wu, J. Su, and C. Liang, "Evolution of topics in education research: A systematic review using bibliometric analysis," *Educ. Rev.*, vol. 72, no. 3, pp. 281–297, May 2020.

[20] D. Zou, S. Luo, H. Xie, and G.-J. Hwang, "A systematic review of research on flipped language classrooms: Theoretical foundations, learning activities, tools, research topics and findings," *Comput. Assist. Lang. Learn.*, vol. 35, no. 8, pp. 1811–1837, Nov. 2022.

[21] A. Behl, N. Jayawardena, V. Pereira, N. Islam, M. D. Giudice, and J. Choudrie, "Gamification and e-learning for young learners: A systematic literature review, bibliometric analysis, and future research agenda," *Technol. Forecasting Social Change*, vol. 176, Mar. 2022, Art. no. 121445.

[22] M. Younas and Y. Dong, "The impact of using animated movies in learning English language vocabulary: An empirical study of lahore, Pakistan," *Sage Open*, vol. 14, no. 2, pp. 1–20, Apr. 2024, doi: 10.1177/21582440241258398.

[23] A. Gull, M. Imran, M. Yiunas, and M. Afzaal, "A descriptive study of challenges faced by English language teachers in integrating information and communication technology (ICT) tools at elementary level in Pakistan," *Int. J. Adv. Sci. Technol.*, vol. 29, no. 8, pp. 290–305, 2020.

[24] G. Wang and J. He, "Bibliometric analysis on research trends of digital literacy in higher education from 2012 to 2021," *Int. J. Emerg. Technol. Learn.*, vol. 17, no. 16, pp. 43–58, Aug. 2022.

[25] U. Noor, M. Younas, H. Saleh Aldayel, R. Menhas, and X. Qingyu, "Learning behavior, digital platforms for learning and its impact on university student's motivations and knowledge development," *Frontiers Psychol.*, vol. 13, Nov. 2022, Art. no. 933974, doi: 10.3389/fpsyg.2022.933974.

[26] C.-W. Shen and J.-T. Ho, "Technology-enhanced learning in higher education: A bibliometric analysis with latent semantic approach," *Comput. Hum. Behav.*, vol. 104, Mar. 2020, Art. no. 106177.

[27] S. F. Ahmad, M. K. Rahmat, M. S. Mubarik, M. M. Alam, and S. I. Hyder, "Artificial intelligence and its role in education," *Sustainability*, vol. 13, no. 22, p. 12902, May 2021.

[28] E. Y. Barakina, A. V. Popova, S. S. Gorokhova, and A. S. J. E. J. O. C. Voskovskaya, "Digital technologies and artificial intelligence technologies in education," *Eur. J. Contemp. Educ.*, vol. 10, no. 2, pp. 285–296, 2021.

[29] V. Maphosa and M. Maphosa, "Artificial intelligence in higher education: A bibliometric analysis and topic modeling approach," *Appl. Artif. Intell.*, vol. 37, no. 1, Dec. 2023, Art. no. 2261730.

[30] S. Hajkowicz, C. Sanderson, S. Karimi, A. Bratanova, and C. Naughtin, "Artificial intelligence adoption in the physical sciences, natural sciences, life sciences, social sciences and the arts and humanities: A bibliometric analysis of research publications from 1960–2021," *Technol. Soc.*, vol. 74, Aug. 2023, Art. no. 102260.

[31] X. Chen, D. Zou, H. Xie, G. Cheng, and C. Liu, "Two decades of artificial intelligence in education," *Educ. Technol. Soc.*, vol. 25, no. 1, pp. 28–47, 2022.

[32] K. C. Li and B. T.-M. Wong, "Research landscape of smart education: A bibliometric analysis," *Interact. Technol. Smart Educ.*, vol. 19, no. 1, pp. 3–19, Feb. 2022.

[33] M. Younas, U. Noor, X. Zhou, R. Menhas, and X. Qingyu, "COVID-19, students satisfaction about e-learning and academic achievement: Mediating analysis of online influencing factors," *Frontiers Psychol.*, vol. 13, Aug. 2022, Art. no. 948061, doi: 10.3389/fpsyg.2022.948061.

[34] N. E. Akrami, M. Hanine, E. S. Flores, D. G. Aray, and I. Ashraf, "Unleashing the potential of blockchain and machine learning: Insights and emerging trends from bibliometric analysis," *IEEE Access*, vol. 11, pp. 78879–78903, 2023.

[35] S. K. M. Brika, A. Algamdi, K. Chergui, A. A. Musa, and R. Zouaghi, "Quality of higher education: A bibliometric review study," *Frontiers Educ.*, vol. 6, May 2021, Art. no. 666087.

[36] Y. Zhang, A. L. Porter, S. Cunningham, D. Chiavetta, and N. Newman, "Parallel or intersecting lines? Intelligent bibliometrics for investigating the involvement of data science in policy analysis," *IEEE Trans. Eng. Manag.*, vol. 68, no. 5, pp. 1259–1271, Oct. 2021, doi: 10.1109/TEM.2020.2974761. https://doi.org/10.1109/TEM.2020.2974761

[37] O. Zawacki-Richter, V. I. Marín, M. Bond, and F. Gouverneur, "Systematic review of research on artificial intelligence applications in higher education—Where are the educators?" *Int. J. Educ. Technol. Higher Educ.*, vol. 16, no. 1, pp. 1–39, Dec. 2019, doi: 10.1186/s41239-019-0171-0.

[38] Y. Sun, G. Wang, and H. Feng, "Linguistic studies on social media: A bibliometric analysis," *SAGE Open*, vol. 11, no. 3, Jul. 2021, Art. no. 215824402110475, doi: 10.1177/21582440211047572.

[39] Y. Chen, M. Lin, and D. Zhuang, "Wastewater treatment and emerging contaminants: Bibliometric analysis," *Chemosphere*, vol. 297, Jun. 2022, Art. no. 133932, doi: 10.1016/j.chemosphere.2022.133932.

[40] Y. Chen and C. Wu, "The hot spot transformation in the research evolution of maker," *Scientometrics*, vol. 113, no. 3, pp. 1307–1324, 2017.

[41] A. Syahid and A. Qodir, "Journal of language and linguistic studies: A fifteen-year bibliometric quest for a bigger impact," *Dil ve Dilbilimi Çalsmaları Dergisi*, vol. 17, no. 1, pp. 290–314, Mar. 2021.

[42] C. Cuccurullo, M. Aria, and F. Sarto, "Foundations and trends in performance management. A twenty-five years bibliometric analysis in business and public administration domains," *Scientometrics*, vol. 108, no. 2, pp. 595–611, Aug. 2016, doi: 10.1007/s11192-016-1948-8.

[43] O. Ellegaard, "The application of bibliometric analysis: Disciplinary and user aspects," *Scientometrics*, vol. 116, no. 1, pp. 181–202, Jul. 2018, doi: 10.1007/s11192-018-2765-z.

[44] Y.-M. Guo, Z.-L. Huang, J. Guo, X.-R. Guo, H. Li, M.-Y. Liu, S. Ezzeddine, and M. J. Nkeli, "A bibliometric analysis and visualization of blockchain," *Future Gener. Comput. Syst.*, vol. 116, pp. 316–332, Mar. 2021, doi: 10.1016/j.future.2020.10.023.

[45] J. Song, H. Zhang, and W. Dong, "A review of emerging trends in global PPP research: Analysis and visualization," *Scientometrics*, vol. 107, no. 3, pp. 1111–1147, Jun. 2016, doi: 10.1007/s11192-016-1918-1.

[46] A. Aria and C. Cuccurullo, "Bibliometrix: An R-tool for comprehensive science mapping analysis," *J. Informetrics*, vol. 11, no. 4, pp. 959–975, 2017.

[47] N. J. van Eck and L. Waltman, "Software survey: VOSviewer, a computer program for bibliometric mapping," *Scientometrics*, vol. 84, no. 2, pp. 523–538, Aug. 2010.

[48] M. Pradana, H. P. Elisa, and S. Syarifuddin, "Discussing ChatGPT in education: A literature review and bibliometric analysis," *Cogent Educ.*, vol. 10, no. 2, pp. 1–29, Dec. 2023, doi: 10.1080/2331186x.2023.2243134.

[49] Z. Lin and L. Lei, "The research trends of multilingualism in applied linguistics and education (2000–2019): A bibliometric analysis," *Sustainability*, vol. 12, no. 15, p. 6058, Jul. 2020, doi: 10.3390/su12156058.

[50] J. Kleinberg, "Bursty and hierarchical structure in streams," in *Proc. 8th ACM SIGKDD Int. Conf. Knowl. Discovery Data Mining*, Jul. 2002, pp. 1–29.

[51] L. C. Freeman, "Centrality in social networks conceptual clarification," *Social Netw.*, vol. 1, no. 3, pp. 215–239, Jan. 1978.

[52] C. Chen, "Searching for intellectual turning points: Progressive knowledge domain visualization," *Proc. Nat. Acad. Sci. USA*, vol. 101, no. 1, pp. 5303–5310, Apr. 2004.

[53] S. A. D. Popenici and S. Kerr, "Exploring the impact of artificial intelligence on teaching and learning in higher education," *Res. Pract. Technol. Enhanced Learn.*, vol. 12, no. 1, p. 22, Dec. 2017.

[54] M. J. Cobo, A. G. López-Herrera, E. Herrera-Viedma, and F. Herrera, "Science mapping software tools: Review, analysis, and cooperative study among tools," *J. Amer. Soc. Inf. Sci. Technol.*, vol. 62, no. 7, pp. 1382–1402, Jul. 2011.

[55] F. Tahiru, "AI in education: A systematic literature review," *J. Cases Inf. Technol. (JCIT)*, vol. 23, no. 1, pp. 1–20, 2021.
[56] Z. Dai, Q. Zhang, X. Zhu, and L. Zhao, "A comparative study of Chinese and foreign research on the Internet of Things in education: Bibliometric analysis and visualization," *IEEE Access*, vol. 9, pp. 130127–130140, 2021.

MUHAMMAD AFZAAL received the Ph.D. degree from Shanghai Jiao Tong University, China. He has extensive research fellow experience with The Hong Kong Polytechnic University, Hong Kong, and seven years teaching experience with Foundation University Islamabad, Pakistan. He joined the Institute of Corpus Studies and Applications, Shanghai International Studies University, China, as an Associate Professor. He is the author of the book *Corpora and Discourses of the Belt and Road Initiative* (Springer Nature, 2023). He has published extensively academic articles in SSCI, Scopus, and ESCI-indexed international journals, such as *Critical Discourse Studies*, *Corpora*, *International Journal of Applied Linguistics*, *Discourse Studies*, *Asia Pacific Business Review*, *Chinese Journal of Communication*, *Asian Journal of Communications*, *Frontiers in Psychology*, *Humanities and Social Science Communications* (HSSC), *Australian Journal of Applied Linguistics*, and *Asian Journal of Comparative Politics*. His research interests include corpus linguistics, discourse analysis, critical discourse analysis, translation studies, and more particularly the merging of language sciences with NLP and big data. He received the Yang Yong Research Award from Shanghai Jiao Tong University's Graduate School, China. Google Scholar: https://scholar.google.com/citations?user=QN9vjPoAAAAJ&hl=en.

XIAO SHANSHAN is currently pursuing the master's degree in linguistics with the School of English Studies, Shanghai International Studies University. She has published her work in SSCI journals. Her co-authored work has been accepted by international renowned conference, such as Annual Conference of the British Association for Applied Linguistics (AILA), Critical Approaches to Discourse Analysis Across Disciplines (CADAAD), and Symposium on Second Language Writing (SSLW). Her research interests include language sciences, applied linguistics, and the integration of language science with big data and NLP.

DONG YAN was born in Henan, China, in 1973. She received the Ph.D. degree in education technology (major) from the School of Psychology, Beijing Normal University, Beijing, China, in June 2007. She was a Visiting Scholar with the Institute of Learning and Instruction, The University of Sydney, Sydney, Australia, from July 2004 to November 2004. From 1998 to 2000, she was a Research Assistant with the Department of Electronic, Beijing Normal University. Since 2001, she has been an Advanced Lecturer. In 2006, she was an Associate Professor with the Laboratory of Web Education and the School of Information Science. In 2015, she was a Professor with the Faculty of Education, Beijing Normal University. She is the author of 40 articles and the host of 15 projects, three of which are key at ministerial and provincial-level funding. Her research interests include teachers' TPACK knowledge, 21st-century learning, feedback literacy, technology-enhanced learning, and STEM project-based learning. She received the Excellent Paper Award (East China Normal University, 2017).

MUHAMMAD YOUNAS received the Ph.D. degree in higher education from Soochow University, China. He is a Researcher with the School of Educational Technology, Beijing Normal University. He has published academic articles in various SSCI and Scopus-indexed journals related to language teacher education and technological teaching/learning. His research interests include artificial intelligence in education, language teacher education, CALL, e-learning in higher education, technology-enhanced learning, MALL, and virtual learning environment (VLE). He received the Jiangsu Province Outstanding International Researcher Award from Soochow University.