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Bibliometric Mapping of Teachers' Roles in Artificial Intelligence: A Visualization Study

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Abstract

This bibliometric study examines the evolving research landscape on teachers' roles in AI-enhanced education from 2020 to 2024. Using the PRISMA 2020 guidelines, we analyzed 54 relevant publications using VOSviewer and Scimago Graphica tools. The study reveals a significant publication surge, peaking at 25 in 2023, indicating growing academic interest in this field. China, the United States, and South Korea emerge as leading contributors, highlighting the global nature of this research area. Keyword analysis emphasizes the centrality of "artificial intelligence" and "teacher," reflecting the focus on AI's impact on educators' roles. The prominence of "integration" and "transformation" suggests a shift in perceiving AI as a supplementary tool to a transformative force in education. Citation network analysis reveals influential works shaping the field, with recent publications garnering significant attention. The study also highlights strong international collaborations, particularly among institutions in China and the United States. Key themes identified include the integration of AI in teaching practices, transforming teachers' roles, and AI's potential for personalized learning. This comprehensive analysis provides valuable insights for educators, policymakers, and researchers navigating the future of AI-enhanced education, emphasizing the need for ongoing research, international collaboration, and interdisciplinary approaches to optimize the role of teachers in this rapidly evolving field.

Keywords: artificial intelligence, education, teachers' roles, bibliometric analysis, international collaboration

1. Introduction

The dawn of the 21st century has ushered in an era where Artificial Intelligence (AI) is rapidly reshaping the landscape of education, presenting both unprecedented opportunities and formidable challenges. As AI technologies become increasingly sophisticated and ubiquitous in classrooms worldwide, they are not merely augmenting traditional teaching methods but fundamentally transforming the very nature of education (Xue et al., 2022). This technological revolution is redefining the role of teachers, shifting them from mere information providers to facilitators of AI-enhanced learning environments (Celik et al., 2022). The integration of AI in education has sparked a global dialogue on the future of teaching, raising critical questions about the skills educators need to thrive in this new paradigm and the potential implications for educational equity and effectiveness (Humble & Mozelius, 2022). The stakes are high. AI has the potential to democratize education, offering personalized learning experiences tailored to individual student needs (Li & Wong, 2023). Adaptive learning systems powered by AI can analyze vast amounts of student performance data to create customized learning pathways, potentially revolutionizing educational delivery (AlGerafi et al., 2023). In assessment, AI tools promise more accurate, timely, and comprehensive feedback, opening new avenues for evaluating student progress (Owan et al., 2023).

However, this technological shift also brings forth significant ethical considerations and challenges. Concerns about data privacy, algorithmic bias, and the potential exacerbation of educational inequalities loom large (Nguyen et al., 2022; Karan & Angadi, 2023). As AI becomes more prevalent in classrooms, there is an urgent need to understand its impact on student-teacher relationships and the overall learning experience.

Given the rapid evolution of this field, it is crucial to map the current research landscape, identify emerging trends,

and anticipate future directions. This study aims to address this need by conducting a comprehensive bibliometric analysis of research related to teachers' roles in AI-enhanced education from 2020 to 2024. By analyzing publication trends, citation patterns, keyword networks, and collaborative relationships, we seek to provide a holistic view of the state of research in this critical area.

Specifically, this research aims to answer the following questions:

1) What are the publication trends in research on teachers' roles in AI from 2020 to 2024?

2) Which countries and institutions are leading research efforts in this field?

3) What are the key themes and concepts emerging in the research on teachers' roles in AI-enhanced education?

4) How has international collaboration shaped the research landscape in this area?

5) What are the most influential publications and authors in this field?

The findings of this study will not only provide a snapshot of the current research landscape but also offer valuable insights for educators, policymakers, and researchers navigating the future of AI-enhanced education. By identifying emerging trends, challenges, and opportunities, this research contributes to the ongoing dialogue about the future of education in an AI-enhanced world (Daykan & O'Reilly, 2023).

As we stand on the brink of a new educational era, understanding the evolving role of teachers in AI-enhanced learning environments is not just an academic exercise—it is a crucial step in shaping the future of education. This study aims to illuminate this path, providing a comprehensive and nuanced understanding of the complex interplay between AI and the teaching profession.

2. Literature Review

2.1 The Emergence and Evolution of AI in Education

AI integration in education has experienced significant growth and evolution in recent years (Xue et al., 2022; Shafique et al., 2023). This technological advancement has led to the development of adaptive learning systems, intelligent tutoring systems, and automated assessment tools, revolutionizing traditional educational practices (AlGerafi et al., 2023; Owan et al., 2023; Chiu et al., 2023). The potential of AI in education spans from personalized learning experiences to more efficient administrative processes (Li & Wong, 2023; Khan et al., 2022; Shrivastava, 2023).

However, the integration of AI in education also brings forth challenges, including concerns about data privacy, algorithmic bias, and the potential exacerbation of educational inequalities (Karan & Angadi, 2023; Nguyen et al., 2022; Sanabria-Navarro et al., 2023). These issues highlight the need for careful consideration and ethical implementation of AI technologies in educational settings (Mouta et al., 2023; Osmanoglu, 2023).

2.2 Transforming Teacher Roles and Pedagogical Approaches

The proliferation of AI technologies in educational settings is significantly transforming the role of teachers (Celik et al., 2022; Barrett & Pack, 2023; Ye, 2021). Educators are increasingly expected to act as facilitators and guides, leveraging AI tools to enhance their teaching methods and student engagement (Humble & Mozelius, 2022; Mujiono, 2023). This shift necessitates the development of new competencies in AI literacy and digital pedagogy among teachers (Abramowitz & Antonenko, 2022; Dec et al., 2022).

The integration of AI in classrooms has led to a reconsideration of traditional teaching methodologies. For example, the use of AI-powered chatbots as learning assistants has shown promise in supporting student motivation and engagement (Chiu et al., 2023; Ebadi & Amini, 2022). However, this technological shift also raises questions about the emotional aspects of teaching in an AI-enhanced environment, with studies exploring teachers' anxiety towards AI (Banerjee & Banerjee, 2023) and the potential for AI to minimize emotional labor in teaching (Guo, 2023).

2.3 AI-Enhanced Personalized Learning and Assessment

One of the most promising applications of AI in education is its potential to enable personalized learning experiences tailored to individual student needs (Li & Wong, 2023; Gowrabhathini et al., 2023). AI-powered adaptive learning systems can analyze vast amounts of data to create customized learning pathways for each student, potentially revolutionizing educational delivery (Khan et al., 2022; AlGerafi et al., 2023).

In the realm of assessment, AI tools are being developed to provide more accurate, timely, and comprehensive feedback on student performance (Owan et al., 2023; Lawrie, 2023). This includes automated essay scoring systems and intelligent tutoring systems that can provide real-time guidance to students. However, the use of AI

in assessment also raises concerns about fairness, transparency, and the potential for bias (Mohammadkarimi, 2023; Hsu, 2023).

The integration of AI in personalized learning and assessment also has significant implications for special education. AI technologies show promise in diagnosing and supporting students with neurodevelopmental disorders (Vashisht & Jatain, 2023; Rapti, 2023) and in creating more inclusive educational environments (Bakkum et al., 2023).

2.4 Ethical Considerations and Challenges in AI-Enhanced Education

The adoption of AI in education brings forth various ethical considerations and challenges that need to be addressed (Nguyen et al., 2022; Mouta et al., 2023; Karan & Angadi, 2023). These include concerns about data privacy, algorithmic bias, and the potential exacerbation of educational inequalities (Sanabria-Navarro et al., 2023; Humble & Mozelius, 2022).

There are also growing concerns about the impact of AI on academic integrity. The rise of generative AI tools has led to discussions about their potential misuse in academic writing and the need for new approaches to ensuring academic honesty (Mohammadkarimi, 2023; Hsu, 2023). Furthermore, the implementation of AI technologies in education requires careful consideration of their impact on student-teacher relationships and the overall learning experience (Daykan & O'Reilly, 2023; Osmanoglu, 2023).

2.5 Future Directions and Global Perspectives in AI-Enhanced Education

As AI continues to evolve, its potential applications in education are expanding, offering new opportunities for innovation in teaching and learning (Park et al., 2023; Zhang, 2023; Qiu et al., 2024). Research in this field is increasingly taking on a global perspective, with studies examining the impact of AI on education in various cultural contexts (Guo, 2023; Ebadi & Amini, 2022).

There is growing interest in the role of AI in specific educational domains, such as vocational education (Suparyati et al., 2023), art direction in film education (Brako & Mensah, 2023), and science education (Park et al., 2023). These studies highlight the diverse applications of AI across different educational contexts and disciplines.

Looking ahead, future research and development in this field must focus on creating AI systems that complement and enhance human teaching, rather than replacing it entirely (Daykan & O'Reilly, 2023; Celik et al., 2022). This includes exploring innovative applications such as AI-based sport management systems (Feng, 2023) and the use of AI in class scheduling and management (Taye et al., 2023).

The successful integration of AI in education requires a balanced approach that considers both the technological possibilities and the human aspects of learning (Lawrie, 2023; Barrett & Pack, 2023). As the field continues to evolve, there is a clear need for ongoing research, international collaboration, and interdisciplinary approaches to fully understand and optimize the role of AI in enhancing teaching and learning experiences (Dec et al., 2022; Bhatt et al., 2023; Shafique et al., 2023).

In conclusion, integrating AI in education presents significant opportunities and challenges. It can potentially revolutionize personalized learning, assessment, and educational administration (AlGerafi et al., 2023; Owan et al., 2023). However, it also raises important ethical considerations and challenges that must be carefully addressed (Nguyen et al., 2022; Karan & Angadi, 2023). As we move forward, it is crucial to strike a balance between leveraging the benefits of AI and maintaining the irreplaceable human elements of education that are crucial for holistic development (Xue et al., 2022; Chiu et al., 2023; Li & Wong, 2023).

3. Research Method

This study employed a comprehensive bibliometric analysis approach to examine the trends, patterns, and relationships in research related to teachers' roles in AI. The methodology followed the PRISMA 2020 guidelines for systematic reviews, ensuring a rigorous and transparent process.

3.1 Data Collection and Screening

The data collection process consisted of the following steps:

1) Initial Search:

- Database: Dimension.ai
- Search terms: "teacher role" AND "artificial intelligence"
- Time frame: 2020–2024 (The search query was executed on August 7th, 2024)
- Initial yield: 56 records

2) Screening Process:

- All 56 records were assessed for eligibility based on predefined criteria.
- Exclusion criteria: preprints and non-journal articles
- 2 records were excluded based on these criteria.
- Final sample: 54 records

3) Retrieval and Inclusion:

- Full texts of all 54 records were retrieved.
- Language check: All records were in English, so no language-based exclusions were necessary.
- All 54 reports were included in the final review.

3.2 Data Analysis

The bibliometric analysis was conducted using a combination of tools, primarily VOSviewer and Scimago Graphica, to provide a comprehensive view of the research landscape. The analysis included the following components:

1) Publication Trend Analysis (2020–2024):

- Used Scimago Graphica to create time-based visualizations of publication volumes.
- Analyzed year-wise distribution of publications to identify trends in research output.

2) Citation Analysis:

- Utilized VOSviewer to create citation networks.
- Identified highly cited papers and influential authors in the field.
- Created citation maps to visualize the relationships between key publications.

3) Keyword Network Analysis:

- Employed VOSviewer to generate keyword co-occurrence networks.
- Identified key themes and concepts in the research field.
- Used overlay visualizations to show the evolution of keywords over time.

4) Co-authorship Analysis:

- Created co-authorship networks using VOSviewer.
- Analyzed collaboration patterns among researchers and institutions.
- Identified key research clusters and influential research groups.

5) Geographical Distribution Analysis:

- Used Scimago Graphica to create world maps showing the distribution of research output.
- Analyzed country-wise contributions and international collaborations.
- Created bar charts and heat maps to represent country-wise publication and citation counts.

6) Journal and Source Analysis:

- Utilized VOSviewer to analyze the distribution of publications across different journals and sources.
- Identified key journals in the field of AI in education.

7) Organizational Network Analysis:

- Created organizational co-authorship networks using VOSviewer.
- Analyzed collaborations between different institutions and their research output.

3.3 Visualization and Interpretation

The data analysis results were visualized using various techniques:

1) Network Visualization:

- Used VOSviewer to create network maps for keywords, authors, organizations, and countries.
- Applied different layout algorithms (e.g., force-directed layout) to optimize the visual representation of relationships.

2) Temporal Analysis:

- Utilized the overlay visualization feature in VOSviewer to represent the temporal aspects of publications and citations.
- Created timeline visualizations using Scimago Graphica to show the evolution of research over the 2020-2024 period.

3) Geospatial Visualization:

- Employed Scimago Graphica to create world maps and regional maps showing the geographical distribution of research.

4) Statistical Charts:

- Generated bar charts, line graphs, and scatter plots using Scimago Graphica to represent various bibliometric indicators.

3.4 Interpretation and Synthesis

The final step involved a careful interpretation of the visualizations and statistical data. This included:

- Identifying key trends in the evolution of research on teachers' roles in AI.
- Recognizing emerging themes and research fronts.
- Analyzing the shift in research focus over the studied period.
- Evaluating the impact of geographical and institutional factors on research output and collaborations.

By combining VOSviewer's powerful visualization capabilities with Scimago Graphica's advanced mapping and charting features, this study provides a multi-faceted view of the research landscape. This approach allows for a deep understanding of the current state, trends, and future directions in research on teachers' roles in the context of artificial intelligence in education.

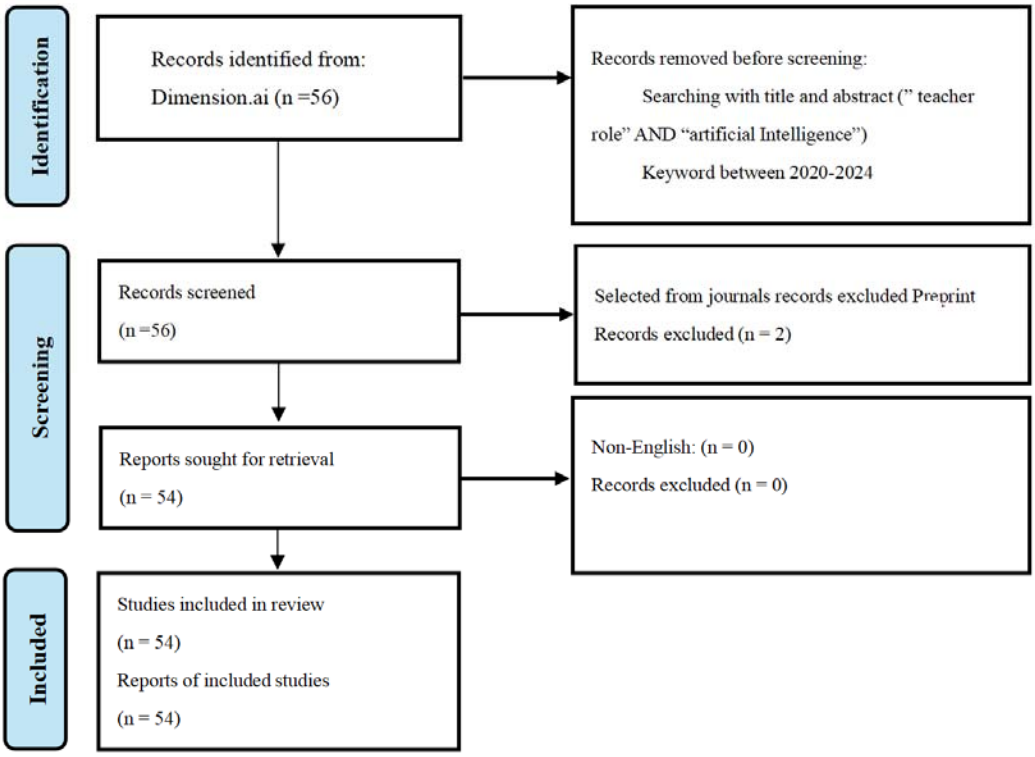

Figure 1. PRISMA 2020

Figure 1 illustrates the PRISMA 2020 flow diagram for this study's guided bibliometric review procedure. Initially, 56 records were identified from Dimension.ai using the search terms "teacher role" AND "artificial intelligence" with keywords from 2020–2024. During the identification phase, these records were filtered to remove any that did not meet the criteria, but none were excluded at this stage. All 56 records were assessed in the screening phase, and two records were excluded because they were preprints or not from journals. This left 54 records for further evaluation. In the retrieval phase, all 54 records were sought for full-text retrieval, and no records were excluded for being non-English, as all were in English. Finally, all 54 reports were included in the review. This flowchart details the systematic process employed to ensure that the studies included in the review were relevant and met the predetermined criteria, ensuring a thorough and rigorous selection process.

4. Results

4.1 Publication Trend

Figure 2, supported by data from Table 1, illustrates the publication trend related to the role of teachers with AI from 2020 to 2024. The trend shows a significant increase in scientific production over the years. Starting with two publications in 2020, the interest grew to 6 in 2021, followed by a slight dip to 3 in 2022. However, there was a remarkable surge to 25 publications in 2023, indicating a peak in research activity, likely driven by increased interest or advancements in AI applications in education. In 2024, the number of publications is projected to be 18, showing a slight decline from the previous year but still maintaining a high level of research activity compared to the initial years. This trend reflects an overall growing interest and sustained academic engagement in AI and education.

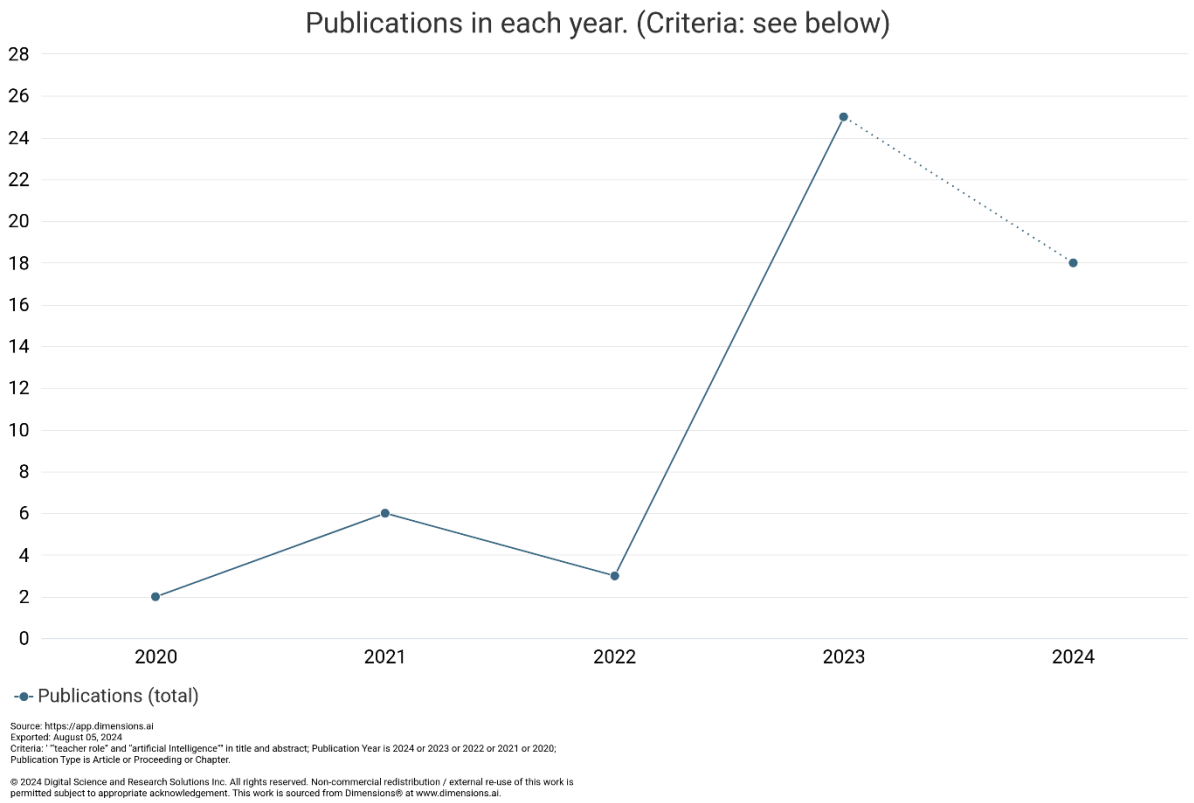

Figure 2. The visualization shows the number of publications published each year

Table 1. Annual scientific production

Year	Publication
2020	2
2021	6
2022	3
2023	25
2024	18
Total	54

Figure 3, based on data from Table 2, illustrates the annual scientific citations for research on the role of teachers with AI from 2020 to 2024. The trend shows a significant increase in citations over the years. In 2020 and 2021, no citations were recorded, indicating the nascent research stage or limited impact. In 2022, the number of citations started to rise, reaching 17. This growth continued more prominently in 2023, with a substantial jump to 147 citations. The projection for 2024 shows an even more remarkable increase to 296 citations, nearly doubling the previous year's count. This sharp rise in citations reflects the growing recognition and influence of research in this field, suggesting that studies on the role of teachers in AI have gained significant academic attention and impact in recent years. The cumulative citations from 2020 to 2024 total 460, highlighting the accelerating interest and scholarly engagement in this area.

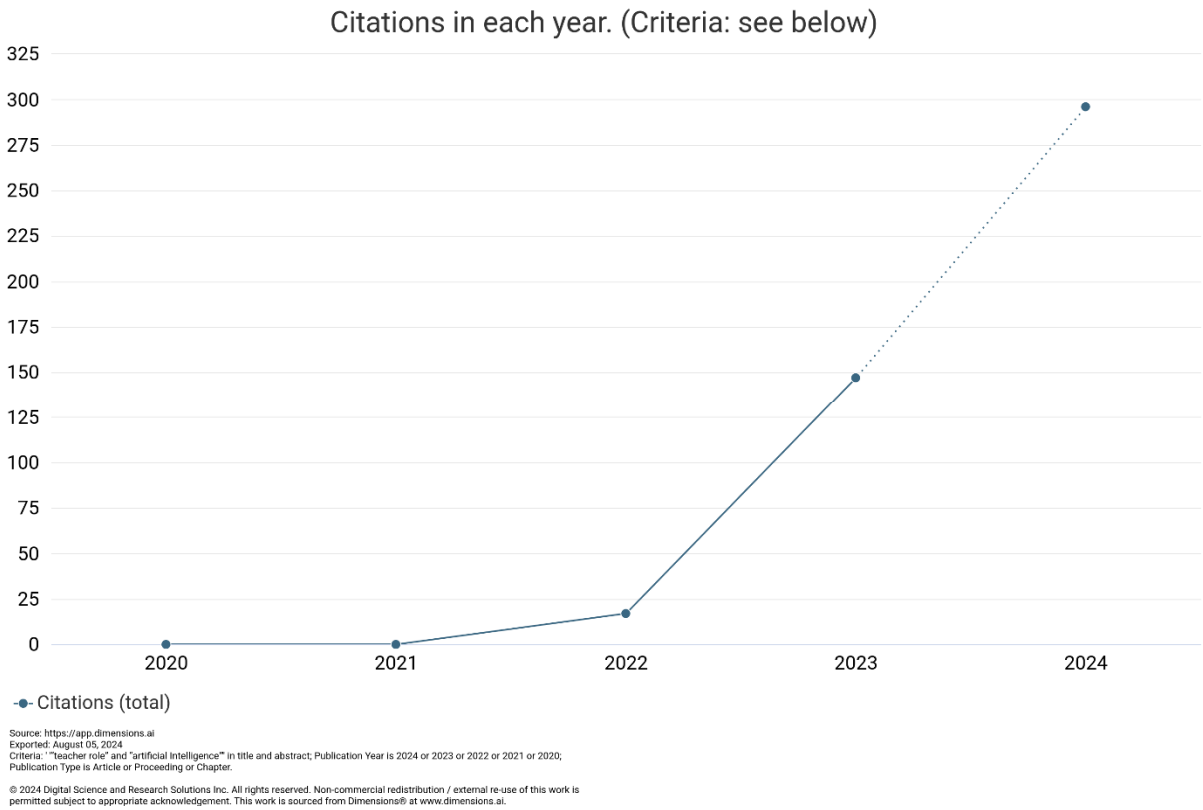

Figure 3. The visualization shows the number of citations in each year

Table 2. Annual scientific citation

Year	Citations
2024	296
2023	147
2022	17
2021	0
2020	0
Total	460

Figure 4, supported by data from Table 3, categorizes the research fields related to the role of teachers with AI. The majority of research falls under the category of Education (ANZSRC code 39), with 40 publications, primarily focusing on Curriculum and Pedagogy (36 publications), Education Systems (33 publications), and Specialist Studies in Education (4 publications). Information and Computing Sciences (ANZSRC code 46) is the second most represented category with 14 publications, highlighting areas such as Artificial Intelligence (3 publications) and Human-Centred Computing (2 publications). Other categories, such as Language, Communication, and Culture (5 publications), Built Environment and Design, Commerce, Management, Tourism and Services, Health Sciences, Human Society, and Philosophy and Religious Studies, each have a single publication. This distribution underscores the interdisciplinary nature of research on teachers in AI, with a strong emphasis on educational methodologies and systems.

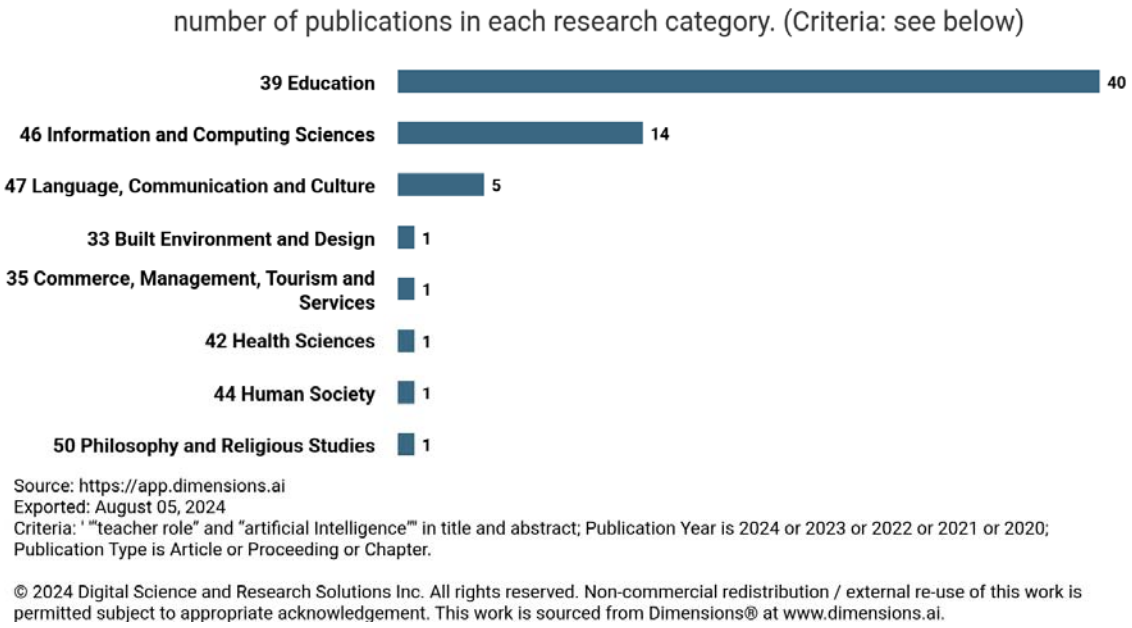

Figure 4. Research category

Table 3. Research category

Category	Fields of Research (ANZSRC 2020)
39 Education	40
3901 Curriculum and Pedagogy	36
3903 Education Systems	33
3904 Specialist Studies In Education	4
3902 Education Policy, Sociology and Philosophy	1
46 Information and Computing Sciences	14
4602 Artificial Intelligence	3
4608 Human-Centred Computing	2
4606 Distributed Computing and Systems Software	1
4610 Library and Information Studies	1
4611 Machine Learning	1
47 Language, Communication and Culture	5
4703 Language Studies	3
4704 Linguistics	2
33 Built Environment and Design	1
3303 Design	1
35 Commerce, Management, Tourism and Services	1
42 Health Sciences	1
4201 Allied Health and Rehabilitation Science	1
44 Human Society	1
4410 Sociology	1
50 Philosophy and Religious Studies	1
5002 History and Philosophy of Specific Fields	1

4.2 Keyword Network Analysis

Figure 5 presents a keyword network map that illustrates the interconnected relationships between various key terms in research on the role of teachers with AI. Central to the map are the terms “artificial intelligence” and “teacher,” indicating their prominence and frequency within the literature. These keywords are surrounded by related concepts such as “research,” “integration,” “transformation,” “knowledge,” and “opportunity,” highlighting the multifaceted nature of this field. The dense web of connections suggests a robust discourse linking the central themes of AI and education, focusing on how AI is integrated into teaching practices, the transformative impacts on education, and the evolving role of teachers. This network map not only emphasizes the key areas of interest but also reveals the strong interrelations and collaborative nature of research in this domain.

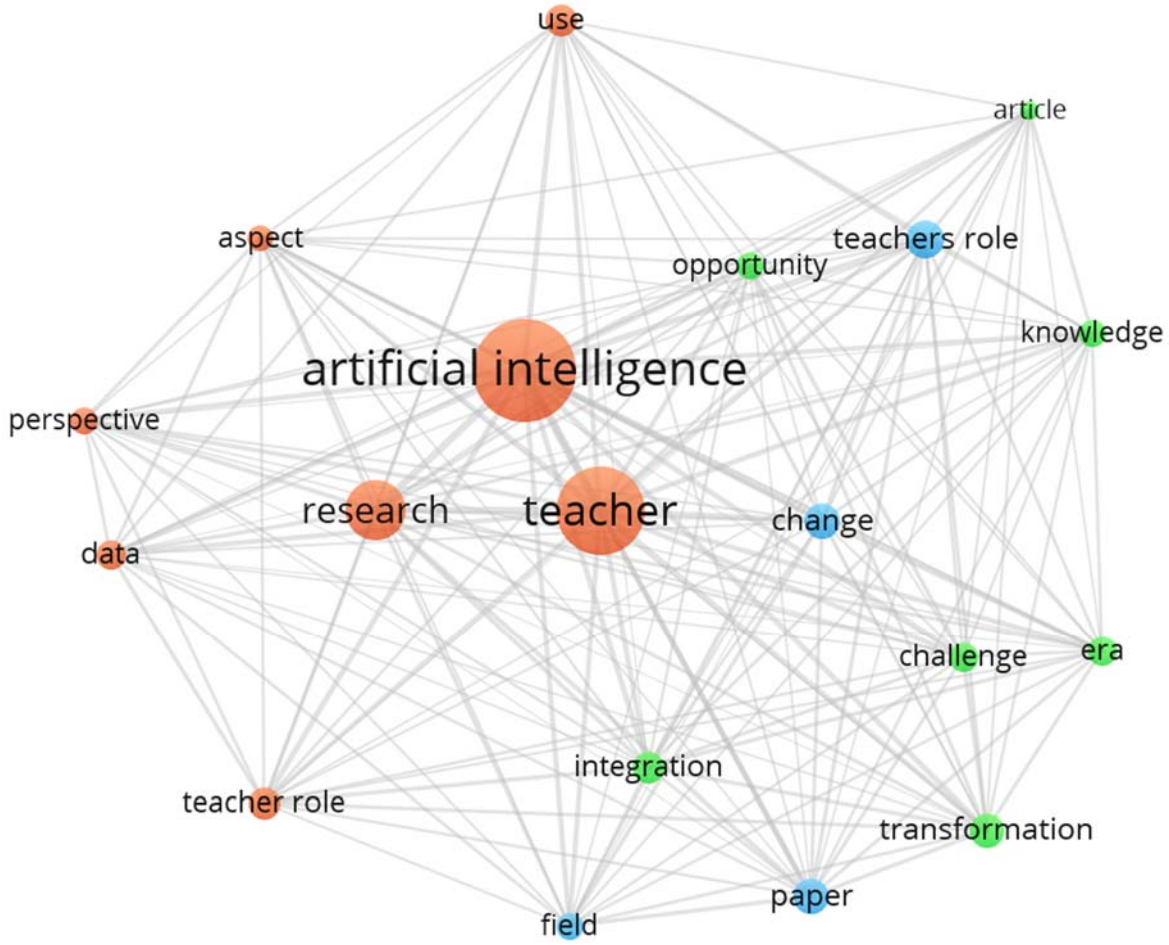

Figure 5. Relationships between keywords

Figure 6 illustrates the key trends and important research topics related to teachers' role with AI. The keywords “artificial intelligence,” “teacher,” and “research” are the most prominent, indicating their central role and frequent discussion in the literature. Keywords such as “teacher’s role,” “change,” and “knowledge” also show significant relevance, highlighting central themes like the evolving responsibilities of teachers and the integration of AI into education. Emerging trends are captured by terms like “integration,” “transformation,” and “opportunity,” which, while less frequent, are highly relevant and suggest areas of future focus. Peripheral keywords like “challenge” and “data” indicate specific practical and technical considerations. Overall, the map emphasizes the primary focus on how AI is integrated into educational practices and the evolving role of teachers in this context.

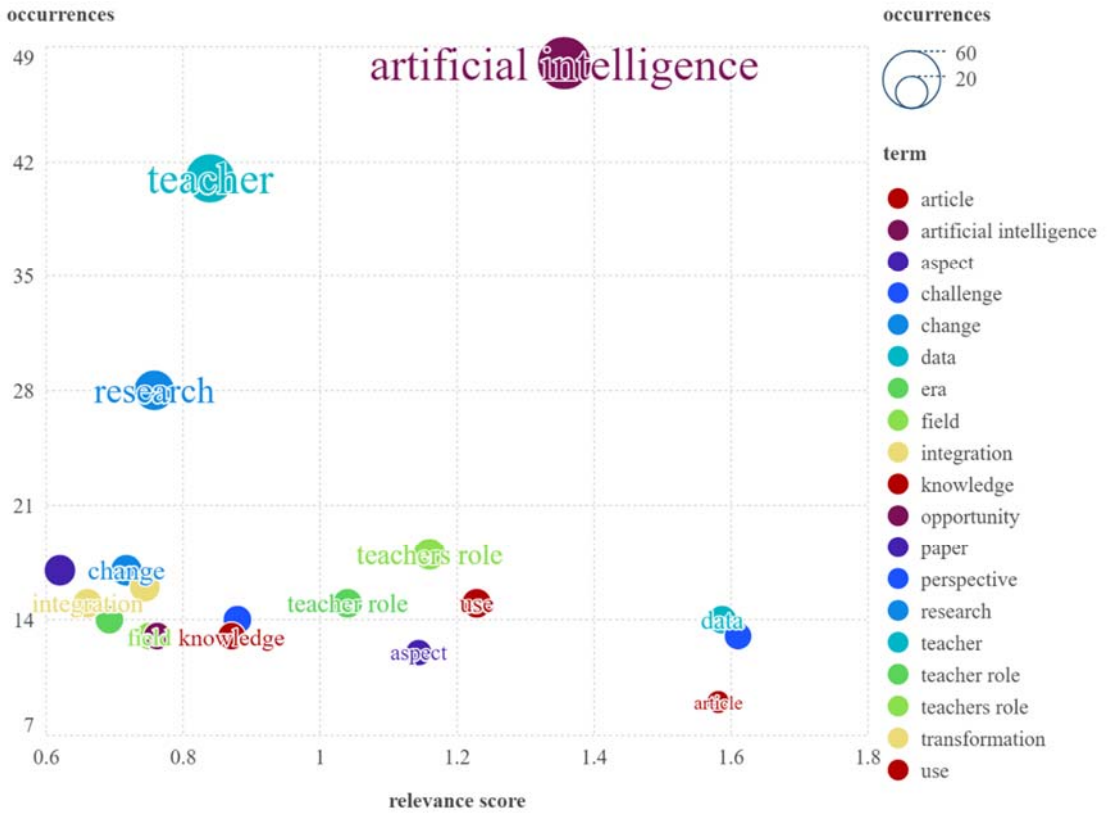

Figure 6. Keywords in research

Table 4. List of the keywords in research

Keywords	occurrences	relevance score
artificial intelligence	48	1.3565
teacher	41	0.8392
research	28	0.7577
teachers role	18	1.1598
change	17	0.7169
paper	17	0.6199
transformation	16	0.7439
integration	15	0.6601
teacher role	15	1.0401
use	15	1.2287
challenge	14	0.8792
data	14	1.5873
era	14	0.6922
field	13	0.75
knowledge	13	0.8706
opportunity	13	0.7621
perspective	13	1.6104
aspect	12	1.1439
article	9	1.5816

Table 4 provides a list of keywords used in research related to the role of teachers with AI, along with their occurrences and relevance scores. The term “artificial intelligence” is the most frequently occurring keyword, with 48 occurrences and a high relevance score of 1.3565, indicating its central role in the research. “Teacher” follows with 41 occurrences and a relevance score of 0.8392, highlighting the focus on educators in AI studies.

Other significant terms include “research” (28 occurrences, 0.7577 relevance), “teachers role” (18 occurrences, 1.1598 relevance), and “change” (17 occurrences, 0.7169 relevance). Keywords like “paper” (17 occurrences),

"transformation" (16 occurrences), and "integration" (15 occurrences) also appear frequently, though with varying relevance scores, indicating their importance in the discussion.

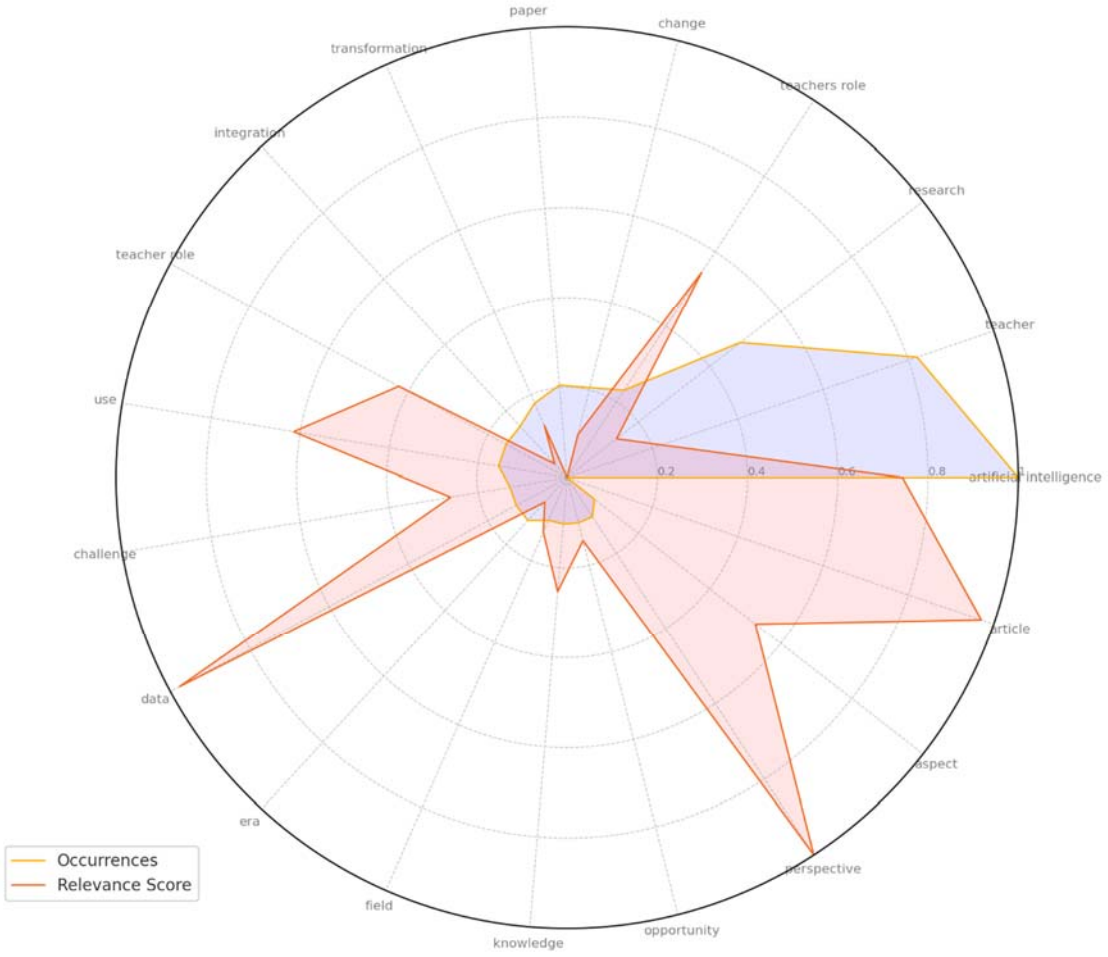

Figure 7. Radar chart of keyword occurrences and relevance score

Figure 7 illustrates a radar chart depicting the occurrences and relevance scores of keywords related to the role of teachers in artificial intelligence (AI). The blue area represents the frequency of each keyword's appearance in the dataset, while the red area indicates the relevance score, reflecting its importance in the research context. Keywords such as "artificial intelligence" and "teacher" exhibit high occurrences and relevance scores, underscoring their central role in the studies. Other terms like "data" and "perspective" have high relevance scores despite lower occurrences, highlighting their significance in AI research in education. This chart provides a succinct overview of key terms and their importance, identifying primary focus areas and emerging topics in the field.

4.3 Citation Network Analysis

Figure 8 presents a citation map that visually represents influential documents concerning the role of teachers with AI, categorizing them by authorship and publication year. Each node on the map corresponds to a specific document, with the node's size indicating the frequency of citations it has received, thereby signifying its impact within the academic community. The color gradient, ranging from purple (representing earlier years) to yellow (representing more recent years), provides a temporal context for the publications. Noteworthy documents, such as those authored by Jeon (2023) and Bin-Hady (2023), are represented by more prominent green nodes, denoting many citations and indicating their significant influence and recent contributions to the field. Conversely, earlier works like that of Lameras (2021), depicted in smaller blue nodes, illustrate foundational research that, while older, continues to be relevant and cited in current studies.

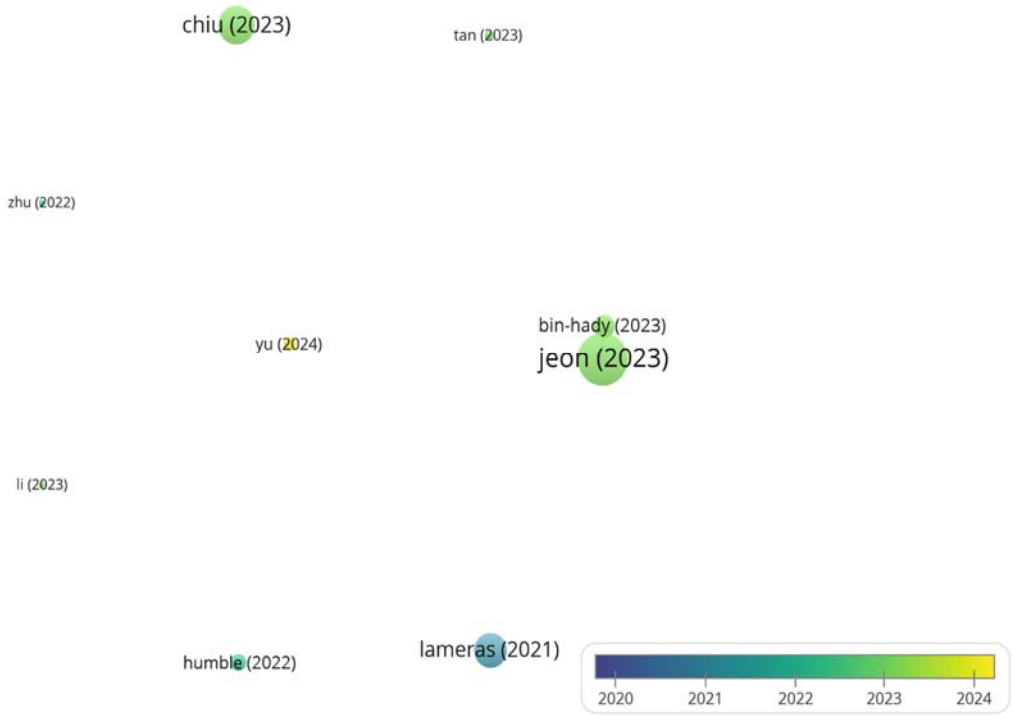

Figure 8. Citation map of influential documents on the role of teachers in AI

Table 5. Top citation of influential documents

document	citations	links
jeon (2023)	131	1
chiu (2023)	86	0
lameras (2021)	77	0
bin-hady (2023)	46	1
humble (2022)	31	0
yu (2024)	25	0
tan (2023)	17	0
zhu (2022)	10	0
li (2023)	8	0

Table 5 provides an overview of the most frequently cited documents related to the role of teachers with AI, detailing both the citation counts and the number of links that indicate connections to other documents. The document by Jeon (2023) stands out with 131 citations and one link, underscoring its significant impact and integration within the academic discourse. Chiu (2023) follows with 86 citations, though it lacks links, suggesting that while highly influential, it does not directly connect with other works. Lameras (2021), despite having 77 citations and no links, remains a pivotal foundational study. Bin-Hady (2023), with 46 citations and one link, shows a balance of influence and network connectivity. Other documents, such as Humble (2022) with 31 citations, Yu (2024) with 25 citations, Tan (2023) with 17 citations, Zhu (2022) with 10 citations, and Li (2023) with eight citations, display varying degrees of impact but no interconnecting links, indicating their isolated yet essential contributions to the field. This table highlights the central documents shaping the academic landscape of AI in education and their respective roles within the scholarly community.

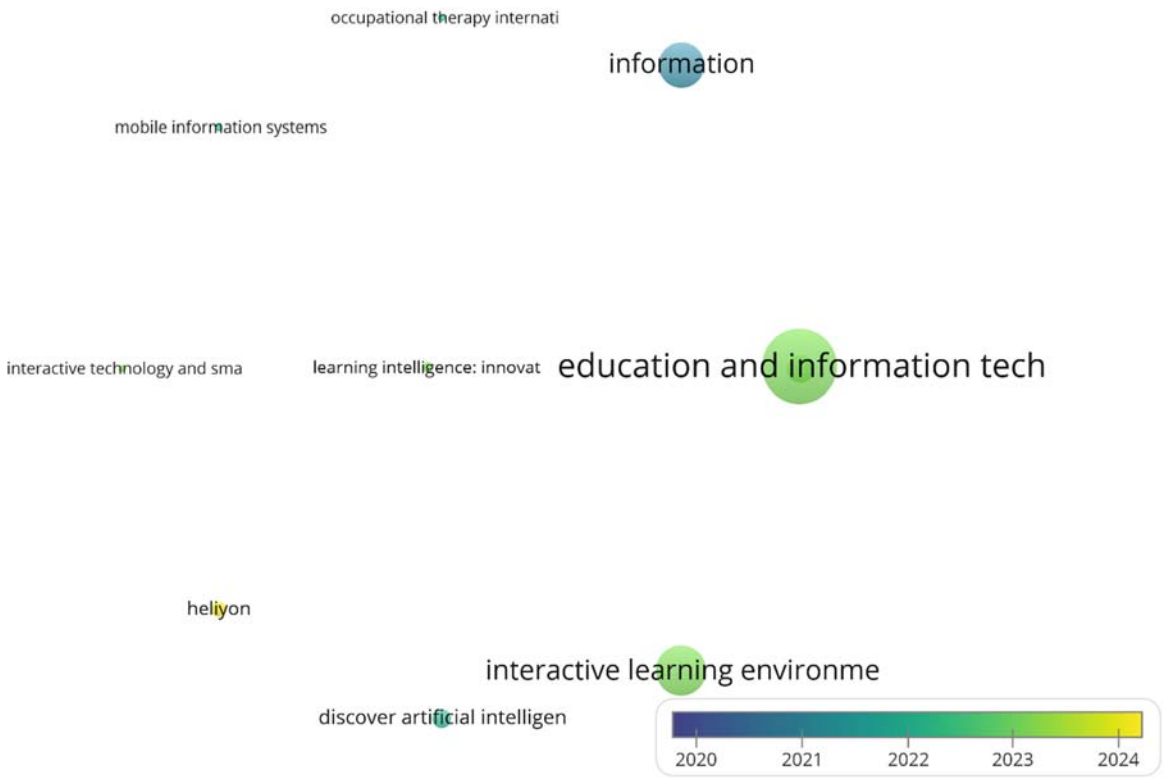

Figure 9. Citation map of sources

Table 6. Top citation of source

source	documents	citations	total link strength
education and information technologies	1	131	1
interactive learning environments	1	86	0
information	1	77	0
library hi tech	1	46	1
discover artificial intelligence	1	31	0
heliyon	1	25	0
learning intelligence: innovative and digital transformative learning strategies	1	17	0
occupational therapy international	1	10	0
interactive technology and smart education	1	8	0
mobile information systems	1	6	0

Table 6 presents an analysis of the top-cited sources in the role of teachers with AI, highlighting the number of documents published, the total citations accrued, and the total link strength. The source Education and Information Technologies emerges as particularly influential, with a single document amassing 131 citations and demonstrating notable connectivity within the research network, as indicated by its link strength of 1. Similarly, Interactive Learning Environments garners significant attention with 86 citations for one document, though it lacks network link strength, suggesting high impact but limited integration. Sources such as Information and Library Hi Tech also show considerable citation counts of 77 and 46, respectively, with Library Hi Tech additionally exhibiting network connectivity. Other sources, including Discover Artificial Intelligence, Heliyon, and Occupational Therapy International, show a range of citation counts (from 31 to 10) but no link strength, indicating recognized yet isolated contributions. The diversity in citation counts and link strengths across these sources underscores the varying degrees of influence and interconnectedness within the academic discourse on the role of teachers in AI.

Figure 10 presents a citation map of authors who have contributed to research on the role of teachers with AI, highlighting their influence and the temporal distribution of their work. Each node represents an author, with the node's size indicating the number of citations received. The color gradient, ranging from purple (representing older

publications) to yellow (representing more recent publications), provides a temporal context. Authors such as Jeon Jaeho and Ismailov Murod are shown with larger green nodes, indicating their recent and highly cited contributions. In contrast, earlier contributors like Lameras Petros and Chiu Thomas K.F. appear with smaller, blue nodes, reflecting foundational work that continues to be relevant. This map effectively illustrates the distribution of influential authors over time, showcasing longstanding and emerging contributions to the field.

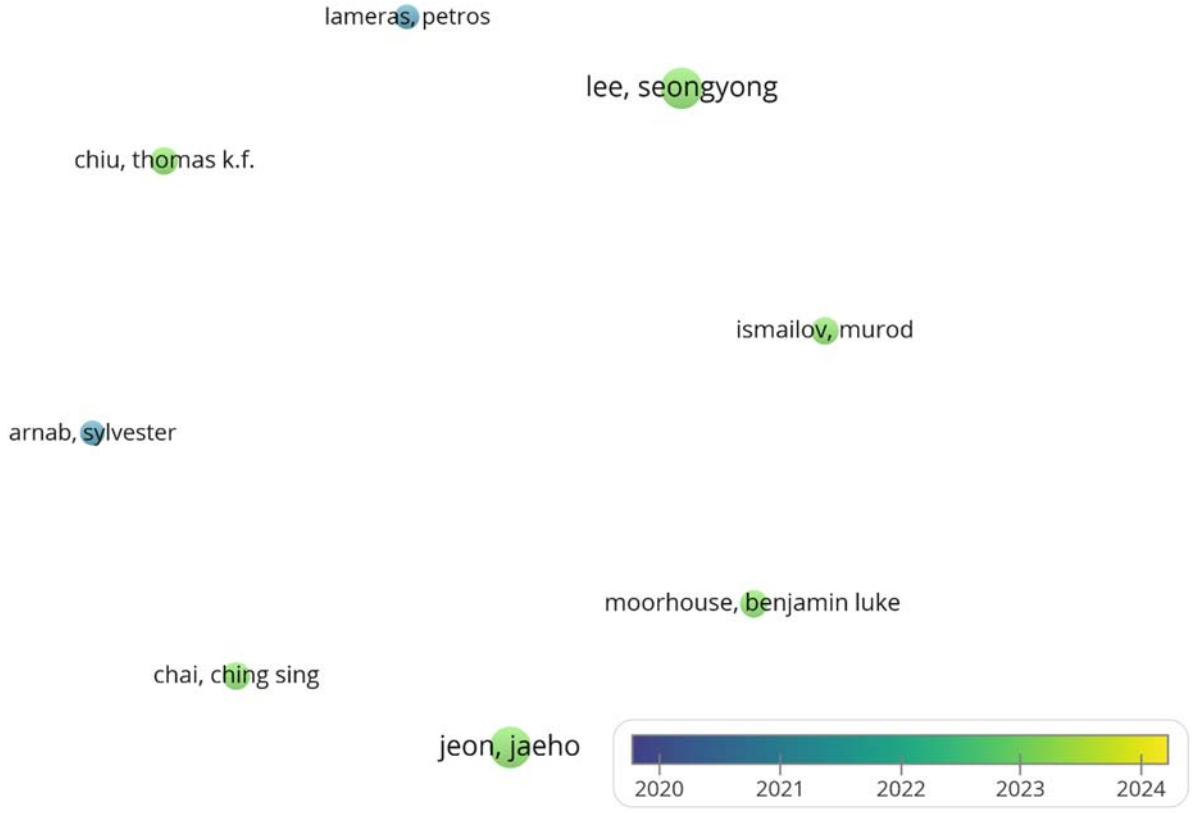

Figure 10. Citation map of authors

Table 7. Top citation of author

author	documents	citations
jeon, jaeho	1	131
lee, seongyong	1	131
chai, ching sing	1	86
chiu, thomas k.f.	1	86
ismailov, murod	1	86
moorhouse, benjamin luke	1	86
arnab, sylvester	1	77
lameras, petros	1	77

Table 7 lists the top-cited authors in the field of the role of teachers with AI, detailing the number of documents each author has published and the total number of citations received. Both Jeon Jaeho and Lee Seongyong have published one document each, both receiving the highest citation count of 131, indicating significant impact. Chai Ching Sing, Chiu Thomas K.F., Ismailov Murod, and Moorhouse Benjamin Luke each have one document with 86 citations, reflecting considerable influence. Arnab Sylvester and Lameras Petros also each have one document, with 77 citations each, indicating their notable contributions. This table highlights the leading authors whose single publications have had substantial influence in the research area.

Figure 11 displays a citation map of organizations involved in research on the role of teachers with AI. Each node

represents an organization, with the node's size indicating the number of citations their publications have received. The gradient from purple (older publications) to yellow (more recent publications) provides a temporal context. Indiana University Bloomington and Hannam University are prominent, with larger green nodes indicating their significant and recent contributions. Other organizations like the University of Bisha, Hadhramout University, Faculty of Arts, University of Amman, and Najran University are connected but have smaller nodes, reflecting fewer citations. This map highlights the key institutions leading research in this area and their relative impact over time.

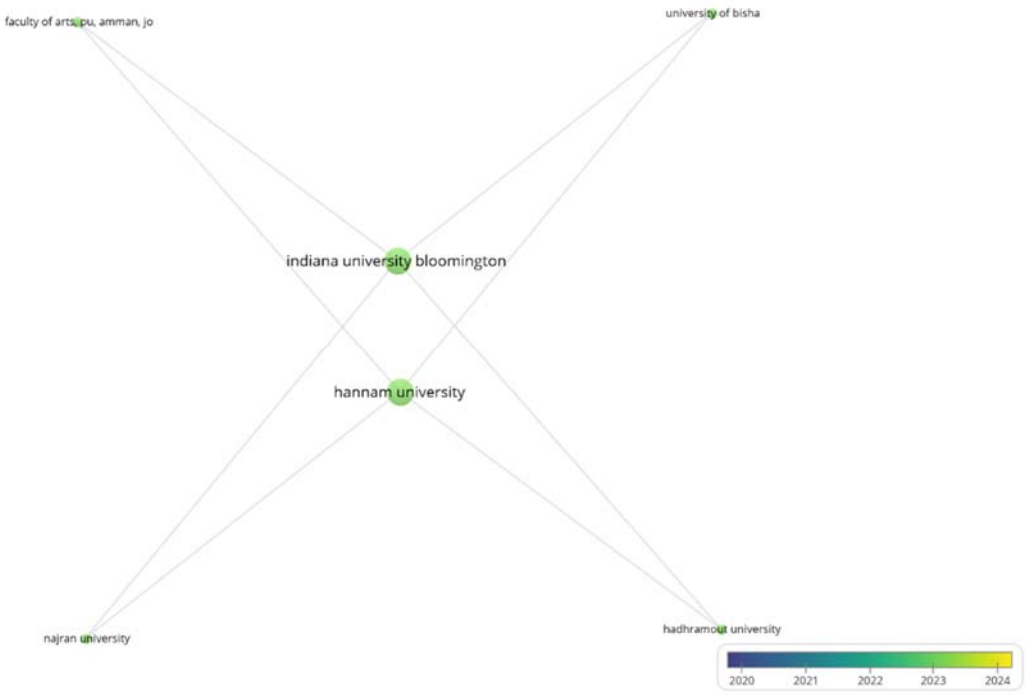

Figure 11. Citation map of organization

Table 8. Top citation of organization

organization	documents	citations	total link strength
hannam university	1	131	4
indiana university bloomington	1	131	4
chinese university of hong kong	1	86	0
hong kong baptist university	1	86	0
university of tsukuba	1	86	0
coventry university	1	77	0
faculty of arts, pu, amman, jordan	1	46	2
hadhramout university	1	46	2
najran university	1	46	2
university of bisha	1	46	2

Table 8 provides an overview of the top-cited organizations in the role of teachers with AI, listing the number of documents published, total citations received, and total link strength, which indicates the degree of connectivity with other organizations. Hannam University and Indiana University Bloomington have one document with 131 citations and the highest link strength 4, highlighting their significant impact and extensive network connections. Other institutions like the Chinese University of Hong Kong, Hong Kong Baptist University, and the University of Tsukuba have one document with 86 citations but no link strength, indicating high impact but isolated contributions. Coventry University has one document with 77 citations. Organizations such as the Faculty of Arts, PU, Amman, Jordan, Hadhramout University, Najran University, and the University of Bisha have one document with 46 citations and a link strength of 2, showing moderate influence and some network connections. This table underscores the leading institutions in AI research and their relative influence and interconnectedness in the

academic community.

Figure 12 and Figure 13 illustrate the geographical distribution and citation impact of research on the role of teachers with AI across various countries. Figure 10 presents a world map with countries shaded in orange, where darker shades signify higher citation counts. It shows that the United States, China, and South Korea are major contributors to this research. Figure 11 complements this by providing a bar chart detailing each country's citation counts. China leads with 138 citations, followed by the United States and South Korea with 131. Japan, the United Kingdom, and Saudi Arabia contribute significantly, with 86, 77, and 46 citations, respectively. Other countries like India, Indonesia, Thailand, Sweden, Ukraine, and Yemen have fewer citations, indicating a more minor impact. Together, these figures highlight the dominant role of China, the United States, and South Korea in AI research related to education while also acknowledging the contributions of other nations.

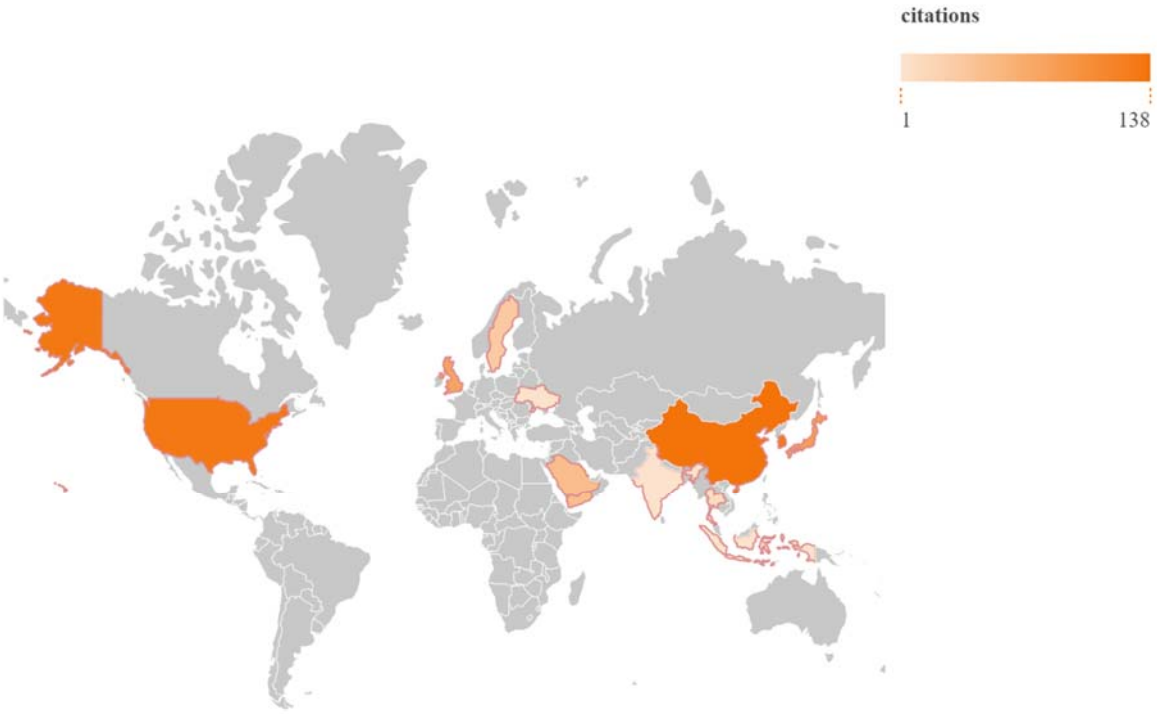

Figure 12. Citation map by country

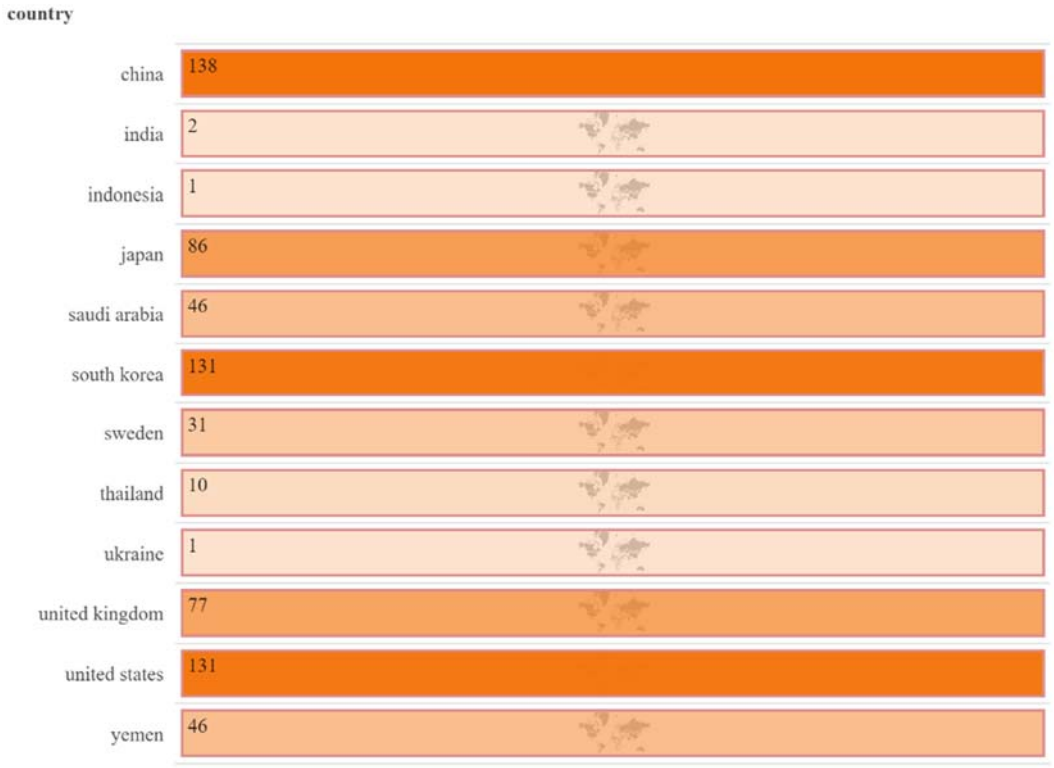

Figure 13. Citation counts by country

Figure 14 presents a citation map illustrating the interconnections between countries involved in research on the role of teachers with AI. Each node represents a country, with the size indicating the number of citations their publications have received and the color gradient from purple (indicating older publications) to yellow (indicating more recent publications) providing temporal context. South Korea and the United States are the most prominent, represented by larger green nodes, signifying recent and highly cited contributions. In contrast, Saudi Arabia and Yemen are depicted with smaller nodes, indicating fewer citations. The connections between these countries represent collaboration or citation links, underscoring the global nature of research efforts in this field. This map highlights the significant role of South Korea and the United States in AI-related educational research while also acknowledging contributions from Saudi Arabia and Yemen, demonstrating the interconnectedness of international research endeavors.

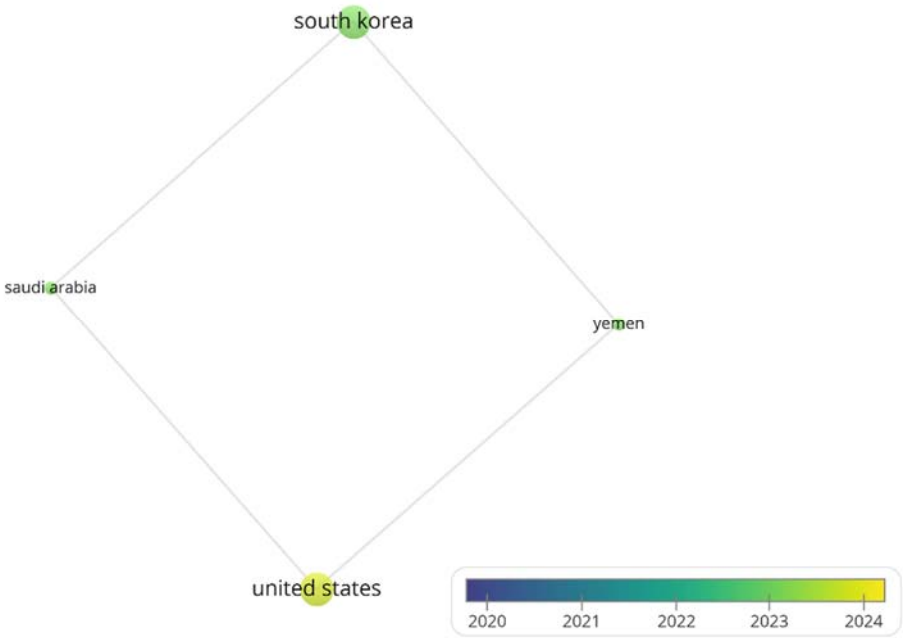

Figure 14. Citation map of country contributions

Table 9. Top cited countries

country	documents	citations	total link strength
china	17	138	0
south korea	1	131	2
united states	3	131	2
japan	1	86	0
united kingdom	1	77	0
saudi arabia	1	46	2
yemen	1	46	2
sweden	1	31	0
thailand	1	10	0
india	1	2	0
indonesia	2	1	0
ukraine	1	1	0

Table 9 provides an overview of the top-cited countries in research on the role of teachers with AI, listing the number of documents, total citations, and total link strength. China leads with 17 documents and 138 citations, though it has no link strength, indicating significant output but isolated contributions. The United States, with three documents and 131 citations, and South Korea, with 1 document and 131 citations, both show high citation counts and a total link strength of 2, highlighting their influential and well-connected research efforts. Japan has 86 citations from 1 document, while Saudi Arabia and Yemen each have 46 citations and a link strength of 2, showing moderate impact and connectivity. Other countries like India, Indonesia, Sweden, Thailand, Ukraine, and the United Kingdom have fewer citations and no link strength, indicating less impact and fewer connections within the research network. This table underscores the leading roles of China, the United States, and South Korea in AI-related educational research while also recognizing contributions from other nations.

Figure 15 visually represents the relationship between the number of documents, citations, and total link strength for various countries involved in research on the role of teachers in AI. The lines connecting the three axes—country, documents, citations, and total link strength—highlight several trends. China has the highest number of documents (17) and citations (138), but no link strength, indicating significant output but isolated contributions. The United States and South Korea have high citation counts (131 each) and strong link strengths (2), reflecting influential and well-connected research outputs. Japan shows significant influence with 86 citations from fewer documents. Countries like Saudi Arabia and Yemen, while having fewer documents, demonstrate moderate impact with notable citations and link strength (2). Countries like the United Kingdom, Sweden, Thailand, India, Indonesia,

and Ukraine have fewer citations and documents, indicating lesser impact and fewer connections within the research network. Overall, the figure illustrates the prominent role of specific countries in AI and education research, emphasizing the interconnectedness and influence of their contributions.

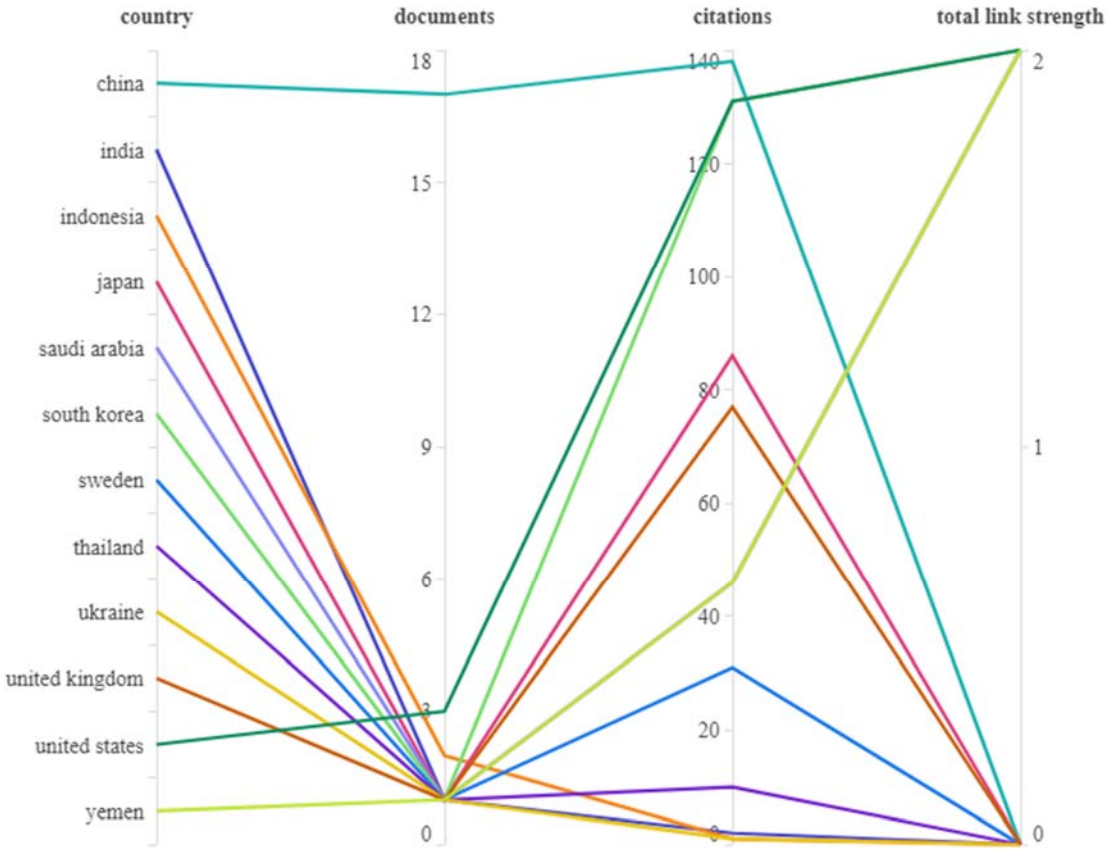

Figure 15. Relationship between documents, citations, and link strength by country in teachers' roles in artificial intelligence

4.4 Co-Authorship Analysis

Figure 16 illustrates a co-author network, depicting the collaboration between different researchers over time in the field of the role of teachers with AI. Each node represents an author, with the lines connecting them indicating co-authorship relationships. The size of the nodes and the thickness of the lines denote the frequency and strength of these collaborations. The color gradient, ranging from purple (representing older collaborations) to yellow (representing more recent collaborations), provides a temporal context. Authors such as Du Jing, Wu Libao, Zhang Yongjian, Jiang Mingxue, and Jiang Zheng are interconnected, indicating a closely-knit research network. This map highlights the active collaboration among these researchers and their joint contributions to the field, with varying degrees of recent and historical cooperation.

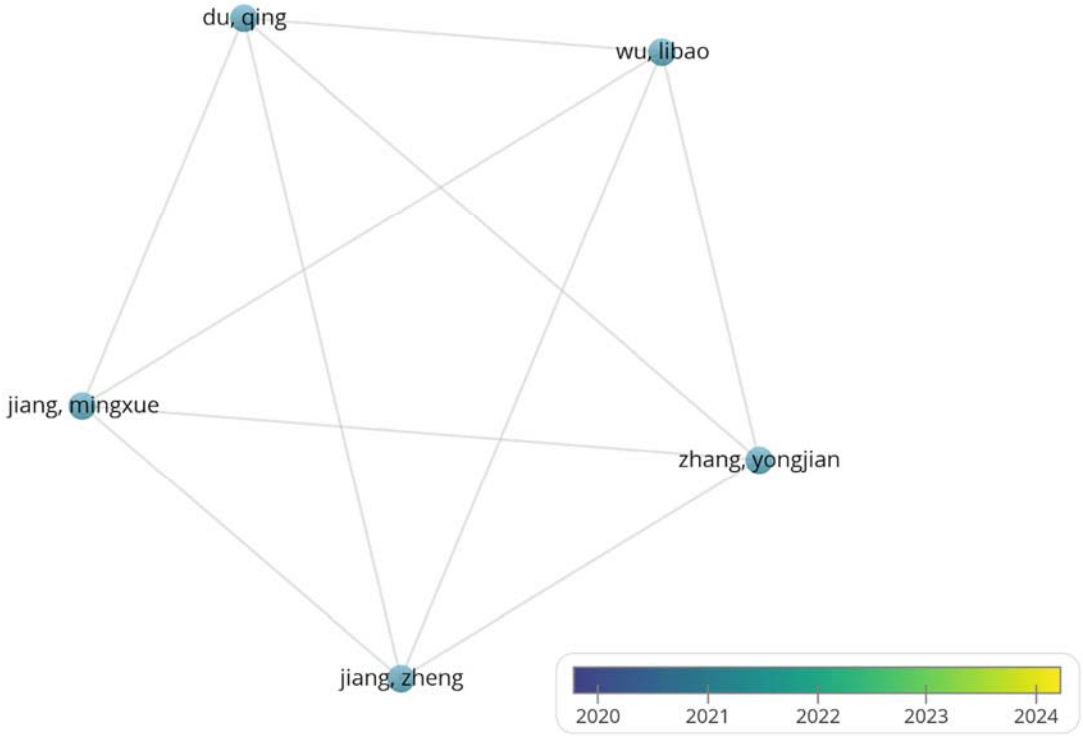

Figure 16. Co-author network

Table 10. Co-authors and their collaborative metrics

author	documents	citations	total link strength
du, qing	1	1	4
jiang, mingxue	1	1	4
jiang, zheng	1	1	4
wu, libao	1	1	4
zhang, yongjian	1	1	4

Table 10 provides an overview of the co-authors involved in a specific research study in the field of the role of teachers with AI, detailing the number of documents they have contributed to, the total number of citations received, and the total link strength, which indicates the degree of their collaborative connections. All listed authors—Du Qing, Jiang Mingxue, Jiang Zheng, Wu Libao, and Zhang Yongjian—have contributed to one document, received one citation, and possess a total link strength of 4. This indicates that these authors have a strong collaborative relationship, having worked closely together on the same research project. The uniformity in their link strength and citation count highlights these co-authors' equal contribution and interconnectedness within this study.

Figure 17 illustrates a co-organization network depicting the collaborative relationships between different institutions involved in the role of teachers with AI research. Each node represents an institution, with the size and color of the nodes indicating the volume and recency of their collaborative publications, respectively. The color gradient ranges from purple (indicating older collaborations) to yellow (indicating more recent collaborations). The institutions shown Faculty of Arts, PU, Amman, JO; University of Bisha; Hadhramout University; and Najran University—are interconnected, suggesting active collaboration in their research efforts. This network highlights the strong cooperative ties among these institutions, emphasizing their collective contribution to advancing research in AI and education.

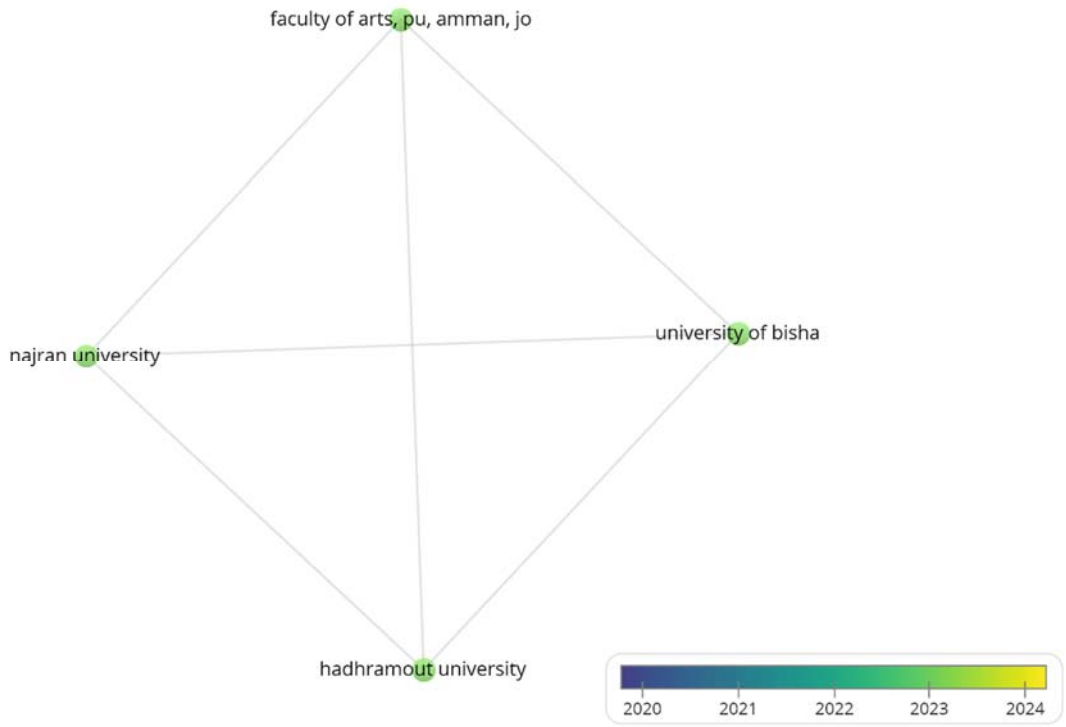

Figure 17. Co-organization network

Table 11. Co-organization network collaborative metrics

organization	documents	citations	total link strength
faculty of arts, pu, amman, jordan	1	46	3
hadhramout university	1	46	3
najran university	1	46	3
university of bisha	1	46	3

Table 11 provides an overview of the collaborative metrics within the co-organization network for research on the role of teachers with AI. Each listed organization Faculty of Arts, PU, Amman, Jordan; Hadhramout University; Najran University; and University of Bisha has contributed one document, each receiving 46 citations. The total link strength for all organizations is 3, indicating collaborative solid ties among these institutions. This uniformity in documents, citations, and link strength highlights an equally distributed and well-connected network of collaboration, suggesting that these institutions are actively working together and contributing significantly to the research field.

Figure 18 illustrates the co-country network for research on the role of teachers with AI, highlighting the collaborative relationships between different countries. Each node represents a country, with the size and color of the nodes indicating the volume and recency of their collaborative publications, respectively. The color gradient ranges from purple (indicating older collaborations) to yellow (indicating more recent collaborations). China is the central node, indicating its significant role and extensive collaborations with countries like Thailand, Japan, the United States, and South Korea. The connections suggest active international partnerships in AI and education research, emphasizing China's pivotal role in fostering global research collaborations. This network underscores the interconnected nature of research efforts, with China is a major hub for international academic partnerships.

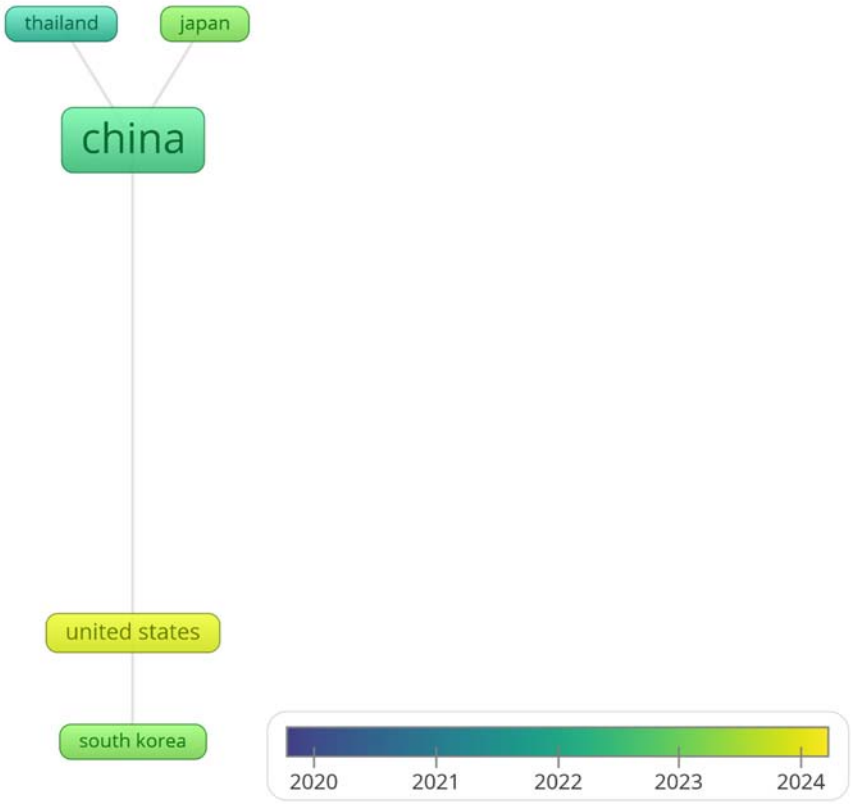

Figure 18. Co-country network

Table 12. Co-country network collaborative metrics

country	documents	citations	total link strength
china	17	138	3
united states	3	131	2
japan	1	86	1
south korea	1	131	1
thailand	1	10	1

Table 12 provides an overview of the collaborative metrics within the co-country network for the role of teachers with AI research, detailing the number of documents, citations, and total link strength for each country. China leads with 17 documents and 138 citations, demonstrating its extensive research output and strong collaborative presence, indicated by a total link strength of 3. The United States follows with 3 documents and 131 citations, and a total link strength of 2, highlighting its significant contributions and connections within the network. Japan, South Korea, and Thailand each have fewer documents and citations, with Japan and South Korea both having 1 document and a notable number of citations (86 and 131, respectively), reflecting influential but less extensive collaboration. Thailand, with 1 document and 10 citations, also shows some collaborative efforts, albeit to a lesser extent. This table underscores China's central role and extensive collaborations in the field, while also recognizing significant contributions from the United States, Japan, South Korea, and Thailand.

5. Discussion

The discussion section for this bibliometric study on teachers' roles in AI-enhanced education could be structured as follows:

This bibliometric analysis reveals significant trends in research on teachers' roles in AI-enhanced education from 2020 to 2024. The sharp increase in publications, peaking in 2023, indicates growing academic interest in this field (Sanabria-Navarro et al., 2023). China, the United States, and South Korea emerge as leading contributors, highlighting the global nature of this research area (Park et al., 2023).

The keyword analysis emphasizes the centrality of "artificial intelligence" and "teacher" in the discourse, reflecting

the focus on AI's impact on educators' roles (Chiu et al., 2023). The prominence of terms like "integration" and "transformation" suggests a shift in how AI is perceived in education—from a supplementary tool to a transformative force.

Citation network analysis reveals influential works shaping the field, with recent publications garnering significant attention. This suggests rapid evolution in research, driven by technological advancements and changing educational paradigms (Barrett & Pack, 2023).

The co-authorship and organizational network analyses indicate strong collaborative ties, particularly among institutions in China and the United States. This international collaboration is crucial for addressing the global challenges and opportunities presented by AI in education.

These findings underscore the need for continued research on AI's impact on teaching roles, emphasizing the importance of interdisciplinary approaches and international cooperation in navigating the future of AI-enhanced education.

6. Conclusion

This bibliometric analysis provides valuable insights into the evolving research landscape on teachers' roles in AI-enhanced education from 2020 to 2024. The study reveals a significant surge in publications, peaking in 2023, indicating this field's growing academic interest and relevance (Sanabria-Navarro et al., 2023).

The research questions posed at the outset have been addressed comprehensively:

1) Publication trends show a marked increase from 2 publications in 2020 to 25 in 2023, with a projected 18 in 2024, demonstrating rapidly growing interest in this area.

2) China, the United States, and South Korea emerge as leading contributors, highlighting the global nature of this research area. However, the analysis also reveals contributions from a diverse range of countries, indicating the worldwide relevance of this topic.

3) Key themes identified include the integration of AI in teaching practices, transforming teachers' roles, and the potential of AI for personalized learning. The prominence of terms like "integration" and "transformation" in the keyword analysis suggests a shift in perceiving AI as a supplementary tool to a transformative force in education.

4) International collaboration is evident, with strong ties between institutions in China, the United States, and other countries, fostering a global approach to addressing AI in education. This collaborative nature is crucial for addressing the complex challenges and opportunities presented by AI in educational settings.

5) The most influential publications, such as those by Jeon (2023) and Chiu (2023), have significantly shaped the discourse on teachers' roles in AI-enhanced education, indicating rapid evolution in the field driven by technological advancements and changing educational paradigms.

These findings underscore the rapid evolution of AI in education and its impact on teaching roles. The research's interdisciplinary nature, spanning education, computer science, and other fields, reflects AI's complex challenges and opportunities in educational settings.

As the field continues to develop, there is a clear need for ongoing research, international collaboration, and interdisciplinary approaches to fully understand and optimize the role of teachers in AI-enhanced education. Future research should focus on creating AI systems that complement and enhance human teaching rather than replacing it entirely while addressing ethical considerations and potential educational inequalities.

This study provides a foundation for educators, policymakers, and researchers to navigate the future of education in an AI-enhanced world, emphasizing the importance of balancing technological possibilities with the irreplaceable human aspects of learning.

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Authors' contributions

Sutidan Phonrawatjaradwat was responsible for the conceptualization, methodology, formal analysis, writing-original draft preparation, writing-reviewing, editing preparation for creating the published work, project administration, and funding acquisition. Teeramate Jirawutthipan and Assistant Professor Dr. Thada Jantakoon supervised the conceptualization, methodology, validation, investigation, writing review, and editing preparation. All authors read and approved the final manuscript.

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Competing interests

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

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Obtained.

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The Publication Ethics Committee of the Canadian Center of Science and Education.

The journal's policies adhere to the Core Practices established by the Committee on Publication Ethics (COPE).

Provenance and peer review

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Data availability statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

Data sharing statement

No additional data are available.

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