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Artificial Intelligence in Education: A Bibliometric Study on Its Role in Transforming Teaching and Learning

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Abstract

This study aimed to present a comprehensive bibliometric analysis of 1,726 academic studies from among those indexed by the Web of Science database platform between 2013 and 2023, to provide a general framework for the concept of artificial intelligence in education (AIEd). Trends in publications and citations across countries, institutions, academic journals, and authors were identified, as well as collaborations among these elements. Several bibliometric analysis techniques were applied, and for each analysis, the motivations behind the execution and method of producing findings were documented. Our findings showed that the number of studies on the concept of AIEd has increased significantly over time, with the U.S. and China being the most common countries of origin. Institutions in the U.S. stand out from those around the world. Pioneering journals in education have also emerged as prominent in the field of AIEd. On the other hand, collaboration between authors has been limited. The study was supplemented with keyword analysis to reveal thematic AIEd concepts and to reflect changing trends. For those exploring artificial intelligence in education, our insights on popular topics offer valuable guidance toward greater understanding of the latest advancements and key research areas.

Keywords: artificial intelligence, bibliometric analysis, bibliographic coupling, co-authorship analysis, co-citation analysis, co-occurrence analysis

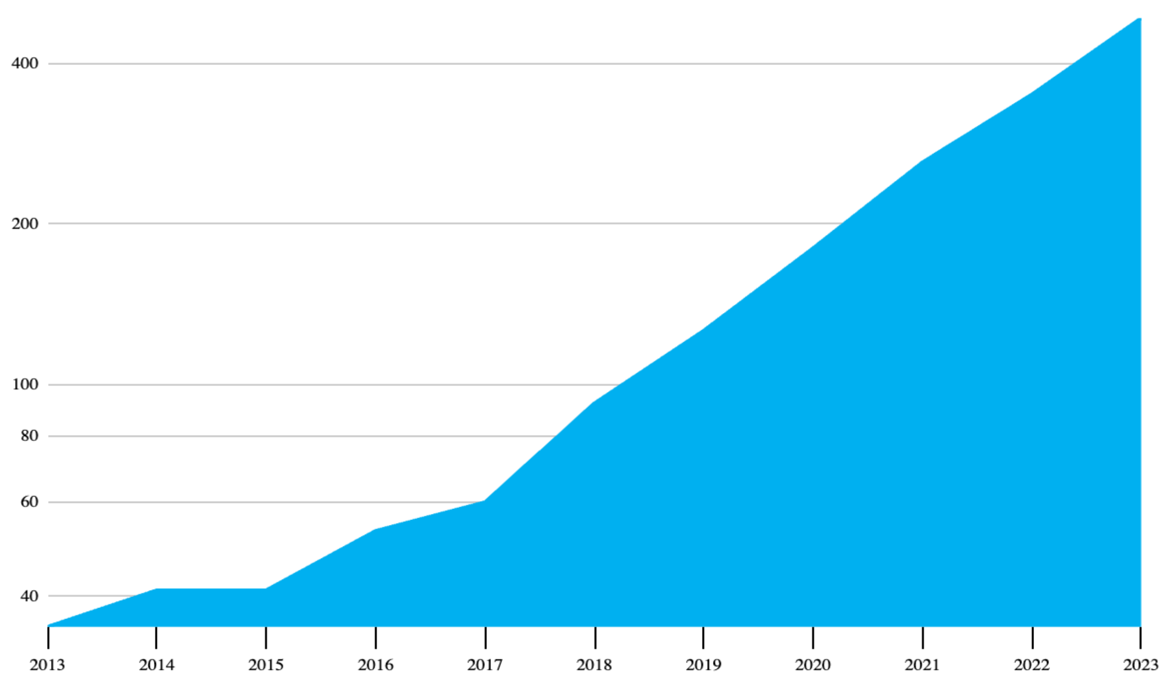
Artificial Intelligence in Education: A Bibliometric Study on Its Role in Transforming Teaching and Learning

Artificial intelligence (AI) represents a broad domain within computer science dedicated to the development of smart machines capable of undertaking tasks akin to those performed by humans (Bartneck et al., 2021; Joiner, 2018). The objective is to imbue computers with intelligence, enabling them to think and learn through programmed algorithms or to emulate human thought processes and actions. With recent technological advancements, it is reasonable to say that AI has acquired the capability to execute operations far beyond the rapid processing capacities of the human mind (Khanam et al., 2021). Understanding AI is crucial if we aim to integrate it meaningfully into society, and this involves a deep dive into what we mean by AI, its developmental trajectory, and its current standing (Bozkurt, 2023).

One of the transformative impacts of AI in our lives has manifested in the education sector. AI has swiftly emerged as an instrumental force there, paving the way for a new era of personalized learning, enhanced engagement, and data-driven insights to foster an enriched educational experience and optimize academic outcomes (Chaudhry & Kazim, 2022). According to the Horizon Report 2023, the following two concepts are at the top of the key technologies and practices section: (a) AI-enabled applications for predictive personal learning and (b) generative AI (Pelletier et al., 2023). Figure 1 illustrates the number of studies conducted in the field of AI in education (AIEd) in the Web of Science (WoS) database platform over the last 10 years.

Figure 1

Number of Academic Publications on AIEd in the Web of Science



According to Figure 1, the concept of AIEd has become the center of attention for many researchers in recent years, and there has been a great increase in the number of studies. This increasing number of studies has made it difficult to follow the research in the field. The bibliometric analysis method can be used for the follow-up and detailed analysis of research in a particular field and can be enriched with various graphics. The aim of this study was to explore AIEd, using the bibliometric analysis method to evaluate research developments comprehensively and methodically. This study sought to provide a thorough understanding of the AIEd research field through a bibliometric analysis on articles indexed in WoS. Concentrating on AIEd, this study addressed the following research questions. In the AIEd literature in the WoS database platform:

1. What is the distribution of leading countries and institutions?
2. What are the patterns of research connections and collaborations among countries and institutions?
3. What are the leading journals and authors?
4. What patterns of citation networks can be observed among leading journals?
5. What does analysis reveal about the nature of author collaborations and the impact of co-citation among prominent researchers in this field?
6. Which topics are most prevalent, and how are they interconnected, as indicated by the analysis of commonly used keywords?

The Importance of Bibliometric Analysis of Artificial Intelligence in Education

Bibliometric analysis plays a key role in providing an in-depth understanding of scientific research. The importance of the parts of the bibliometric analysis method is explained as follows. The number of publications shows the growth rate of the research, while citation and co-citation analyses reveal the most influential studies and authors in the field. Keyword analyses identify the key topics on which research has focused. Journal analyses show which journals have dominated each field, while geographic distribution reveals which regions or countries have been more active. Research trends indicate which topics are on the rise or ignored, and network analysis visualizes the relationships between different authors, institutions, and topics. In other words, bibliometric analysis is a method that can be used to comprehensively assess the current state, impact, and potential future directions of scientific research.

A bibliometric analysis of AIEd offers a systematic, quantitative, and insightful examination of the scholarly landscape, elucidating prevalent trends, key contributors, and emergent areas of interest within this interdisciplinary domain (Donthu et al., 2021; Ho, 2008). As the education sector grapples with the challenges and promises of AI integration, a bibliometric analysis provides evidence-based insights to educators, developers, and policymakers (Argente et al., 2023). By showcasing where we have been and indicating where we might go, such an analysis serves as both a historical record and a strategic compass, ensuring that AI's incorporation into education is thoughtful, research-informed, and optimized for pedagogical efficacy (Gavira-Marin et al., 2018; Yin, 2013). A bibliometric analysis of AIEd is not merely an academic exercise; it is a critical tool in comprehending the intricacies of a rapidly evolving research domain (Ellegaard & Wallin, 2015; Moral-Munoz et al., 2020). By providing clarity, direction, and insight, such a study enriches the scholarly community's collective understanding and paves the way for impactful and informed innovations in the intersection of AI and education (Martins et al., 2022).

In general, bibliometric analyses has been important in evaluating the current and future status of scientific research. In addition, since the results are presented objectively, they have been free from researchers' biases. However, search criteria have not been given enough importance in most such studies, raising doubts about whether the publications included because of the search criteria fully reflected the relevant concept. One of the most powerful aspects of this study was that it analyzed all systematic review, content analysis, and bibliometric analysis studies published in the relevant field, and analyzed the keywords used in those studies. The search criteria for this study were developed in an appropriate way which was explained in detail in method section.

Literature Review

Table 1 presents the bibliometric analysis and systematic reviews related to AIEd in the literature. The table provides brief information about (a) author(s) of the systematic review studies; (b) the databases where the publications were obtained for systematic review in these studies; (c) the total number of publications reviewed in these studies; and (d) the number of citations for the studies. This curated list serves as a testament to the increasing prominence and relevance of AIEd.

Table 1

Bibliometric and Review Studies in the Field of AIEd

Author(s)	Database	Number of publications reviewed	Number of citations
Zawacki-Richter et al. (2019)	EBSCO Education Source, WoS, Scopus	146	1,302
Hinojo-Lucena et al. (2019)	WoS, Scopus	132	181
Prahani et al. (2022)	Scopus	457	26
Tang et al. (2023)	WoS	86	154
Durso & Arruda (2022)	Brazilian Digital Library of Dissertations and Theses	63	3
Hwang & Tu (2021)	WoS, Scopus	129	127
Sapci & Sapci (2020)	PubMed, IEEE, CINAHL, Plus, ScienceDirect	76	94

Liang et al. (2023)	WoS	71	51
Baek & Doleck (2020)	WoS	135	18
Salas-Pilco & Yang (2022)	WoS, IEEE Xplore, Scielo, CAPES	31	52
Chiu (2021)	WoS, Scopus, ERIC	45	36
Celik et al. (2022)	ProQuest, ERIC, WoS	44	86
Salas-Pilco et al. (2022)	WoS, ScienceDirect, IEEE	30	34
Xu & Ouyang (2022)	WoS, Science Direct, Scopus, IEEE, EBSCO, ACM, Taylor & Francis, Wiley	63	60
Mohamed et al. (2022)	ScienceDirect, Scopus, Springer Link, ProQuest, EBSCO Host	20	7
García-Martínez et al. (2023)	WoS, Scopus	25	8
Pua et al. (2021)	WoS, Scopus, Google Scholar	135	3
Kaban (2023)	Wos	1,153	0
Jia et al. (2023)	Wos, Scopus	76	0

Note. Citation values taken from Google Scholar in December 2023.

Based on the data in Table 1, the following themes are evident in recent publications exploring the multifaceted applications and implications of AIEd.

General Trends in Higher Education

Zawacki-Richter et al.'s (2019) study delved into the role of educators in the rapidly developing field of AI applications in higher education. Similarly, Hinojo-Lucena et al. (2019) conducted a bibliometric study the same year, evaluating AI's influence on higher education through a thorough analysis of scientific literature. Finally, Prahani et al. (2022) and Baek and Doleck (2020) comprehensively examined the general trends and impacts of AI in higher education. These studies provided overarching insights into AI's growth in academia and its potential implications for educators and students.

Focus on Specific Educational Domains

Several studies narrowed down AI's application to specialized educational domains. Complementing these, Jia et al. (2023) presented a bibliometric analysis and content analysis that examined the significant role of AI in science education at the primary and secondary levels, and its growing influence over the past decade. For instance, Hwang and Tu (2021) mapped AI's roles and research trends in mathematics education. Liang et al. (2023) explored the fusion of AI with language education. Chiu (2021) ventured into the intersection of emerging technologies, including AI, in the context of chemical education. Finally, the studies by García-Martínez et al. (2023) and Pua et al. (2021) were included in this category as they examined the impact and trends of AI in specific educational fields. These contributions demonstrated the versatile nature of AI and its adaptability to cater to various academic disciplines.

Regional and Specific Case Analyses

Salas-Pilco and Yang (2022) conducted a targeted review of AI applications in Latin American higher education. Another work by Durso and Arruda (2022) delved into AI's impact on distance education within Brazilian studies. Similar to the other studies mentioned above, it can be said that Kaban's (2023) study focused on specific regions or situations. By focusing on particular regions or cases, these papers offered unique perspectives, addressing localized challenges and potentials of AI in education.

AI's Role in Analyzing and Enhancing Pedagogy

Celik et al. (2022) and Salas-Pilco et al. (2022) investigated the promises, challenges, and roles AI plays in teacher education, and how it has intertwined with learning analytics. Their findings emphasized the transformative power of AI in reshaping pedagogical strategies and aiding educators in their teaching processes.

Method

This study used bibliometric analysis to investigate the vast landscape of academic literature related to AIEd. This section delineates the methodological framework, databases included, criteria for including and excluding publications, and the analytical tools employed to interpret the data.

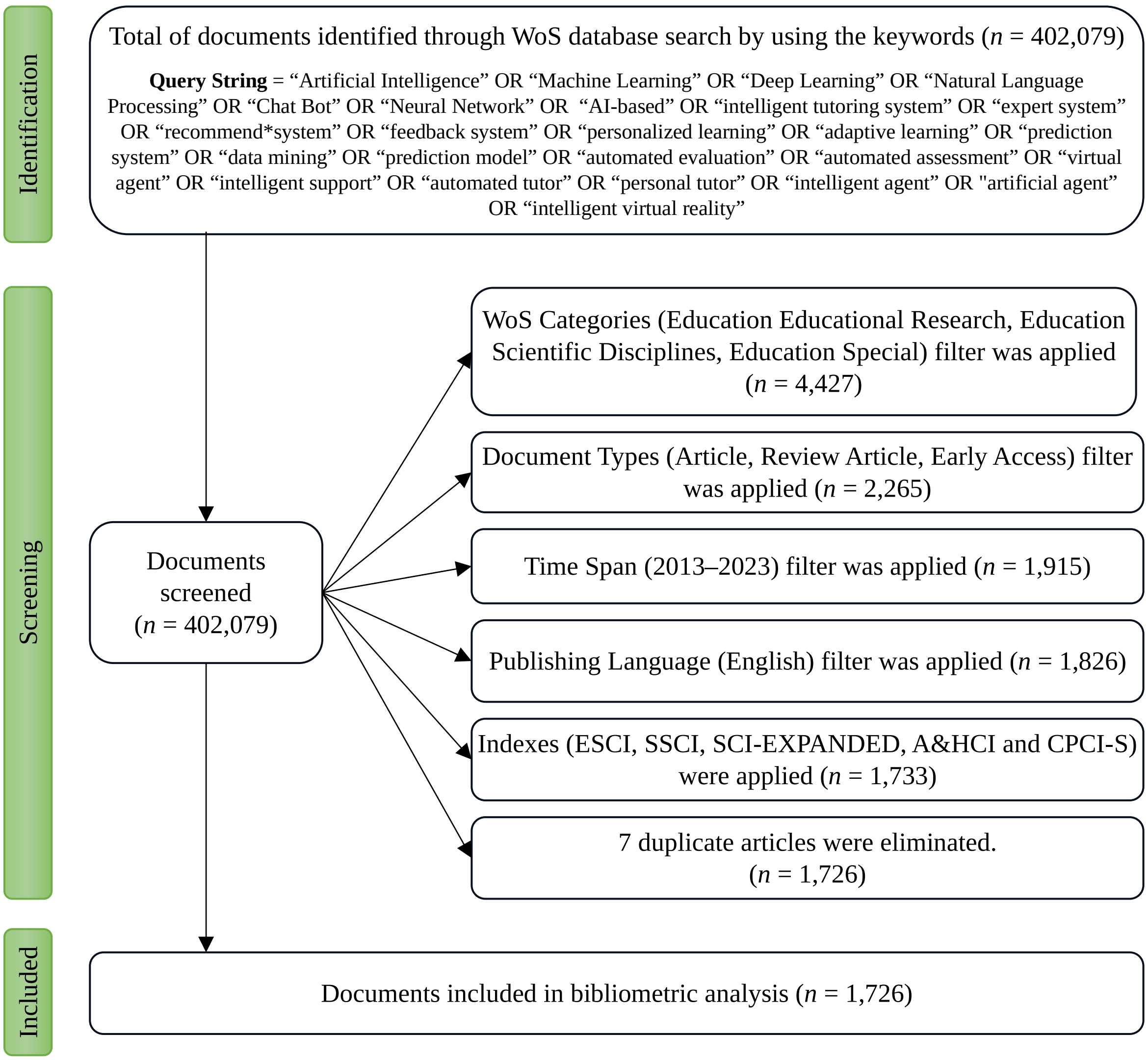
Determination of Studies

This bibliometric analysis was carried out using WoS, a highly esteemed and comprehensive research platform that covers a wide range of disciplines. Using WoS for a bibliometric study ensured a methodical approach to quantitatively analyze the academic literature in terms of publications and citations. Conducting a bibliometric study using the WoS database ensured access to high-quality, peer-reviewed journals and publications, which offered a credible and reliable overview of the research landscape. Additionally, WoS offered robust citation tracking; this enabled researchers to effectively trace the impact and evolution of research trends in the field. Given its comprehensive nature and the emphasis on citation data, the WoS database platform was particularly well suited for bibliometric analyses, ensuring a rigorous examination of the topic within the context of established academic scholarship.

Figure 2 outlines the data collection process and the key search terms that were identified after a thorough examination of bibliometric analysis and systematic review studies in the domain of AI using the PRISMA method. These search terms encompassed a wide spectrum of AI-related concepts and tools, and also offered a robust framework for extracting relevant publications from academic databases.

Figure 2

PRISMA Flowchart for Bibliometric Analysis



To maintain clarity and precision in our bibliometric analysis, it was essential to define clear criteria for including and excluding research papers. The inclusion criteria were adopted to ensure that the selected publications aligned with the study's objectives and maintained a consistent standard of quality and relevance.

Data Analysis

This study employed the VOSviewer program to analyze information from studies obtained from the WoS database, categorizing the data into various types. The findings included graphs that were generated using a total of five different networks of analyses, explained in detail in the findings section:

- Bibliographic coupling assessed the overlap in references between AIEd papers, indicating research connections.
- Co-authorship analysis focused on analyzing the collaborations between authors and countries in AIEd research.
- Citation analysis was employed to determine the most frequently referenced journals in the field of AIEd.
- Co-citation analysis identified frequently co-cited AIEd studies, revealing influential research relationships.
- Co-occurrence analysis in which keywords from the articles were selected and classified to illustrate the most popular topics and their connections.
-

Findings

The results from the bibliometric analysis of the articles retrieved from the WoS database platform are presented here under headings that align with the research questions.

Leading Countries and Institutions

To identify the countries targeted in the examined studies, country information was retrieved from the WoS database and depicted as bubble charts using an online tool in venngage.com. Figure 2 displays the distribution of these articles by country.

Figure 3

Bubble Graph of the Distribution of Selected Articles by Country

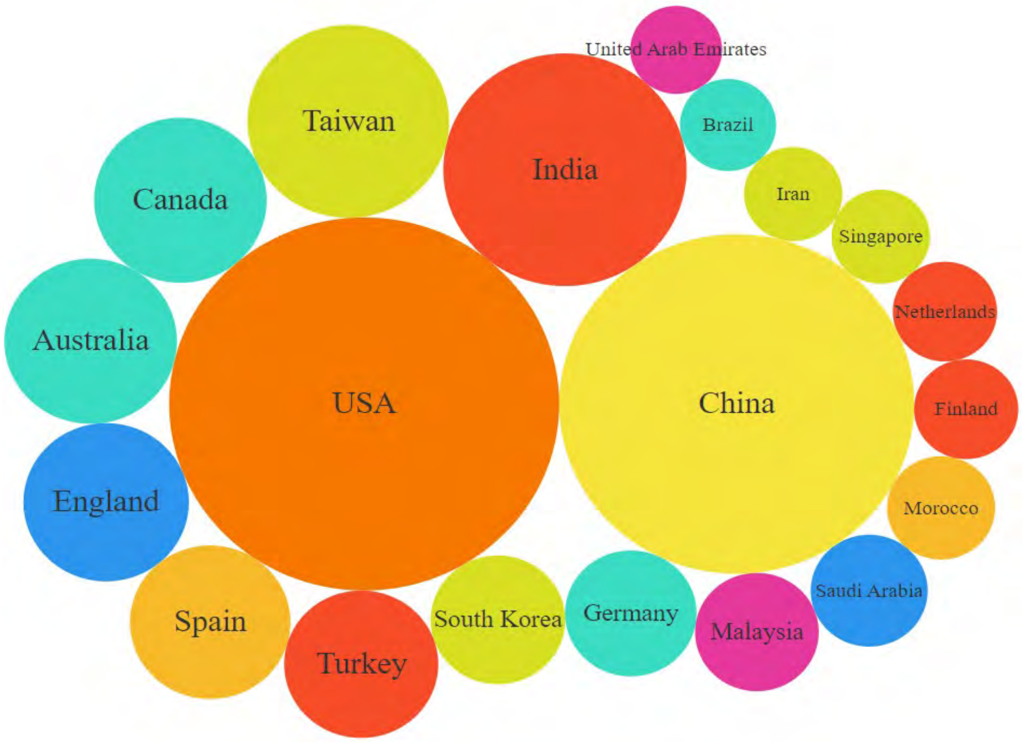
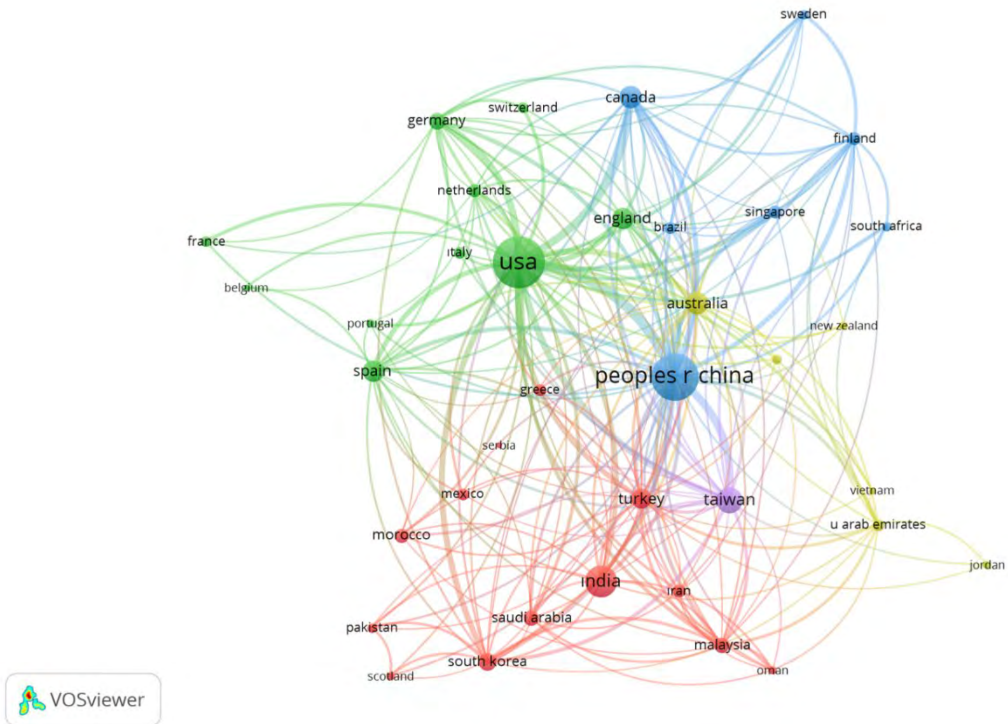


Figure 3 shows 20 countries that have published a minimum of 16 articles. As per the illustration, the U.S. led with 378 articles, followed by China with 313, and India with 147. In total, researchers from 95 distinct countries contributed to 1,726 articles.

Figure 4 displays the bibliographic coupling of the countries with network visualization, offering a comprehensive view of the interconnections among citing publications, which helped to trace the thematic evolution and current advancements in AIEd. As the condition we set, a country must have had a minimum of two documents and 100 citations to be included. Out of 95 countries, 37 met this criterion. For all of the countries, the number of publications, the number of citations, and total link strength (TLS), which represents the number of cited references that two countries share, were calculated.

Figure 4

Bibliographic Coupling of Countries

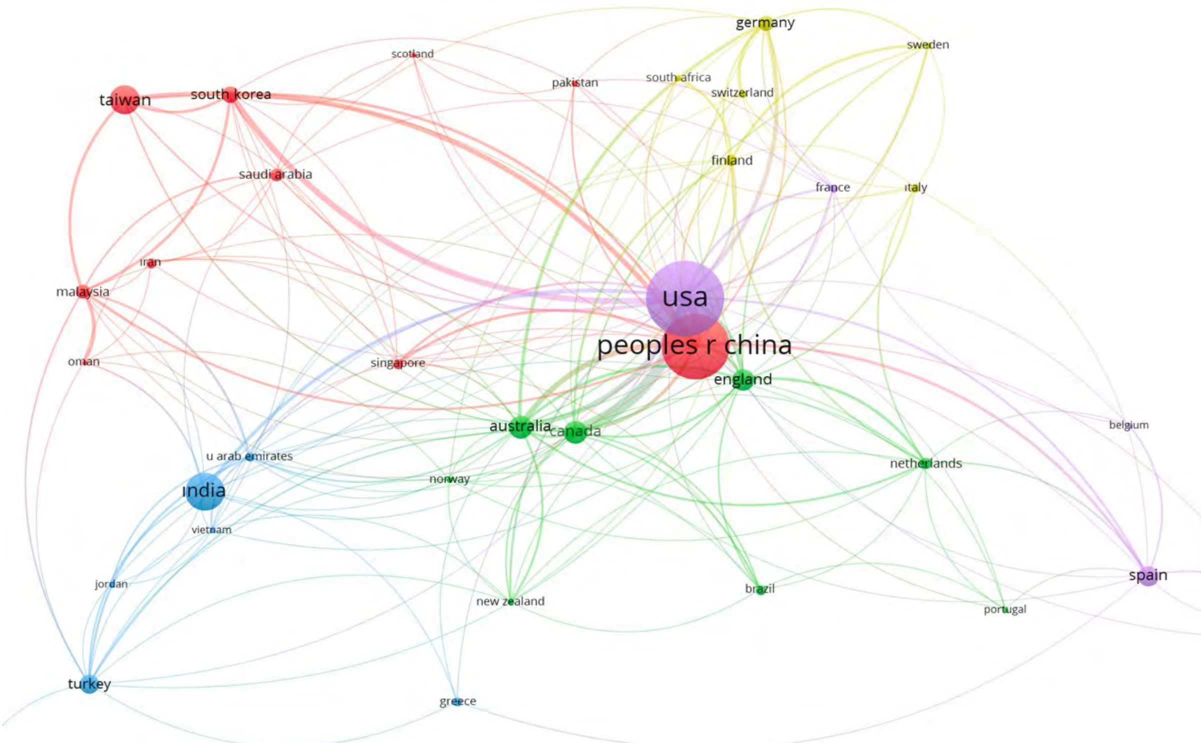


In our analysis of the bibliographic coupling ranked by the number of citations from each country, the U.S. topped the list with 4,533 citations, China came second with 2,513 citations, and Taiwan was third with 1,574 citations. Regarding the highest TLSs, the U.S. dominated with a link strength of 31,570, China followed with 24,166, Taiwan had 12,145, and Turkey had 7,984. Distinct colors represent various clusters that were more commonly interconnected. The line between any two circles indicates that papers from those two countries had similar citations in their reference list. The thickness of the lines shows a greater bibliographic coupling between the countries (Van Eck & Waltman, 2014). Large circles show the dominance of the countries in terms of citations. The green cluster, one of the big clusters, included China and Taiwan. The other big cluster comprised the U.S., England, Germany, Netherlands, Portugal, Spain, Canada, Italy, Switzerland, France, and Belgium. In the third cluster, we found Australia, the People's Republic of China, and Portugal.

Figure 5 represents the co-authorship network of countries. Each circle in the figure represents the country of an author, with the size of the circle indicating the number of their publications. Lines between circles signify the network of collaboration, with thicker lines indicating more intense collaboration. Various clusters are represented by distinct colors to denote similar research areas (van Eck & Waltman, 2018). As the condition we set, the analysis required a minimum of two documents and 100 citations per country, and 37 countries met this criterion.

Figure 5

Co-Authorship Networks of Countries

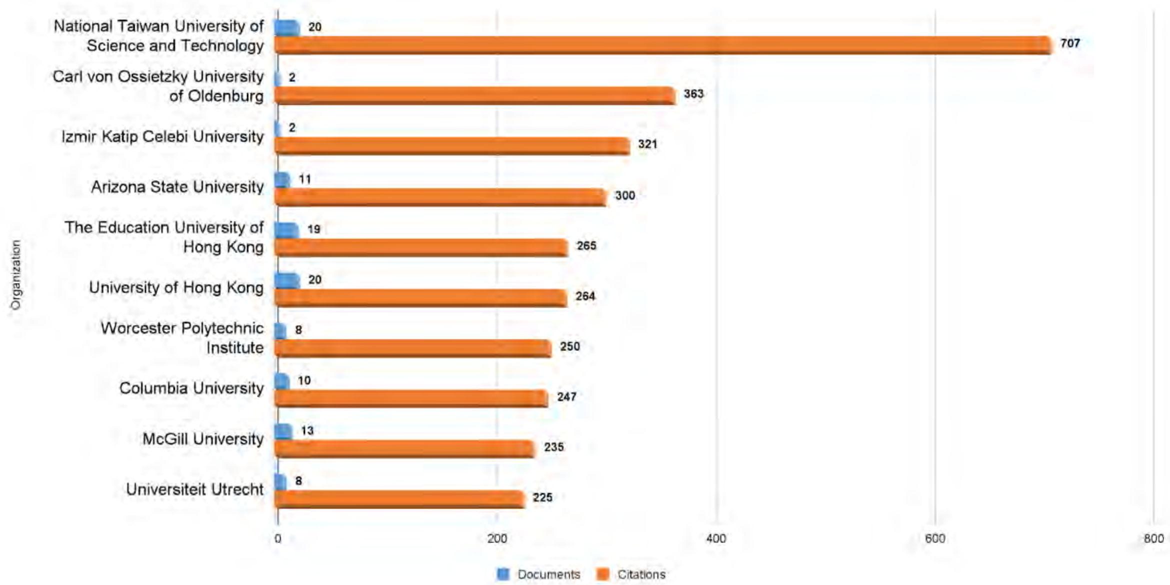


The results revealed 5 clusters through 141 connections. The U.S. emerged as the country with the most frequent collaborations with 113 total link strength, particularly strong with China. Both China and Australia, China and Taiwan, U.S. and South Korea also showed high levels of international collaboration. Specific clusters, such as China, Taiwan, and South Korea (Cluster 1); U.S. and Spain, (Cluster 2); and India and Turkey (Cluster 3) were noted for having similar research focuses. The map provides a detailed view of the collaboration patterns among these and other countries.

In the context of this study, which aimed to map out the key players in the field, Figure 6 plays a crucial role. It displays the leading institutions based on the authors' affiliations, offering insights into which academic and research organizations were most prominently represented in this area of research.

Figure 6

Number of AIEd Publications and Citations of Top 10 Institutions



According to Figure 6, National Taiwan University of Science and Technology was the leading institution with 20 article and 707 citations. Based on the number of citations, it was followed by Carl von Ossietzky University of Oldenburg, İzmir Katip Çelebi University, Arizona State University, and so on. When the number of citations per article was evaluated, Carl von University was prominent. While Figure 6 highlights the leading institutions based on article count and citations, Figure 7 shifts the focus to the interconnectedness of these institutions, showcasing the bibliographic coupling based on the authors' affiliations, which includes only those institutions with at least two articles and 100 citations.

Figure 7

Bibliographic Coupling of Institutions

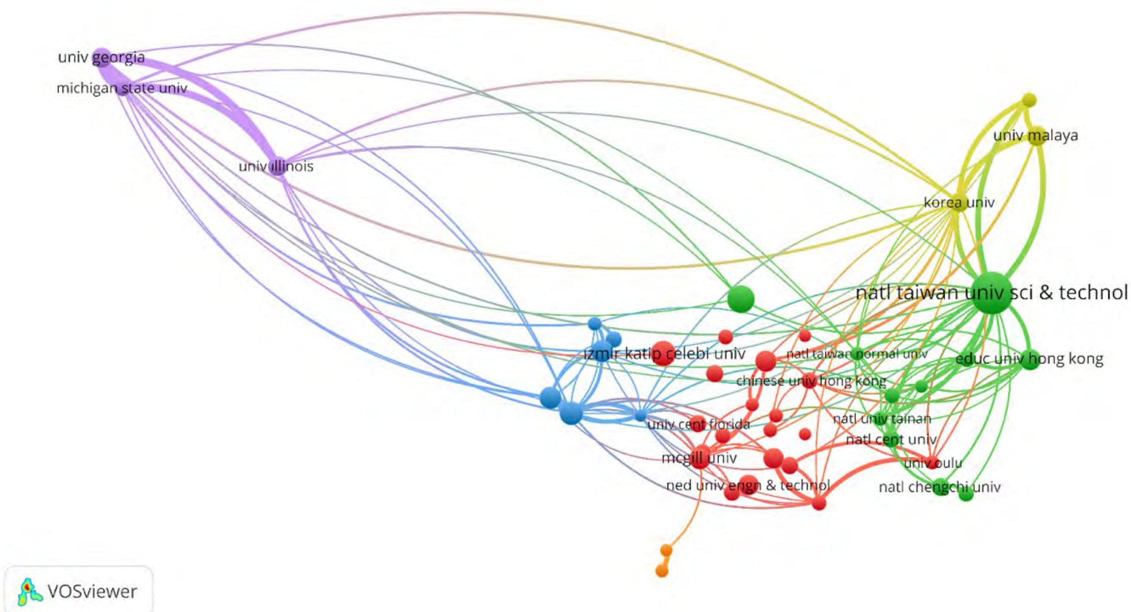


Figure 7 identifies six distinct clusters, each represented by different colors. These clusters highlight key terms such as the number of publications (NP), the number of citations (NC), and the TLS. Out of 2,003 institutions, only 54 had bibliographic coupling ties. The institutions were mapped based on the authors' affiliations and ranked by their total citation count. Considering total link strength values apart from total citation values, the leading institutions can be listed as follows:

- University of Georgia (NP = 11, NC = 224, TLS = 2,580) part of the purple cluster.
- Michigan State University (NP = 11, NC = 184, TLS = 2,282) part of the purple cluster.
- National Taiwan University of Science and Technology (NP = 20, NC = 707, TLS = 2,007) part of the green cluster.
- University of Illinois (NP = 12, NC = 217, TLS = 1,633) part of the purple cluster.
- University of Hong Kong (NP = 20, NC = 264, TLS = 1,460) part of the red cluster.

Leading Journals and Authors

The 1,726 articles examined appeared in 291 unique journals. When these journals were ranked by their publication count, 147 of them had just one article each. A list of the top 10 journals can be found in Table 2.

Table 2

The 10 Most-Cited Journals Regarding AIEd Research (2013–2023)

Journal	NP	NC	TLS
Computers & Education	43	2,131	117
Education and Information Technology	154	1,380	159
International Journal of Emerging Technologies in Learning	116	884	65
Educational Technology & Society	39	907	69
Computer Applications in Engineering Education	43	699	34
International Journal of Educational Technology	21	596	9
Interactive Learning Environments	63	629	69
British Journal of Educational Technology	30	507	33
IEEE Transactions on Learning Technologies	27	362	13
Technology Knowledge and Learning	12	315	31

Table 2 reveals that *Educational Technology & Society* led with 154 articles, followed by *International Journal of Emerging Technologies in Learning* with 116 articles, and *Interactive Learning Environments* with 63 articles. When considering citation counts, *Computers & Education* topped the list with 2,131 citations from 43 articles, *Education and Information Technology* has 1,380 from 154 articles, and *Educational Technology & Society* received 907 citations from 39 articles.

The research examined the citation network map of leading journals as illustrated in Figure 8, focusing on those with at least 2 articles and 100 citations to ensure the inclusion of publications with significant scholarly impact. This citation analysis was employed to evaluate the influence and prestige of these journals, reflected by the frequency of citations they received within the academic community, as a measure of their contribution to the field.

Figure 8

Citation Network Map of Leading Journals

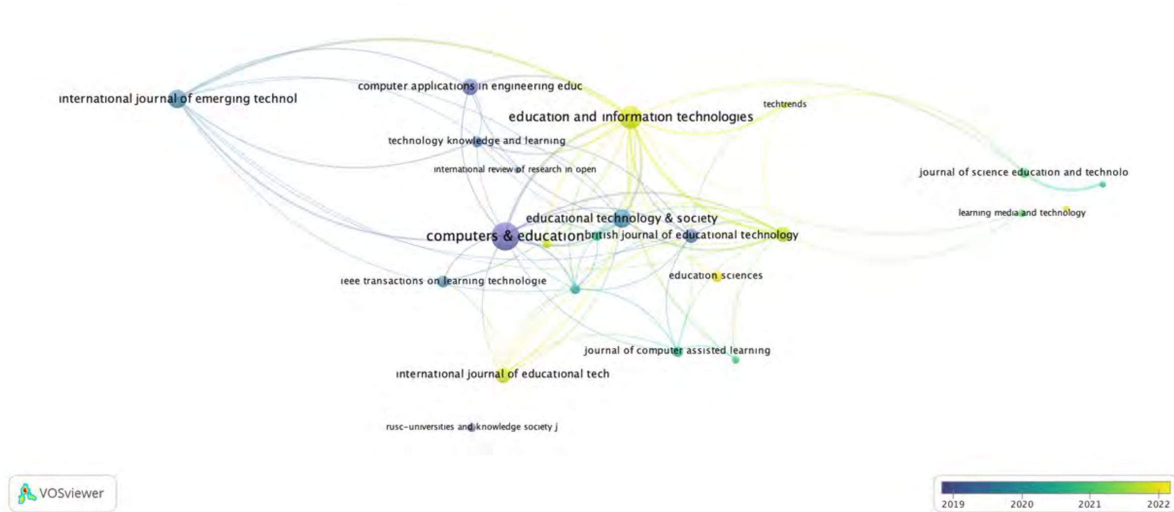


Figure 8 identifies 10 distinct clusters, each represented by a different color. These clusters highlight key terms such as the number of documents, the number of citations, and the total link strength. Out of 348 journals, only 193 had citation ties. *Computers & Education*, *Education and Information Technology*, *Interactive Learning Environments*, and *Educational Technology & Society* also stood out in the citation rankings, maintaining robust citation connections with numerous other journals. When evaluated in terms of popularity (shown in yellow), we observed that journals such as *Education and Information Technologies*, *Interactive Learning Environments*, and *International Journal of Educational Technology in Higher Education* were prominent.

Following the analysis of academic journals, the study presented a ranking of the top 10 authors based on citation counts, and subsequently examined the network of collaborations among authors. Table 3 below highlights the 10 most prominent authors based on their citation numbers.

Table 3

Top 10 Authors by the Number of Citations

Author	NP	NC
Hwang, G.-J.	14	542
Papamitsiou, Z.	2	346
Onan, A.	3	345
Baker, R. S.	3	224
Xie, H.	4	224
Zhai, X.	8	178
Hew, K. F.	3	177
Qiao, C.	2	175
Tang, Y.	2	175
Chu, H.-C.	2	171

Table 3 shows that Hwang, G.-J. was notable with 14 articles and 542 citations. Out of the 77 authors who surpassed the criteria of at least 2 articles and 100 citations, 29 were part of an affiliated network.

Building on the identified leading scholars, the subsequent phase of the study employed co-authorship analysis to delve into the broader landscape of intellectual collaboration among researchers. Co-authorship analysis, an essential tool for understanding intellectual partnerships among researchers, is employed to reveal how scholars interact and contribute collectively. Figure 9, a co-authorship network map, visually interprets these relationships, highlighting significant connections among 828 authors based on specific inclusion criteria. Inclusion in the map required authors to have authored at least two documents and received 100 citations, a criterion met by only 29 authors.

Figure 9

Co-Authorship Analysis

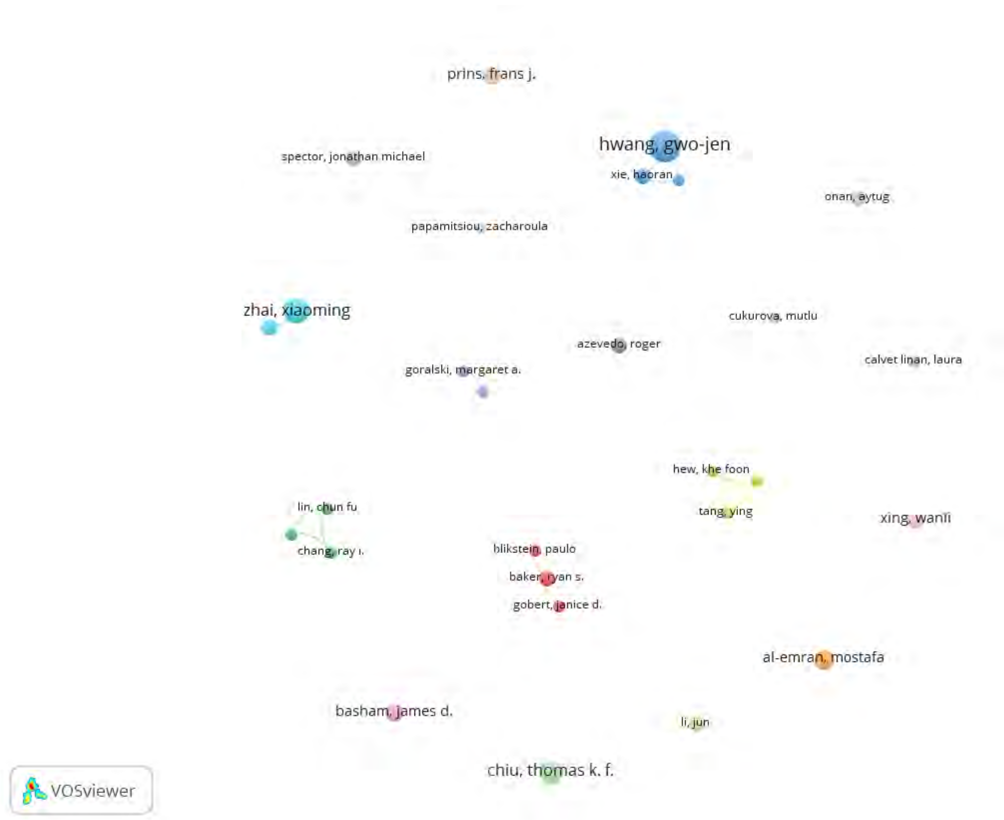
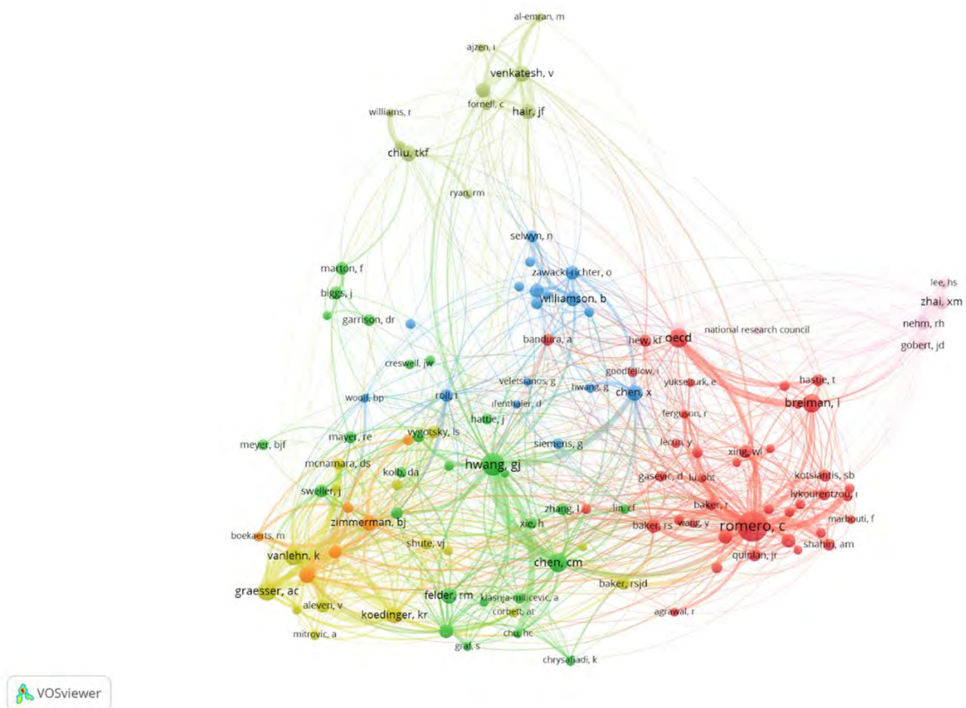


Figure 9 illustrates that 14 clusters were formed in the co-authorship network map of 29 linked authors. Baker, R. S., Blikstein, P., and Gobert, J. D. stood out in terms of centrality and inter-cluster linking. The connections between Lin, C. F. and Chang, R. I. suggested a partnership, likely indicating they had co-authored works. Similarly, Hwang, G.-J. appeared to be another significant contributor, with ties to Xie, H. and Chu, H.-C. which could indicate a shared research interest or a history of collaboration. The overall structure of the network, with its various clusters and connections, indicated a dynamic community of scholars who often work together, sharing ideas and contributing to the collective knowledge of their discipline.

Transitioning from the detailed co-authorship network, the analysis now turned to co-citation patterns to further explore the impact and interrelations of scholarly work within this academic community. This approach not only highlighted how authors were interlinked through shared references, but also shed light on the influential works and ideas that have shaped the discourse and development within the academic community. Figure 10 presents the co-citation analysis of authors, illustrating the patterns of how their works were cross-referenced and interconnected within the scholarly network.

Figure 10

Most-Cited Authors (Co-Citation Analysis)



When the common citation network was examined, seven different colored clusters were seen. Authors who received many citations together were gathered in the same cluster. Publications in the center showed that they were often cited from different fields and had more detailed connections with many clusters. When Figure 10 was examined in its entirety, authors such as Romero, C., Hwang G.-J., Graesser, A. C., Chiu, T. K. F., Chen, X., and Zhai, X. M. were represented by larger clusters, which suggested that these authors were central to their respective clusters. This prominence implied that their work was highly regarded and frequently referenced together with other researchers in their area. Each cluster may have represented a different subfield or a specific area of research focus. For instance, researchers like Chen, C. M. and Hwang, G.-J. appeared to be in the same cluster, which could indicate that they worked on similar topics or within the same discipline.

When evaluated in terms of total link strength, high values for an author suggested widespread recognition and influence in the academic community, indicating their work's diversity across various topics or disciplines and their central role in research networks. It was observed that the authors with the highest TLS values were Romero, C., Hwang, G.-J., Vanlehn, K., and Graesser, A. C. The quantity of lines originating from an author and the thickness of these lines in a bibliometric network map signified the extent and frequency of citations, with thicker lines indicating stronger co-citation connections, all contributing directly to the author's TLS value.

Keyword Analysis

Co-word analysis was essential in this study for mapping the intellectual structure and thematic interrelations within AIEd research, revealing how various concepts within this field were interconnected and how they have evolved over time. It also provided strategic insights into prominent research trends and potential future directions by analyzing the co-occurrence of keywords in the literature. Figure 11 illustrates the network created by incorporating author keywords from WoS dataset that have appeared at least twice in distinct publications. Larger circles represented subjects that were more commonly discussed, and those in yellow showed the most popular subjects.

Figure 11

Analysis of Keyword Co-Occurrence Between 2013 and 2023

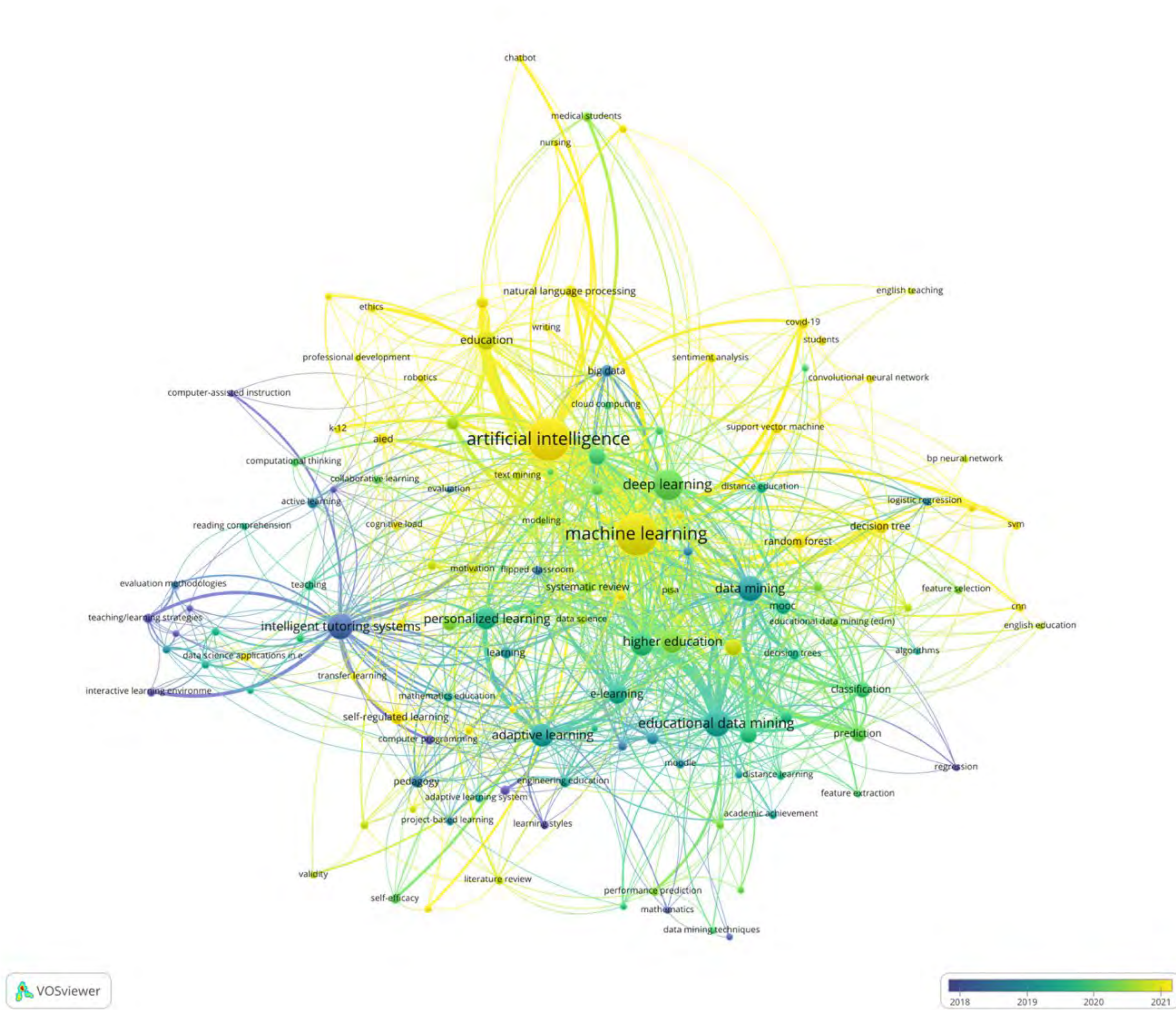


Figure 11 revealed terms such as artificial intelligence, machine learning, deep learning, data mining, and educational data mining situated at the core of the map. These terms stood out as the keywords used most, indicative of concepts frequently researched in conjunction with other thematic clusters. The figure also showed that terms such as intelligent tutoring systems, personalized learning, and adaptive learning were frequently used. When evaluated in terms of popularity (shown in yellow), it was observed that concepts such as artificial intelligence, machine learning, artificial neural network, and decision tree were prominent.

Conclusion and Discussion

The bibliometric analysis of AIEd literature over the past decade revealed the field's evolution, highlighting key countries, institutions, journals, authors, and trends. The study showed a stable publication rate from 2013 to 2017, followed by a sharp increase after 2017, reflecting growing interest in AIEd. This surge was likely due to advancements in AI and its potential in education, as well as a global need for AI educational solutions. Grassini (2023) suggested that AI's role in shaping future educational paradigms and its growing interest among educators will continue to rise.

The analysis showed the U.S., China, and India as leaders in AIEd research, consistent with previous studies (Baek & Doleck, 2020; Chen et al., 2020; Hinojo-Lucena et al., 2019; Jia et al., 2023; Liang et al., 2023; Mohamed et al., 2022; Moreno-Guerrero et al., 2020; Song & Wang, 2020; Talan, 2021; Tang et al., 2023; Zawacki-Richter et al., 2019). Contrary to Baek and Doleck (2020), this research found significant international cooperation, especially in bibliometric coupling and co-authorship networks, with the U.S. and China being particularly collaborative. Both China and Australia, China and Taiwan, U.S. and South Korea also showed high levels of international collaboration. The U.S. dominance in AIEd publications and collaborations has been attributed to its high research and development budgets, prestigious universities, innovation culture, and diverse academic community. These factors, also noted by Hebebci (2021) and Talan (2021), have contributed to the country's pioneering role in AIEd.

The National Taiwan University of Science and Technology led in AIEd publications and citations, with other institutions excelling in either publications or citations. Both metrics are crucial for assessing scientific impact. In bibliometric coupling, US universities like the University of Georgia, Michigan State University, and the University of Illinois, along with National Taiwan University of Science and Technology and Korea University, were notable, aligning with Talan's (2021) findings. Bibliometric coupling measures research integration and collaboration, indicating institutional impact and relationships in specific fields. The prominence of three US universities underscored the U.S. leadership in AIEd across publications, collaborations, and citations, highlighting its global influence and scientific leadership.

In assessing AIEd journals, article count, citation numbers, and total link strength scores were analyzed for academic impact. High article count suggests a journal's activity and content diversity, while high citations and link strength indicate influence and authority. These metrics, important for evaluating a journal's scientific contribution and prestige, should be considered together for a comprehensive understanding of a journal's impact. Additionally, a citation network analysis highlighted *Computers & Education, Education and Information Technologies*, and *Educational Technology & Society* as prominent, with strong citation connections and network popularity. *Computers & Education*, despite fewer publications, had high citation numbers, while *Education and Information Technology* scored highly across all metrics, indicating their significance in AIEd. These findings aligned with studies like Hwang and Tu (2021) and Liang et al. (2023), who attributed the results to the journals' long-standing publication, high impact factors, prestigious academic standing, and attraction of leading AIEd researchers. Their role in disseminating new ideas and accelerating scientific knowledge, reaching wide audiences, and promoting interdisciplinary studies has also contributed to their prominence.

The analysis of AIEd authors focused on their publication count and citation numbers, identifying influential researchers like Hwang G.-J. and Zhai, X. in terms of the number of publications, with Hwang leading in citations, followed by Papamitsiou, Z. Despite fewer publications, some authors' work received high citations, indicating the field's popularity and the impact of these publications. Our study did not compare these findings with the literature due to the dynamic nature of publication and citation data. Additionally, co-authorship and co-citation analyses were conducted. Co-authorship analysis, requiring at least two publications and 100 citations, revealed limited collaborations, suggesting either a lack of collaboration in AIEd or high criteria for analysis. Co-citation analysis helped us understand how researchers' ideas and trends interact and spread within the field.

In bibliometric analysis, keywords are considered the basic elements of representing knowledge concepts. They have been frequently used to uncover the knowledge structure of research domains (Su & Lee, 2010). As expected, the terms artificial intelligence, machine learning, deep learning, data mining, and educational data mining have been used quite extensively, with other keywords typically clustered around them. Similarly, when assessed in terms of popularity, it has been concluded that in recent years, these terms have been the most frequently used. The keyword analysis results of the bibliometric analysis studies applied directly in AI in education or in specific fields of AI were generally on basic topics such as artificial intelligence, deep learning, and machine learning (Baek & Doleck, 2020; Chen et al., 2020; Hwang & Tu, 2021; Kaban, 2023; Liang et al., 2023; Pua et al., 2021) as well as concepts such as mathematics education (Hwang & Tu, 2021), and engineering education (Pua et al., 2021), depending on the specific field of the study. Partial differences in these results can be explained by the period in which the bibliometric analysis was performed and the fact that it was conducted in a specific field.

The following are some recommendations for future research directions in the field of AI applications in education, based on the findings and scope of the current study:

- This study was conducted on the WoS database platform, considered to be one with the most influential publications in the literature. Again, the scope of the related concept can be increased by searching the Scopus database, one of the largest databases in the world, and other field indexes.
- Considering that the concept of AIEd is very popular and of increasing importance, studies comparing some of our findings of the study on a country-by-country basis can be conducted.
- Thematic analysis of the most cited studies in the related field may be important to express the importance of the related studies.
- Detailed analysis of AIEd studies at more specific educational levels (e.g., higher education or high school level) can help reveal and articulate the specific needs and trends in this field.

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