

Article | Received 20 February 2026; Revised 13 March 2026; Accepted 18 March 2026; Published 17 September 2026
<https://doi.org/10.55092/phess20260002>

Hotspots and trends in interdisciplinary research in artificial intelligence education—based on bibliometric analysis

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Abstract: Artificial Intelligence has triggered a new research boom, and Artificial Intelligence education and interdisciplinary integration have become new trends in educational development. To identify the current research status and development status of Artificial Intelligence education in interdisciplinary fields, 760 journal articles published from 2017 to 2024 from the WoS Core Collection were selected as research objects, and knowledge mining and analysis were conducted to explore the current research status and content evolution of this field through visual analysis. Using bibliometrics, the software Cooc14.9 and VOSviewer were used to map the relevant knowledge on the number of publications, research institutions, authors, interdisciplinary research, and keywords in this field, and to analyse its research hotspots and development trends. The results show that research in the field of interdisciplinary integration of Artificial Intelligence education is currently in a stage of rapid development, but cooperation between research fields is relatively weak and interdisciplinary research is insufficient. Research hotspots mainly focus on Artificial Intelligence, Machine Learning, Interdisciplinary, and Deep Learning. Research frontiers mainly focus on Embedded Ethics, Large Language Models, ChatGPT, and Generative Artificial Intelligence. Based on the above analysis of the results, the article proposes a future outlook of the field from three aspects to understand the latest research trends and future development directions.

Keywords: artificial intelligence; artificial intelligence education; interdisciplinary; bibliometrics.

1. Introduction

In today's era of rapid technological development, a new generation of Artificial Intelligence technology is booming and gradually becoming an important driving force for a new round of technological and industrial revolutions. It not only integrates a set of emerging technologies such as the internet of things, big data, blockchain, cloud universes, and 5G technology, but also integrates knowledge from several



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interdisciplinary fields such as computer science, engineering, mathematics, and programming. Since the concept of “Artificial Intelligence” first appeared at the Dartmouth Conference in 1956, the theories and principles of Artificial Intelligence have attracted the attention of many scholars. With the continuous development and gradual maturity of computer technology, Artificial Intelligence, as a branch of computer science, is gradually becoming the focus of change in various industries around the world. To better advance Artificial Intelligence to a new stage, at the end of 2022, Open AI officially launched the ChatGPT large language model, which can learn and understand human language and engage in conversations. In 2023, the multimodal ChatGPT can more accurately solve user problems. At the same time, Musk’s brain–computer interface company implanted a chip into a human brain for the first time in early 2024. In February of the same year, Open AI officially released the Vincent video model Sora. This series of events shows that Artificial Intelligence is becoming integrated into our lives. With the advent of Industry 4.0, AI is increasingly being applied to various important fields, including social sciences [1], generative applications [2], cultural preferences [3], education [4], and distributed learning environments [5]. The field of AI education covers a wide range of complex content and is deeply integrated with many other disciplines. It is necessary to sort out its research content.

Bibliometrics, as a research method, uses mathematical and statistical tools in combination with the specific characteristics of literature to quantitatively describe, evaluate, and predict the progress, results, and trends in a given field of research and to infer future research trends accordingly. At present, some researchers have used bibliometric software to systematically organize and analyze the research progress and development trends in the field of Artificial Intelligence. For example, Wang [6] from the perspective of algorithmic principles, combined the development of Artificial Intelligence with existing research results to provide an overview and outlook on the future direction of Artificial Intelligence. Mahligawati [7] from the perspective of physical education, provided a comprehensive and detailed overview of the field of Artificial Intelligence. Gao [8] has systematically analysed the evolution of Artificial Intelligence over the past two decades from a bibliometric perspective. It has been found that existing research has focused on bibliometric analysis and future trend prediction for the development of artificial intelligence, while lacking an in–depth analysis of the interdisciplinary development process, status quo, hotspots, and development trends of AI education. There is an urgent need to conduct bibliometric analysis of scientific literature in this research field. Therefore, in order to comprehensively and systematically understand the current research status, hotspots and trends of the interdisciplinary integration of AI education, and to show the broad panorama of this field, this paper systematically sorts and analyzes the literature published in recent years in this field from the perspective of bibliometric analysis, with the aim of providing a certain reference for in–depth research on the interdisciplinary integration of AI education.

2. Data sources and preprocessing

To ensure that the data collected is representative and authoritative, the Web of Science Core Collection databases SCI–E and SSCI were used as data sources, and the search type was set to “advanced search + exact search”. The search topic was (((TS = (“Artificial Intelligence”)) OR TS = (“AI”)) OR TS = (“artificial intelligence education”)) AND TS = (“Interdisciplinary”). Document type and language were set to articles and English respectively. During the literature search, it was found that the literature on AI education has only entered a period of significant growth since 2017. Therefore,

the time period was limited to 2017–01–01–2024–11–01. The search date for this study was 1 November 2024, and a total of 801 articles were retrieved. By using Cooc14.9 software to clean and deduplicate the data in the literature, mainly for missing keywords, missing authors, removal of conference announcements, withdrawn publications, *etc.*, 760 articles were finally obtained as the sample source for this study.

3. Research tools and methods

Bibliometrics is a quantitative method of analysis based on data and information. It aims to visualize data using mathematical and statistical methods in order to reveal the latest developments, hot topics and trends in a field of research. Currently, the most commonly used visualization tools for bibliometric analysis include Citespace and VOSviewer. CiteSpace is typically used to analyze data on keywords, authors, countries, institutions and subject categories in a large number of related documents in order to predict new trends in research fields. VOSviewer is software that uses bibliographic data to create maps of institutional, author and country collaborations or keyword co-occurrences. Co-occurrence (Cooc14.9 for short) is an emerging bibliometric software that provides a useful complement to the analysis results of VOSviewer and CiteSpace by providing additional dimensions of measurement. The software can customize data cleaning and deduplication, co-occurrence matrices, multidimensional relationship construction and transformation, biclustering, system clustering, hotspot tracking, centrality metrics and network topology metrics that cannot be directly implemented in VOSviewer or CiteSpace. In this paper, firstly, Cooc14.9 was used to clean, deduplicate and merge synonyms of the collected data, and then the main countries, high-yielding institutions, institutional collaborations and author collaborations in the research on interdisciplinary integration of AI education were statistically analysed to analyse the current status of research on interdisciplinary integration of AI education. Second, a keyword cluster analysis was performed using Cooc14.9 and VOSviewer to explore research hotspots in the interdisciplinary integration of AI education. Finally, a cumulative keyword map of interdisciplinary integration research in AI education was created to explore the evolution of interdisciplinary integration in AI education.

4. Current status of interdisciplinary research in AI education

4.1. Annual volume of documents issued

First, the bibliometric software Cooc14.9 was used to perform a descriptive statistical analysis of the volume of literature in the interdisciplinary field of AI education. Second, the software was used to plot a time series distribution of the literature, as shown in 0. Between 2017 and 2024, the number of relevant research papers on interdisciplinary AI education increased by a factor of 21, showing an overall trend of rapid growth. This indicates that interdisciplinary AI education is in a period of rapid development and has great potential for growth. In recent years, countries have promulgated AI education policies accordingly. For example, China released the Core Framework of Youth AI Literacy and the AI Innovation Action Plan for Higher Education Institutions. The United States published the National Strategic Plan for Artificial Intelligence Research and Development and Artificial Intelligence and the Future of Teaching and Learning: Insights and Recommendations. And the UK published the National AI Strategy—AI Action Plan. The promulgation of a number of policies in different countries all point

to promoting the integration of AI education with STEAM education. This initiative has attracted a large number of scientists to participate in the field of AI education.

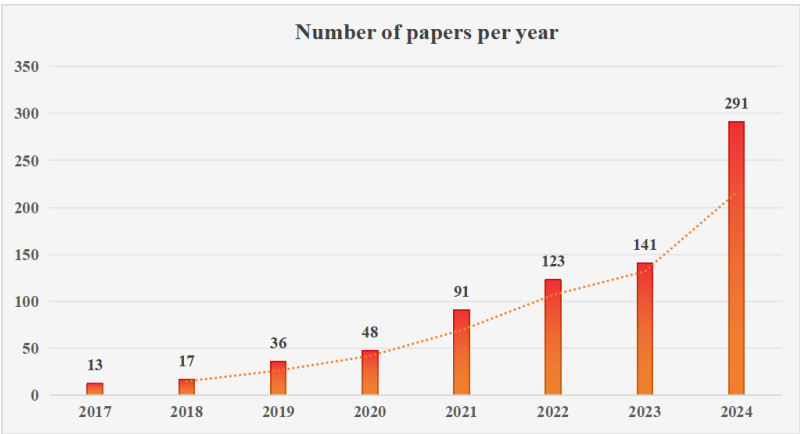


Figure 1. Annual and cumulative number of documents issued.

4.2. Analysis of issuing organizations and collaborative networks

A statistical analysis of the publishing institutions of authors in a field is useful for identifying the core groups in that field and the distribution of institutions. Figure 2 shows the top ten institutions that have published the most papers in the field of interdisciplinary integration of AI education. It can be seen that the institutions involved in interdisciplinary AI education are mostly well-known universities in different countries. Therefore, it is important to make full use of the research strength of universities in the future. As shown in the Figure 2, the Chinese Academy of Sciences has published the most papers (17), followed by the University of Oxford with 14 papers, Tsinghua University with 13 papers, Tech Univ Munich with 11 papers, Columbia Univ with 10 papers, and Univ Cambridge, Purdue Univ, Stanford Univ, Univ Illinois and Harvard Med Sch with 9 papers each. The United States is the country with the most publications, with 46 papers from 5 institutions. Two institutions in China and the United Kingdom published 30 and 23 papers respectively. One institution in Germany published 11 papers. Overall, the United States is the leader in research in this field, and although China ranks second in terms of total publications, its contribution to the field is very significant.

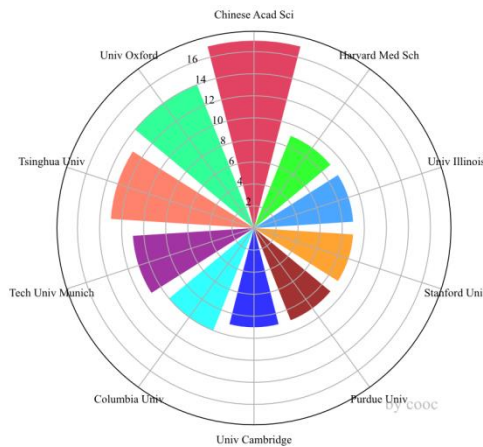


Figure 2. The top 10 institutions in terms of outgoing articles.

To further understand the close collaboration between institutions, a collaborative network map of interdisciplinary research in AI education was generated using the VOSviewer software, as shown in 0. The research institutions in Figure 3 form 10 major collaborative networks, centred on Tsinghua University, Univ Edinburgh, Univ Copenhagen, Columbia Univ, Charite Univ Med Berlin, Univ Cambridge, Univ Melbourne, Leiden Univ, Univ Texas Austin, and Swiss Fed Inst Technol. These collaborative networks are spread across the world, and there are also many inter-regional and inter-company collaborations, and institutions are closely linked. However, there is less cooperation between primary and secondary institutions, suggesting that the intensity of cooperation between scientific research institutions needs to be urgently improved.

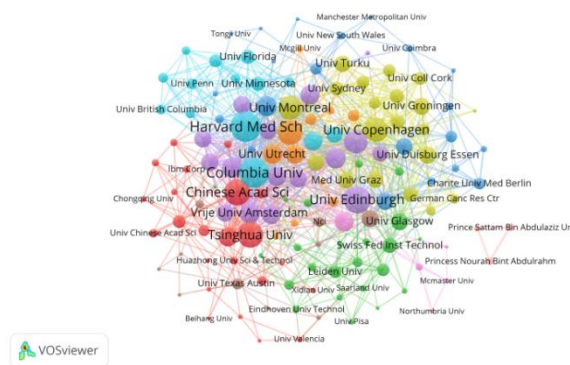


Figure 3. Institutional cooperation network.

4.3. Analysis of authors and collaboration networks

The number of publications by an author may to some extent reflect the author's degree of influence in the field. To explore the distribution of authors who conduct interdisciplinary research in the field of AI education, $M = 0.749\sqrt{N_{\max}}$ is calculated according to Price's theory $M \approx 2$, and the authors with no less than two articles are known as core authors. Due to the limited layout, this study used the bibliometric software Cooc14.9 to perform a descriptive statistical analysis of the author community. A mapping diagram was created for the author community with no less than 4 publications (0), with a total of 11 authors. Among them, the three authors Zhang, Liu and Wang are leading in terms of output and have published the largest number of articles. They are closely followed by Li, who has contributed 6 related studies. Although the remaining authors are also active, the number of published papers is relatively balanced, which shows that the field of interdisciplinary research on AI education has a wide range of authors.

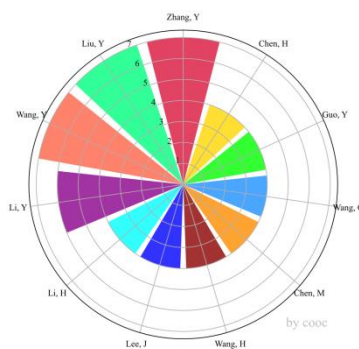


Figure 4. Top 10 authors in terms of number of publications.

Analysing the collaboration of authors in a field can help to track research trends and directions in that field [9]. To further understand the collaboration between interdisciplinary researchers in AI education, a co-occurrence analysis of authors was performed in conjunction with the VOSviewer software. The raw data generated by Cooc14.9 software is incompatible with the input format of the VOSviewer analysis tool and cannot be directly used for subsequent visualization analysis. To address this, the study first parses and reconstructs the co-occurrence matrix output by the software, converting it into adjacency list format. Subsequently, through format conversion processing, the adjacency list is further transformed into the “.net” format file supported by VOSviewer, laying the data foundation for subsequent analytical operations. The parameter was set to 2 to generate a collaboration network diagram of the authors, as shown in 0. The nodes in the figure represent authors, and the number of articles published by the author determines the size and font of the node. The connecting lines between the nodes indicate the existence of collaborative relationships between the nodes. In general, although the cooperation of authors in this field shows a large cluster distribution, there are not many authors in each cluster. Therefore, the cooperation between authors needs to be further strengthened.

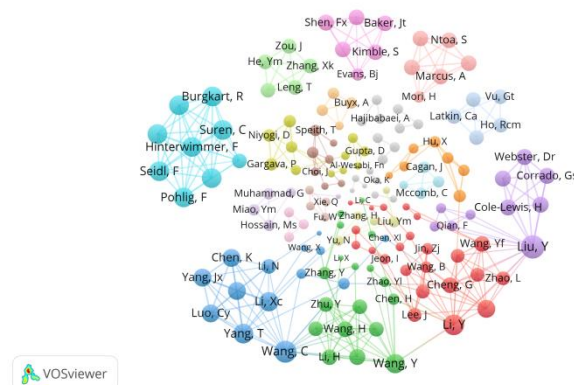


Figure 5. Author collaboration network co-occurrence.

4.4. Analysis of the volume of country publications and collaborative networks

The number of publications in a country reflects the level and impact of research in that country in that field. We counted the top ten most productive countries or regions and created a wind rose diagram, as shown in 0.

Among the 93 countries or regions, China (including Taiwan) published the most related papers (205), followed by the USA (193) and Germany (101). The rest of the rankings are England (87), Australia (48), Italy (46), the Netherlands and Canada each published 43 papers, and South Korea and India each published 37 papers. In terms of number of publications, China published twice as many articles as Germany, 2.4 times as many as England, 4.3 times as many as Australia, 4.5 times as many as Italy, 4.8 times as many as the Netherlands and Canada, and 5.5 times as many as South Korea and India. The United States is 2.2 times as large as England, 4 times as large as Australia, 4.2 times as large as Italy, 4.5 times as large as the Netherlands and Canada, and 5.2 times as large as South Korea and India. China, the United States and Germany account for more than 65.7% of the total publications in this field, which is a significant contribution to research in this field.

To explore the dynamics of collaboration between countries or regions in more depth, and to make the resulting map more intuitive and clearer, a collaboration network was constructed covering

54 countries or regions, with at least 3 papers published in the selected countries or regions, as shown in 0. In this network diagram, the size of the labels and lines visually reflects the number of publications and the strength of the collaboration, while different colours are used to distinguish the sub-networks of collaboration. The research results show that there is strong collaboration between countries in North America, Europe, Oceania and Asia. In contrast, there is relatively little collaboration between other countries or regions.

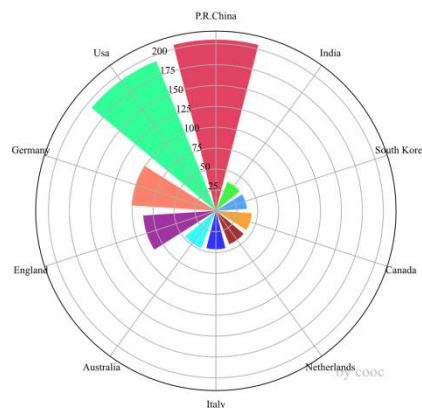


Figure 6. Top 10 countries in terms of outgoing articles.

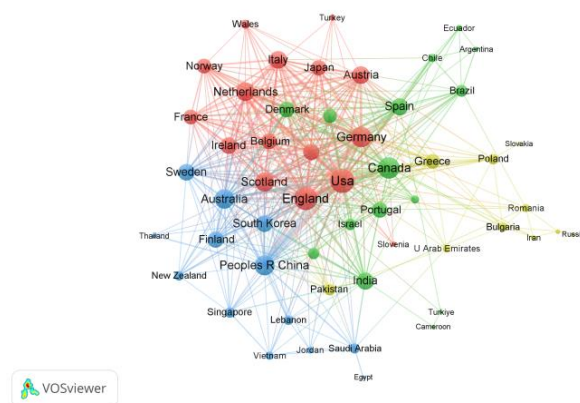


Figure 7. Country cooperation network.

4.5. Highly cited paper

The frequency with which an article is cited is an important indicator of its scholarly influence and informational value, and to some extent it can reveal the degree of recognition and attention it has received in the academic community. In this article, we have selected nine papers with a citation rate of more than 200 times from the 760 data sources collected between 2017 and 2024. The statistics are presented in Table 1. Among them, the article *Artificial Intelligence in Medicine*, published in *Metabolism–Clinical and Experimental* by Canadian scientists Hamet *et al.* [10], has been cited the most with 1120 times. This is followed by *Towards Spike–Based Machine Intelligence with Neuromorphic Computing*, published in *Nature* by American scientist Roy *et al.* [11], which has been cited 1059 times. The topics of these papers cover a wide range of fields, from medicine to computer engineering to marketing, reflecting the widespread interest and demand for research in these areas from both academia and industry. In particular, research on Explainable Artificial Intelligence (XAI), such as “What Do We

Want from Explainable Artificial Intelligence (XAI)?—A Stakeholder Perspective on XAI and a Conceptual Model Guiding Interdisciplinary XAI Research”, shows the importance attached to improving the transparency and interpretability of AI. In terms of geographical distribution, researchers from Canada, the United States and China have performed strongly in terms of producing highly cited papers, with multiple highly cited papers from authors in these countries. In contrast, Germany, Luxembourg, Japan and Vietnam have relatively low citation frequencies, but their contributions should not be overlooked.

Table 1. Articles cited at least 200 times.

Year	Title	First Author	Country or Region	Citation Frequency
2017	Artificial Intelligence in Medicine	Hamet	Canada	1120
2019	Towards Spike-Based Machine Intelligence with Neuromorphic Computing	Roy	Usa	1059
2020	Edge Intelligence: The Confluence of Edge Computing and Artificial Intelligence	Deng	P. R. China	531
2020	Transforming The Customer Experience Through New Technologies	Hoyer	Germany	363
2019	Combating Fake News: A Survey on Identification and Mitigation Techniques	Sharma	P. R. China	271
2018	From Hype to Reality: Data Science Enabling Personalized Medicine	Fröhlich	Luxembourg	252
2019	Seven Hci Grand Challenges	Stephanidis	Japan	252
2021	What Do We Want from Explainable Artificial Intelligence (XAI)?—A Stakeholder Perspective on XAI And a Conceptual Model Guiding Interdisciplinary XAI Research	Langer	P. R. China	225
2022	Digital Twins: A Survey on Enabling Technologies, Challenges, Trends and Future Prospects	Mihai	Vietnam	208

4.6. Interdisciplinary network construction

An in-depth analysis of the subject can help to gain insight into whether comprehensive research has been conducted in related fields. In order to comprehensively and systematically explore the subject ecology of AI education as an interdisciplinary field, the data was converted using Cooc14.9 software, and the results were imported into VOSviewer visualisation analysis software to construct an interdisciplinary relationship network map of AI education, as shown in 0. There are 12 subject clusters and 216 link lines in Figure 8, with a total link strength of 783. The largest cluster can reach up to 15 subjects. Explanation: The interdisciplinary network of AI education involves a wide range of subjects and contents, and the subject relationship network is also loose as a whole, while the internal cooperation is relatively sophisticated. Therefore, it is necessary to strengthen interdisciplinary exchanges and cooperation, and deepen interdisciplinary research in AI education. Intuitively, Computer Science, Engineering, Social Sciences, Materials Science, and Science & Technology all occupy a pivotal position. These disciplines combine and promote each other in terms of knowledge input and output, achieving a mutually beneficial and win-win situation. At the same time, they have reached a certain scale in terms of the breadth and depth of interdisciplinary fields, demonstrating strong integration and influence.

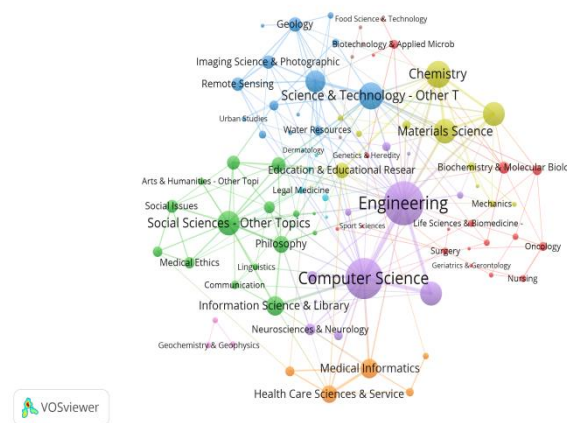


Figure 8. Interdisciplinary network map of AI education.

5. Analysis of interdisciplinary research hotspots in AI education

5.1. Keyword frequency statistics and difference matrix

The frequency of occurrence of keywords is an important indicator in this area. Keywords were extracted from 760 literature sources using Cooc14.9 software, resulting in a total of 4704 keywords. By counting the total frequency of these keywords, it was found that 92 keywords appeared at least 4 times, while 14 keywords appeared 10 times or more. The specific statistical results are shown in Table 2. AI is currently a popular field of research, and the number of mentions of the related keyword “AI” far exceeds that of other keywords, indicating a high level of attention in this field. Other keywords such as “Machine Learning” and “Deep Learning” also show a high level of attention, which may be related to technological progress and the expansion of applications in the field of AI. The distribution of keyword mentions indicates the current research hotspots and trends in academia, which is important for selecting research directions and allocating research resources. It is worth noting that these 14 high–frequency keywords account for 60% of the total number of 92 keywords. These data show that scholars’ research work on AI education and interdisciplinary integration is relatively concentrated and in–depth.

Table 2. High–frequency keywords with a frequency of at least 10

NO.	Keyword	Publication	NO.	Keyword	Publication
1	Artificial Intelligence	310	8	Natural Language Processing	13
2	Machine Learning	101	9	Sustainability	12
3	Interdisciplinary	58	10	Technology	12
4	Deep Learning	33	11	Explainable Artificial Intelligence	11
5	Ethics	24	12	Ai Ethics	11
6	Bibliometric Analysis	17	13	Chatgpt	10
7	Big Data	15	14	Citespace	10

For the above AI training interdisciplinary integration research of 14 high–frequency keyword pair statistics, first build 14×14 keywords co–occurrence matrix, second into complete co–occurrence matrix, because the following system clustering analysis of keywords, so need to complete co–occurrence matrix into phase difference matrix or cosine matrix or similarity matrix. To reduce the error and make it better for systematic clustering, this paper decided to adopt the phase difference matrix, by calculating the Ochiai coefficient, the formula for calculating it is:

$$Ochiai = \frac{n(A \cap B)}{\sqrt{n(A) \times n(B)}} \quad (1)$$

$$DissimilarityMatrix = 1 - \frac{n(A \cap B)}{\sqrt{n(A) \times n(B)}} \quad (2)$$

Where $n(A)$ is the number of occurrence of keyword A; $n(B)$ is the number of occurrences of keyword B; $n(A \cap B)$ is the number of occurrences of words A, A and B as shown in Table 3.

Table 3. Divergence matrix of high frequency keywords.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	0													
2	0.627	0												
3	0.828	0.935	0											
4	0.891	0.827	0.977	0										
5	0.826	0.838	0.946	0.965	0									
6	0.862	0.903	1	1	1	0								
7	0.809	0.897	1	1	0.947	1	0							
8	0.890	0.945	1	0.952	0.887	1	0.928	0						
9	0.902	1	0.962	1	1	1	1	1	0					
10	0.934	0.971	0.962	1	0.941	1	1	0.920	1	0				
11	0.932	0.910	0.921	1	0.938	1	1	1	1	0.913	0			
12	0.932	0.970	0.881	1	1	1	1	1	1	1	1	0		
13	0.946	1	1	1	1	0.923	1	1	1	1	1	1	0	
14	0.874	0.906	0.958	1	1	0.923	0.918	1	1	1	1	1	1	0

5.2. Systematic cluster analysis

Clustering is the process of classifying data into different classes or clusters. Objects in the same cluster are very similar, while objects in different clusters are very different. The research first used Cooc14.9 software to construct 14×14 high-frequency keyword dissimilarity matrix data and then imported the resulting dissimilarity matrix data into the cluster analysis system to obtain a cluster tree map, as shown in Figure 9. As can be seen in 0, research on the interdisciplinary integration of AI education focuses on four research topics: AI ethics and interdisciplinarity, Citespace and bibliometric analysis, explicable AI and ethics, and ChatGPT and machine learning. To ensure the objectivity of the naming process for each group, we introduced the "cohesion force" indicator, which quantifies the importance of keywords to the group. A higher cohesion force indicates that the keyword is more central to the group. The formula is

$$N(A_i) = \frac{1}{n-1} \times \sum_{j=1}^{n \neq i} F(A_i \rightarrow B_j) \quad (3)$$

Where B_j is a keyword in the group that is different from keyword A_i . i, j denotes a node. These four themes are discussed in detail below.

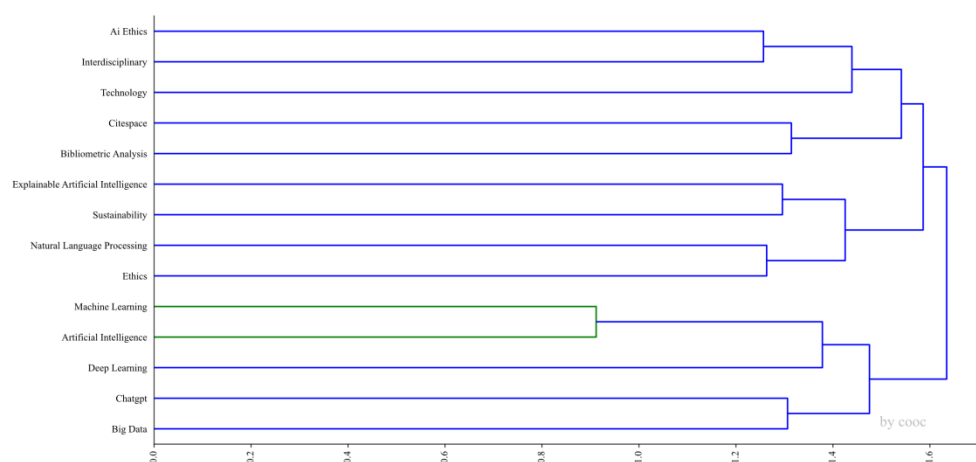


Figure 9. Keyword cluster analysis tree.

5.2.1. AI ethics and interdisciplinary

With the rapid development of artificial intelligence technology, its application in various fields is becoming increasingly widespread and has had a profound impact on human society. However, the widespread use of AI has also raised several ethical issues [12], such as the invasion and protection of personal privacy [13], algorithmic bias and identity discrimination [14], transparency and interpretability of decision-making processes [15], *etc.* These issues concern not only personal privacy and rights and interests, but also the responsibilities of companies and society, as well as the constraints and guidelines for the development of artificial intelligence. The ethics of artificial intelligence is an interdisciplinary field of study that combines knowledge and methods from various disciplines such as computer science, mathematics, psychology, philosophy, ethics and law [16]. Interdisciplinary thematic learning is an effective way of learning that helps us integrate knowledge and methods from different disciplines and gain a more comprehensive understanding of the complex issues in the ethics of artificial intelligence. In the future, with the continuous development of AI technology and the expansion of application areas, the study of AI ethics will become deeper and more comprehensive. We must continue to pay attention to the practice and application of interdisciplinary thematic learning in AI ethics, and continue to promote the rational application and development of AI technology. At the same time, we must also strengthen interdisciplinary exchanges and cooperation to jointly respond to the ethical challenges posed by AI.

5.2.2. Citespace and bibliometric analysis

At present, many scholars have used bibliometrics to comprehensively analyse the relevant literature in the field of artificial intelligence, and they have each chosen different perspectives for in-depth exploration. For example, Pattnaik *et al.* [17] used bibliometrics to review the application of artificial intelligence and machine learning in the financial industry and identified nine core research clusters, including financial technology and risk management, using N-gram analysis and co-occurrence analysis techniques. González-Sarmiento *et al.* [18] conducted a bibliometric study on big data and artificial intelligence in the context of Industry 4.0, highlighting its important position in the new digital era. Furthermore, Nair *et al.* [19] also used bibliometrics to systematically review and analyse literature in the field of finance, covering topics such as machine learning, artificial intelligence and deep learning.

These articles provide an overview of the overall development of the field of artificial intelligence and help to identify research trends in the application of AI.

5.2.3. Explainable artificial intelligence and ethics

The concept of Explainable Artificial Intelligence (XAI) has gained considerable attention in recent years, with a focus on developing AI systems that can be interpreted and understood by humans [20]. XAI methods have been developed to address the need for clear and transparent explanations from AI systems [21]. Stakeholders in various fields, including healthcare, are demanding explanations from AI systems for ethical and transparency reasons. XAI plays a critical role in addressing ethical concerns related to generative AI and machine learning models. By providing clear explanations, XAI can help mitigate issues of bias, fairness, transparency, privacy and accountability in AI systems [22]. The ability of AI systems to provide clear and understandable explanations is essential for improving human decision-making processes. Overall, the XAI movement aims to bridge the gap between AI systems and human understanding, with a focus on ethics and transparency [23]. The research fields of AI ethics and XAI are interrelated, with the common goal of developing AI systems that are responsible, fair and accountable. As XAI develops, it is essential to consider the ethical implications of AI systems and to prioritise transparency and interpretability in AI development [24].

5.2.4. AI education application

The concept of artificial intelligence can be traced back to the 1950s, when British scientist Alan Turing proposed the famous Turing Test to determine whether a machine is intelligent. With the increase in computing power and the rise of big data, machine learning and artificial intelligence have become deeply integrated. Their emergence has produced remarkable results in all areas of human activity. In the field of science education, the integration of artificial intelligence and machine learning technologies can provide students with tailored learning experiences, teachers with instant adaptive feedback and innovative teaching strategies, and deep insights through data analysis. This integration greatly promotes interactive and personalised learning of science content, opening up a new realm of educational experiences [25]. Especially at the beginning of the 21st century, the rise of deep learning (DL) has further promoted this integration process. As a result, deep learning algorithms have been widely used in fields such as image recognition, speech recognition, and natural language processing [26]. In recent years, the popularity of generative AI tools such as ChatGPT has reignited the popularity of instant question-and-answer and writing assistance features to help students solve maths problems more efficiently. Some universities have begun to experiment with integrating ChatGPT into the classroom, for example, using it to generate cases and discussions in class to stimulate students' interest in learning and critical thinking. At the same time, teachers have also begun to use ChatGPT for course design and assessment, optimising teaching content and methods through AI feedback to achieve continuous improvement in teaching quality.

5.3. *Keyword cumulative evolution trend analysis*

To clarify the evolution trend of AI education in interdisciplinary fields, this paper draws a cumulative time zone map of keywords with the help of Cooc14.9 software, as shown in 0.

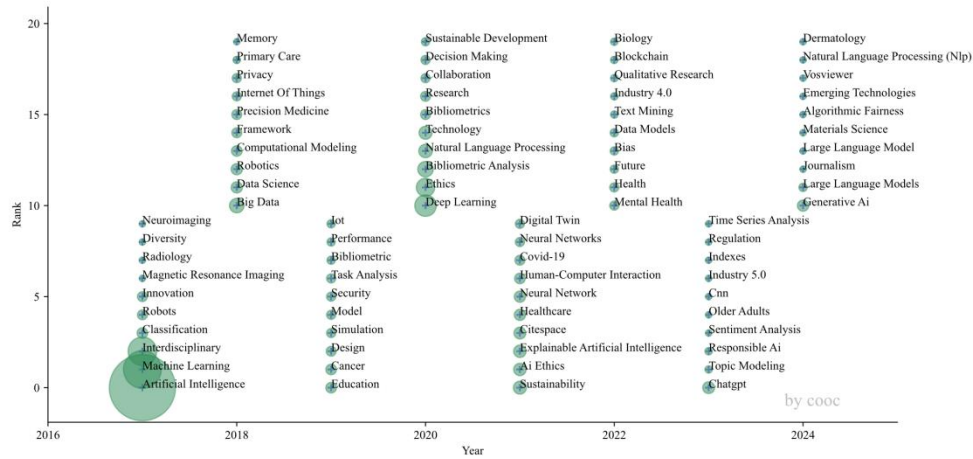


Figure 10. Cumulative keyword trends over time.

This helps scholars to understand the evolution path of keywords in different periods from a temporal dimension. Each node in the figure represents a keyword collected for the first time in that year. The frequency of keywords in subsequent years is accumulated from the first occurrence. The larger the node, the higher the frequency of the keyword. Figure 10 shows the evolution of research topics in AI education in interdisciplinary fields over time. In order to identify the research hotspots in this field, the subject-weighted evolution path is calculated. The formula is as follows:

$$color = \frac{\sum_i year_i \times count_i}{\sum_i counts_i} \quad (4)$$

Where $year_i$ is the year in which the keyword appears; $count_i$ is the frequency with which the keyword appears? i represents the keyword number. Finally, the research hotspots in recent years are Artificial Intelligence, Machine Learning, Interdisciplinary and Deep Learning.

5.4. Frontiers of interdisciplinary research in AI education

A sudden word refers to a keyword that suddenly appears at a certain time and shows a sharp upward trend in terms of attention. By using the Cooc14.9 software to perform mutation detection on interdisciplinary keywords in AI education, future research frontiers of interdisciplinary AI education can be detected. The calculation formula is as follows:

$$P_j(t) = \frac{freq(t, \omega_i) - freq(t - \Delta t, \omega_i)}{freq(t - \Delta t, all)} \quad (5)$$

Where $P_j(t)$ represents the relative frequency mutation rate of t keyword ω_i versus all other words at the time point. $freq(t, \omega_i)$ shows the frequency of the t keyword ω_i at the time point. $freq(t - \Delta t, \omega_i)$ indicates the frequency of $t - \Delta t$ keyword ω_i at the time point. $freq(t - \Delta t, all)$ represents the sum of the occurrence frequency of all keywords at the time point $t - \Delta t$. Δt represents the time window used to compare the frequency changes of keyword ω_i between time points t and $t - \Delta t$. The subscript i denotes “the i -th keyword,” while j represents the auxiliary index, which can be understood as “the mutation rate entry corresponding to that keyword.”

0 shows the 15 emerging terms in interdisciplinary AI education, namely AI in 2017, Model in 2019–2020, Ethics and Natural Language Processing in 2020, Big Data in 2020–2021, Biology and

Digital Technologies, Design, Embedded Ethics and CNN in 2023, Bibliometric Analysis, Large Language Models, Natural Language Processing, Chatgpt, Generative AI in 2024. The current research frontiers are Embedded Ethics, Large Language Models, Natural Language Processing, Chatgpt, and Generative AI.

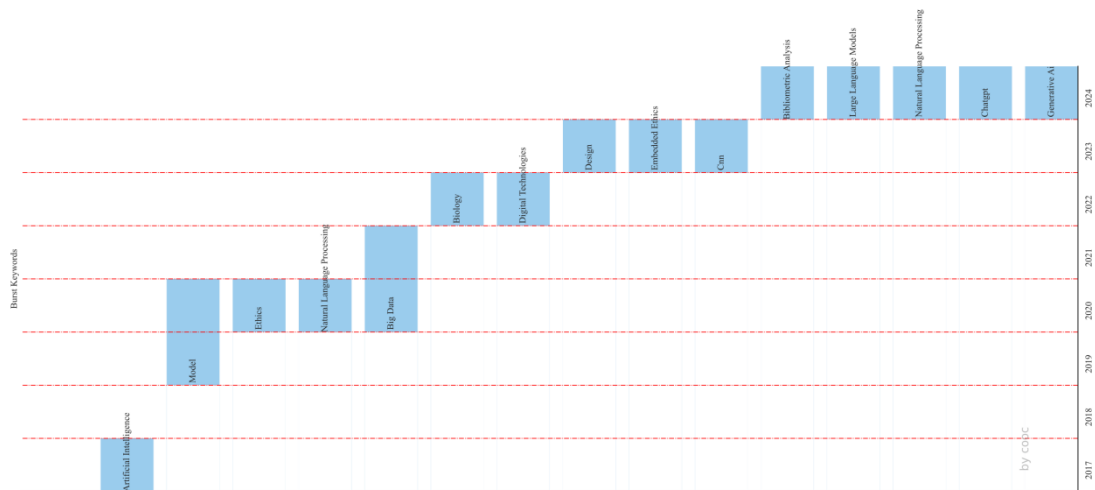


Figure 11. Keywords Frontier 2017–2024.

6. Conclusion and prospects

6.1. Conclusion and deficiencies

This study first conducts descriptive statistics and constructs network maps and visual analysis based on annual publication volume, institutional publication volume, national publication volume, author publication volume, and their collaborative co–occurrence. Judging from the annual publication volume, the literature related to the interdisciplinary field of AI education has shown an upward trend in recent years, covering various aspects from basic theory to practical application, indicating that research in this field is currently deepening and expanding. In the future, with the continuous advancement of technology and the strengthening of interdisciplinary cooperation, research in this field is expected to achieve even more fruitful results. In terms of the number of papers published by countries and institutions, China (including Taiwan) published the most relevant papers (205), followed by the United States (193) and Germany (101) in third place. However, when looking at institutions, the top ten institutions in terms of number of publications include five institutions from the United States with a total of 46 papers, indicating that the United States is the leader in this field. China, on the other hand, has only two institutions, the Chinese Academy of Sciences and Tsinghua University, with a total of 30 publications. Although China ranks second in terms of publications, its contribution to the field is very significant. Although institutions in different countries are closely linked, the interdisciplinary integration of AI education in different institutions in different countries needs to be further strengthened. In terms of the number of papers published by the authors, the highest number of published papers was 7, and the network of author partnerships formed 15 clusters. There are relatively few authors in each cluster, and if the clusters are to become larger, contacts need to be further strengthened.

Second, from the perspective of highly cited articles and interdisciplinary network building. The most highly cited article is AI In Medicine, published in 2017 by scholar Hamet, which has been cited 1120 times.

The interdisciplinary network reaches 12 disciplinary groups, but the disciplinary relationship network is generally loose, with relatively precise internal collaboration. In the future, it is necessary to strengthen interdisciplinary exchanges and cooperation, and deepen interdisciplinary research in AI education.

From the distribution of keywords, including the statistics of high-frequency keywords and the construction of a dissimilarity matrix to lay the groundwork for system clustering. The article first describes the statistics of keywords that appear at least 10 times, finding a total of 14 high-frequency keywords that are the current research hotspots. These keywords have a certain guiding significance for the choice of research directions and the allocation of research resources. By constructing a 14×14 dissimilarity matrix for the high-frequency keywords, it is found that the values in the dissimilarity matrix are between 0 and 1, and most of the values are close to 1, indicating that the analysed objects have a high degree of similarity or consistency. Using the dissimilarity matrix, a cluster analysis of the keywords was carried out, which ultimately resulted in the formation of four thematic clusters.

Finally, an evolutionary trend analysis of the interdisciplinary integration of AI education was conducted in conjunction with the Cooc14.9 software, and it was concluded that the current research frontiers are embedded ethics, large language models, natural language processing, chatgpt, and generative AI. This reflects the latest developments and trends in AI and related technologies, predicted future directions of development and application prospects.

Of course, there are some shortcomings in this study, for example, we only selected the Web of Science database and ignored the data sources of other databases when selecting data. Meanwhile, the keyword co-occurrence analysis may miss important but rare research directions. Therefore, we will further expand the database sources in future research to ensure better research conclusions. It is necessary to incorporate the manual identification of important and infrequent keywords into the keyword co-occurrence analysis to ensure that it is combined with the tool.

6.2. Future prospects

With the continuous development of AI technology and the continuous promotion of educational reform, the interdisciplinary integration of AI education has broad development prospects and research space in the future. The following is an outlook on future research directions:

6.2.1. Deepening the construction of interdisciplinary curriculum systems

In future research, the interdisciplinary curriculum system should be further deepened. On the one hand, the deep integration of different disciplines should be strengthened, not just a simple overlapping of knowledge, but an organic integration and innovation of knowledge. On the other hand, the curriculum content should be constantly updated and improved to keep pace with the development of artificial intelligence technology. With the continuous innovation of AI technology, new application scenarios and problems are constantly emerging. The interdisciplinary curriculum system should incorporate these new contents in a timely manner so that students can be exposed to cutting-edge knowledge and technology.

6.2.2. Improving teachers' ability to teach across disciplines

Teachers are one of the key factors in the interdisciplinary integration of AI education. Future research should focus on how to improve teachers' interdisciplinary teaching skills. On the one hand, teacher

training and professional development should be strengthened, and more interdisciplinary training opportunities and resources should be made available to teachers. On the other hand, teacher incentive mechanisms should be established to encourage teachers to actively participate in interdisciplinary teaching reform and innovation. This can be done by establishing teaching awards and providing research funding to motivate teachers to continuously explore and innovate interdisciplinary teaching methods and to improve the quality and effectiveness of teaching.

6.2.3. Focus on building an evaluation system for interdisciplinary education

Establishing a scientific and reasonable evaluation system is an important means of ensuring the quality of interdisciplinary integration in AI education. Future research should focus on building an evaluation system for interdisciplinary education, and explore evaluation methods and indicators that are suitable for the characteristics of interdisciplinary education. On the one hand, it is necessary to focus on the evaluation of students' comprehensive ability and innovative ability, not only focusing on the degree of knowledge mastery, but also evaluating students' problem-solving ability, teamwork ability, innovative thinking ability, *etc.* On the other hand, it is necessary to strengthen the evaluation of teachers' teaching effectiveness, establish a feedback mechanism for teachers' teaching quality, keep abreast of teachers' teaching situation and existing problems, and provide teachers with suggestions and support to improve teaching.

Declaration of generative AI and AI-assisted technologies

During the preparation of this manuscript, the authors used Grammarly tools only to improve language and readability. The authors take full responsibility for the content of the manuscript.

Acknowledgments

This work was supported by the Guizhou Province Education Science Planning Project under grant Nos. (2023B036, 2024B062), the Qianan Education Science Planning Project under grant under grant Nos. (2023B044, 2023B005, 2023B007)

Authors' contribution

L.H. performed the data collection and analysis and completed the article. J.Z. proposed the structure of the study. Q.P., T.H. and D.W. were responsible for the language work and proofreading the article as well as making some good suggestions. All authors have read and agreed to the published version of the manuscript.

Conflicts of interests

The authors declare no conflict of interest.

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