



Knowledge Dynamics in AI-Driven Natural Science Research: A Bibliometric Review Using VOSviewer

Babawande Emmanuel Olawale

Department of Curriculum and Institutional Studies, University of South Africa, South Africa

*Correspondence Author: beolawale@outlook.com

ABSTRACT

This study examines how artificial intelligence is reshaping knowledge production within the natural sciences. It maps research growth, collaborative structures, and thematic developments to clarify how AI-driven methods are being adopted across global scientific communities. A bibliometric review was conducted using data from Scopus-indexed publications from 2020 to 2025. The quantitative bibliometric approach was employed to examine the structural, thematic, and collaborative aspects of AI-driven research within the natural sciences, combining performance analysis to evaluate publication output, citation impact, and productivity trends with science mapping using VOSviewer to visualise co-authorship networks, keyword co-occurrences, and co-citation relationships. For this review, the Boolean search query that was employed includes "artificial intelligence" OR "machine learning" OR "deep learning" AND "natural science." To ensure thorough coverage, this search was conducted across the database's title, abstract, and keywords fields. The dataset comprised 667 documents after screening and duplicate removal. VOSviewer and complementary analytical techniques were employed to assess publication trends, leading authors and institutions, country-level collaboration, co-citation structures, and thematic clusters derived from Author and index keywords. The results show rapid and sustained growth, with a compound annual rate of 31.55 per cent. China and the United States lead in productivity and citation impact. Several emerging research economies are becoming more visible. The analysis reveals strong international collaboration and distinct thematic areas, including AI-assisted diagnostics, environmental modelling, bioinformatics, and predictive analytics. Co-citation networks reveal a robust intellectual foundation, grounded in widely referenced methodological and field-specific studies. This study provides a recent bibliometric assessment of AI-driven research in the natural sciences. It provides a comprehensive overview of global productivity, research influence, and thematic development. This approach facilitates a deeper understanding of how AI is transforming the field of scientific inquiry.

Keywords: *artificial intelligence, natural science, bibliometric analysis, research collaboration*

INTRODUCTION

In recent years, Artificial Intelligence (AI) has emerged as a transformative force across a broad spectrum of scientific disciplines, profoundly reshaping how knowledge is generated, analysed, and applied. In the natural sciences, which encompass fields such as physics, chemistry, earth sciences, and biology, AI provides powerful tools for data collection, processing, modelling, and prediction (Tamm, 2024). The partnership between AI and the natural sciences is clear in the Earth sciences. AI can manage large datasets, simulate complex systems, and uncover detailed patterns, thereby improving scientific understanding. At the same time, the complexity and changing nature of natural science data refine AI algorithms, support real-world applications, and

promote discussions on AI governance and ethics. This relationship, often referred to as *AIXES* (AI for Earth Systems), expands research possibilities, offers rich data contexts, and encourages innovative methods to address global scientific challenges. The growing use of AI in various scientific fields underscores the importance of understanding the evolving landscape of research knowledge, key focus areas, and emerging trends. For example, AI in biotechnology and applied microbiology has changed disease diagnostics, drug development, and biomarker identification (Xu et al., 2022). In medical imaging, AI technologies, particularly those employed in computed tomography, are rapidly enhancing diagnostic accuracy (Zhu et al., 2024). Likewise, AI is making a significant impact in biomedical genomics, where it processes large, complex genomic datasets to accelerate biomarker discovery and improve genome annotation (Guo et al., 2023). These developments show that AI is no longer just a side issue in scientific research; it is essential to its advancement.

Beyond the health sciences, AI has had a big impact on other domains of study and application. AI systems are being used in K–12 and postsecondary education. Although they offer new opportunities for tailored and flexible education, concerns have been raised about the potential for escalating inequality (Gunadi & Robandi, 2025; Ka et al., 2025; Liu et al., 2024). In a similar vein, publications related to the intersection of AI and renewable energy research have increased, particularly in wind power forecasting. This is because deep learning and machine learning models are good at increasing prediction accuracy (Dhaka & Sreejeth, 2024; Wang et al., 2023). In all these cases, AI plays a consistent role, accelerating discoveries, enhancing data-driven decision-making, and fostering collaboration across various fields. The widespread use of AI within and outside the natural sciences indicates a significant shift in how scientific knowledge is produced. Hajkowicz et al. (2023) identified approximately 3.1 million papers on AI after analysing 137 million peer-reviewed publications from 1960 to 2021. This amounts to roughly 2.3% of all scientific output. Just 14% of scientific disciplines were conducting AI research in 1960. The percentage rose to over 80% by 1986, and by 2021, over 98% of research fields were using AI in some capacity. This spread shows not just technological advancement but also a shift in how intellectual structures and research priorities are organised in global science.

Similarly, bibliometric studies indicate exponential growth in AI-related publications across all domains. AI papers increased at a compound annual growth rate of 25.93% between 2019 and 2023, with an average of 4.28 authors per paper (Erduran et al., 2024), according to Abanga and Acquah (2024). Erduran et al. (2024) noted a simultaneous increase in AI-driven scientometric research, demonstrating that AI is both a subject of study and a tool for scientific investigation. Despite these insights, however, limited bibliometric attention has been given to AI-driven research within the natural sciences, where the methodological integration of AI is redefining the pace, structure, and nature of discovery. A methodical investigation of how AI modifies research collaboration, thematic focus, and citation patterns across disciplines *is necessary to comprehend these knowledge dynamics*. In this study, "knowledge dynamics" refers to the evolving patterns of scientific communication and production. This covers the emergence of research themes, the formation of cross-institutional and cross-national collaborations, and the dissemination of ideas through citations. In traditional natural science fields, knowledge structures have been relatively stable, shaped by long-standing disciplinary boundaries. The incorporation of AI, however, introduces new interdisciplinary intersections, such as computational geoscience, AI-driven chemistry, and bioinformatics, that challenge these boundaries and demand novel analytical approaches.

Bibliometric analysis provides a robust methodological framework for examining such changes. To identify structural and temporal patterns within a research domain, quantitative analysis of scholarly articles is used (Cui et al., 2024). Bibliometrics assists in identifying important contributors, monitoring shifts in topics, and identifying new research directions by analysing metadata such as authorship, keywords, institutional affiliations, and citations. Tools such as VOSviewer and CiteSpace are widely used for these purposes, enabling the visualisation of co-authorship networks, citation relationships, and keyword co-occurrence. For example, VOSviewer was applied in a 2023 study to analyse 4,781 publications on explainable Artificial Intelligence (XAI) from 2004 to 2023, revealing rapid expansion and increasing interdisciplinarity in that field. These tools facilitate analyses across multiple dimensions, author-wise, country-wise, source-wise, and keyword-wise, providing a holistic perspective on how knowledge evolves (Cui et al., 2024).

In the context of the natural sciences, such bibliometric mapping is particularly significant. AI-driven methods are accelerating research cycles, fostering new collaborations, and enabling more complex investigations into natural phenomena. At the same time, they introduce challenges related to data transparency, reproducibility, and ethical oversight. Mapping these developments through bibliometric analysis allows researchers to visualise not only growth patterns but also the changing intellectual and institutional architecture of natural science research. It offers insight into how AI-enabled methods are redefining the traditional scientific workflow and reshaping global research collaborations. As such, the originality of this study lies in its integrated mapping of artificial intelligence applications across multiple disciplines within the natural sciences. Focusing on research published since 2020, the study captures current global trends at the intersection of AI and the natural sciences, reflecting the latest developments in this rapidly evolving field.

Additionally, the analysis compares productivity, collaboration patterns, and thematic trends within a cohesive framework, providing a detailed understanding of how AI influences research activities across various scientific domains. This approach not only contributes valuable insights to the academic community but also establishes a reference point for future research in this area. This study's methodological rigor and timely relevance address the growing need for a systematic understanding of AI integration within scientific research practices. Hence, the need for the present study. More specifically, this study seeks to answer the following research questions: (1) How has the volume, distribution, and growth trajectory of AI-driven natural Science research evolved between 2020 and 2025?; (2) Which countries, institutions, authors, and journals have played the most influential roles in advancing AI-related research within the natural sciences?; (3) What collaborative patterns exist within this research space, and how do co-authorship and co-citation networks reveal the structure and diffusion of knowledge?; (4) How have research themes and intellectual linkages evolved, and what emerging topics or frontier areas can be identified?.

In conclusion, this study is expected to provide a comprehensive and systematic overview of the development of AI-driven research within the natural sciences. By examining publication trends, influential contributors, collaboration networks, and evolving research themes, the findings will offer valuable insights into the dynamics and structure of this rapidly growing field. Furthermore, the results of this study are anticipated to serve as a foundation for future research, support evidence-based decision-making for researchers and policymakers, and contribute to a deeper understanding of the role of artificial intelligence in shaping scientific advancement.

METHODOLOGY

Research Design

This study employs a quantitative bibliometric approach to examine the structural, thematic, and collaborative aspects of AI-driven research within the natural sciences. Bibliometrics, as introduced by Price (1963) and further developed by Small (1973) and van Raan (2005), offers an objective way to map the growth, relationships, and intellectual progress of scientific fields. It is especially suitable for analysing emerging, interdisciplinary areas (Raji-Afolabi & Osho A, 2025) such as the intersection of Artificial Intelligence (AI) and the natural sciences, where rapid growth and diversification render traditional qualitative reviews inadequate. The method combines performance analysis to evaluate publication output, citation impact, and productivity trends with science mapping, which visualises co-authorship networks, keyword co-occurrences, and co-citation relationships. This combined approach allows for both a quantitative assessment of research productivity and a structural understanding of how knowledge is organised and shared across subfields. The visual and analytical outputs were generated using VOSviewer, a software widely used in bibliometric and scientometric research (Van Eck & Waltman, 2010), complemented by CiteSpace for identifying temporal and thematic trends.

Data Sources and Search Strategy

In this study, the bibliometric data were collected from Scopus, a central multidisciplinary database, selected for its comprehensive coverage of peer-reviewed scientific literature and standardised metadata formats. This database, together with the Web of Science, is regarded as the most authoritative source for bibliometric research because of its stringent indexing criteria, citation monitoring systems, and broad disciplinary reach (Mongeon & Paul-Hus, 2016). To document advancements in AI-driven natural science research during the current era of machine learning and deep learning, a search was conducted on November 6, 2025, covering the years 2020 to 2025. The Boolean search query that was employed was as follows: (*"artificial intelligence"* OR *"machine learning"* OR *"deep learning"*) AND (*"natural science"*)

To ensure thorough coverage, this search was conducted across the database's title, abstract, and keywords fields (Adewale & Ndwandwe, 2025). The search was restricted to English-language journal articles, review papers, and conference proceedings to focus on scholarly outputs that advance knowledge. To maintain consistency and reliability, editorials, book chapters, and grey literature were excluded. Following retrieval, bibliographic records were exported in CSV format for additional analysis. These records included the title, Author or authors, affiliations, abstract, keywords, publication year, source title, citations, and references. Initially, 1,127 records were retrieved. The final dataset consisted of 667 entries after duplicates and inappropriate documents (e.g., computational AI studies unrelated to natural science applications) were removed.

Ethical Considerations

Since there were no trials, human subjects, or private information involved, ethical approval was not needed for the study. All analyzed data were obtained from publicly accessible academic databases and used solely for academic research. To guarantee the integrity of the research, proper attribution and citation were kept throughout.

RESULT AND DISCUSSION

Figure 1 below outlines the PRISMA chart used to select the documents for the final dataset. This figure provides a transparent overview of the sequential filtering steps applied to the initial corpus retrieved from Scopus.

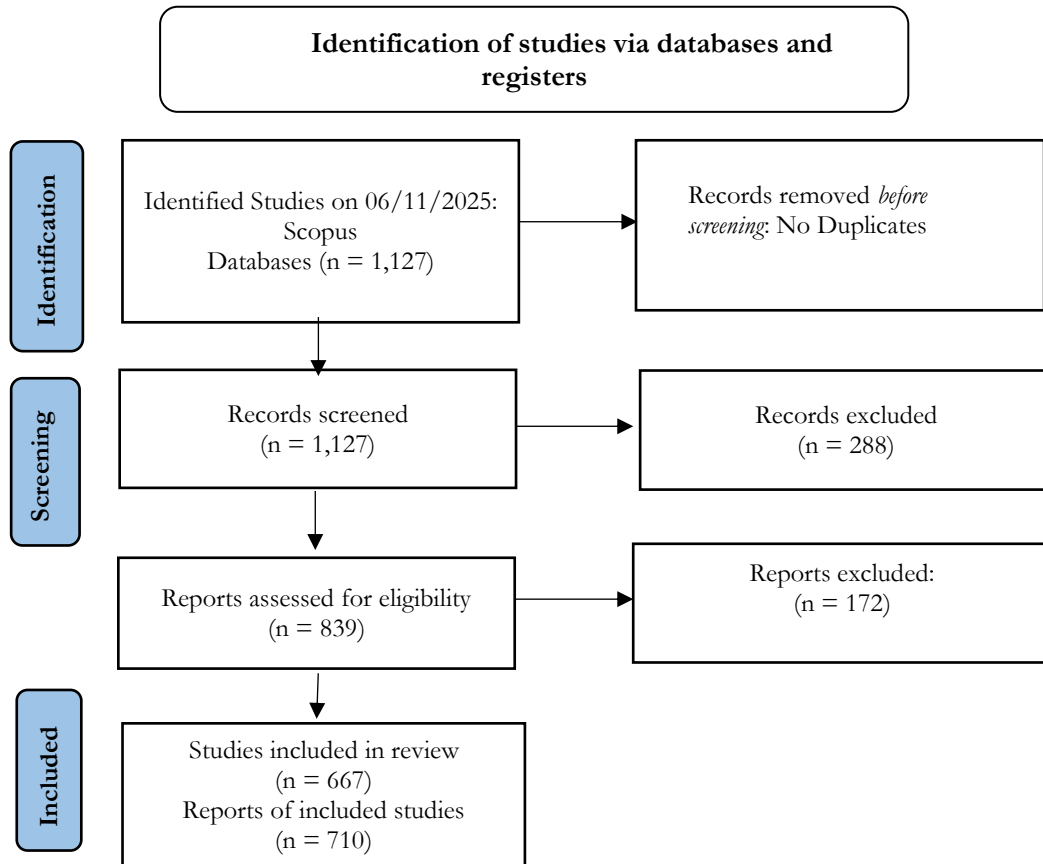


Figure 1. PRISMA Flow Chart

Figure 1 shows the total number of records identified, the removal of duplicates, and the exclusion of papers that did not meet the criteria for AI-driven natural science research. The figure also indicates the number of articles retained after screening titles, abstracts, and full texts. Presenting the process in this structured flow highlights the methodological rigour employed and ensures reproducibility. Such clarity is essential in bibliometric studies because variations in screening practices can significantly influence the resulting publication trends and thematic patterns. As Figure 1 demonstrates, the study followed a systematic, standardised procedure, strengthening the validity of subsequent analyses and ensuring that the final dataset accurately reflects contemporary research at the intersection of AI and the natural sciences.

Furthermore, to ensure the validity and reliability of the study, the quality of each selected study was evaluated. It was done by two independent reviewers (after initial screening by the Author) who systematically assessed the publications using established checklists and the previously outlined data extraction criteria. Throughout this process, the reviewers independently appraised each article, achieving an inter-rater agreement of 76% (Cohen's kappa coefficient), as determined by Cohen's kappa coefficient (Creswell & Poth, 2016; Salas-Pilco et al., 2022). According to Petticrew and Roberts (2008), this methodology enhances transparency by clearly delineating the data extracted from individual studies and acknowledging each study's contribution

to the overall synthesis. Table 1 below shows the characteristics of the included documents in the review.

Table 1. Characteristics of The Included Documents

Description	Results
Time span	2020 – 2025
Source	307
Documents	667
Citations	6697
Country	97
Organization	2823
Compound Annual Growth Rate %	0.3155(31.55%)
Average citation per document	10.04
Average age per document	1.77 years
Authors	5003
Single-authored documents	228
All keywords	6819
Index keywords	5575
Authors keyword	1977

Table 1 summarises the core attributes of the documents that formed the bibliometric dataset. The table indicates that the 2020–2025 period yielded 667 documents from 307 sources, demonstrating a substantial research presence in this emerging domain. The 6,697 citations indicate considerable scholarly engagement, while the average citation per document (10.04) suggests that many papers have achieved early visibility. The inclusion of 97 countries and 2,823 organisations highlights the global and multidisciplinary nature of AI-driven natural science research. The compound annual growth rate of 31.55% provides strong evidence of accelerated research expansion during the study period. The presence of over 5,000 authors and nearly 7,000 keywords indicates a diverse and rapidly evolving field with broad thematic coverage. Overall, Table 1 establishes the scale, collaborative structure, and growth trajectory of the research landscape, providing a foundational context for interpreting subsequent analyses of productivity, networks, and themes.

Research Question 1: How Has the Volume, Distribution, and Growth Trajectory of AI-Driven Natural Science Research Evolved Between 2020 and 2025?

Overview of Publication Growth

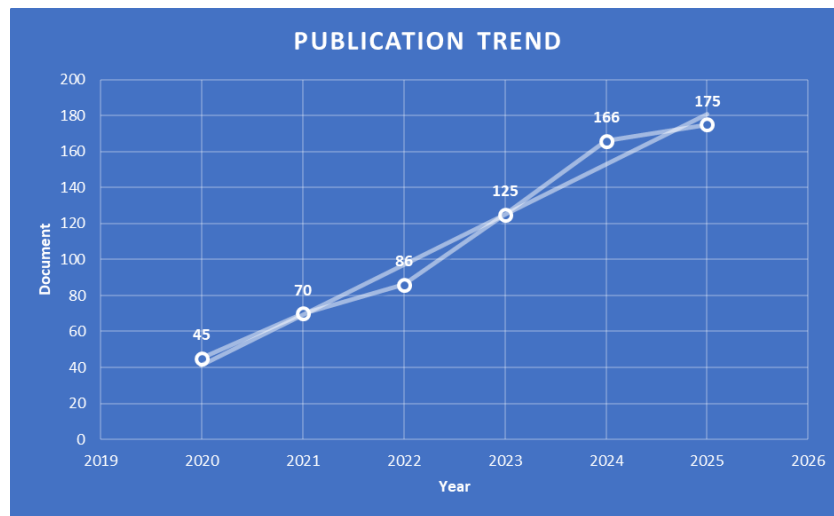


Figure 2. Publication Trend

Figure 2 illustrates the annual publication trajectory for AI-driven natural science research from 2020 to 2025. The figure shows a clear upward trend, indicating consistent growth throughout the period. This pattern aligns with the rapid integration of machine learning and deep learning methodologies across natural science disciplines. The increasing number of publications suggests that AI has become a central tool for modelling, analysing, and interpreting complex scientific data. The trend also reflects the growing trend of interdisciplinary collaboration as researchers adopt computational approaches to address scientific challenges. The visual trajectory in Figure 2 corroborates the high compound annual growth rate reported in Table 1. Notably, the upward curve demonstrates sustained momentum rather than short-term fluctuations, indicating that this research direction is becoming structurally embedded within natural science scholarship. As such, Figure 2 provides strong evidence that AI-driven methodologies are reshaping research priorities and expanding the boundaries of scientific inquiry.

Research Question 2: Which Countries, Institutions, Authors, and Journals Have Played the Most Influential Roles in Advancing AI-Related Research within the Natural Sciences?

Global Distribution and Country-level Performance

Table 2. Most Productive Countries in AI-Driven Natural Science Research

Country	Document	Citations
China	271	6189
United States	144	3445
Germany	69	2115
United Kingdom	51	1380
Australia	28	1118
Switzerland	26	630
Hong Kong	19	259
Canada	24	816
India	30	508
Russian Federation	29	61

Table 2 presents the distribution of publication output and citation performance across leading countries engaged in AI-driven natural science research. China emerges as the dominant contributor, producing 271 documents and accumulating 6,189 citations, indicating both high productivity and strong scholarly influence. The United States follows with 144 publications and 3,445 citations, reaffirming its long-standing leadership in AI development and scientific innovation. European countries, such as Germany and the United Kingdom, also have a notable impact, as reflected in their combined publication volumes and citation counts. Although Australia and Switzerland contribute fewer documents, their citation performance suggests that their outputs are highly influential. The table highlights variations between productivity and citation strength, illustrating that research volume does not always correlate directly with impact. Overall, Table 2 reveals a geographically diverse research landscape, characterised by strong participation from Asia, North America, and Europe, and underscores the global diffusion of AI methodologies within natural science domains.

Institutional and Author Productivity

Table 3. Most Productive Institutions in AI-driven Natural Science Research

Institution	Document	Citation	Strength
Istanbul Tıracet universitesi, Turkey	9	202	111
Sunway University Malaysia	7	31	110
Universidade Federal de Uberlandia, Brazil	6	92	103
Southern Medical University, Guangzhou	10	263	83
Qingdao University, China	7	74	67
Bei Hang University, China	7	394	54
Institute of Automation, Beijing, China	6	369	36
Peking University, Beijing, China	5	150	20
Sun Yat-sen University, China	7	204	12
ETH Zurich, Switzerland	8	303	0
University of Toronto, Canada	7	127	2
University of Oxford, United Kingdom	6	98	0

The institutional component detailed in Table 3 highlights the universities and research centers that are leading the charge in AI-driven natural science research. Notable among them are Istanbul Ticaret University and Sunway University, both of which have demonstrated impressive levels of productivity in their research efforts. In contrast, several research-intensive universities in China—such as Southern Medical University, Qingdao University, and Beihang University—are making their mark through exceptional citation performance. This success underscores the rising significance of Asian institutions in the burgeoning field of AI-enhanced research. Meanwhile, ETH Zurich and the University of Toronto, while exhibiting lower research output compared to their peers, showcase a remarkable citation impact. This suggests that the research they produce, though less frequent, is of exceptionally high quality and carries considerable influence in the scientific community.

Moreover, the reported link strength among these institutions sheds light on the interconnectedness of each within global research networks. Certain universities have emerged as pivotal hubs for scientific collaboration, playing a critical role in fostering partnerships and driving innovation across the globe. In summary, Table 3 paints a picture of a rapidly internationalizing research landscape, where institutions from various continents are united in their quest to advance AI applications in the natural sciences. This distribution not only highlights the interdisciplinary

nature of the field but also reaffirms the vital connections that exist among researchers worldwide, contributing to a more interconnected scholarly environment.

Table 4. Most Productive Authors in AI-driven Natural Science Research

Institution	Document	Citation	Total Link Strength
Ajibade Samuel S M	13	214	164
Adediran, Anthonia Oluwatosin	8	138	138
Zaidi, Abdelhamid Taeib	5	198	84
Liu, Zaiyi	5	112	40
Liu, Yu	6	366	30
Tian, Jie	7	535	26
Wang, Yun	5	150	20
Lin, Fan	5	203	18
LI, Zhenhui	4	326	96
Wang, Ying	4	145	112

The author-focused segment of Table 4 highlights individual research productivity and scholarly influence in AI-driven natural science research. Ajibade Samuel S. M. leads with 13 publications and a high total link strength, indicating extensive collaborative engagement across research networks. Other prominent contributors, such as Adediran Anthonia and Zaidi Abdelhamid, show significant citation counts, demonstrating the visibility and relevance of their work. The inclusion of link strength provides important context for interpreting Author impact, revealing how researchers integrate into broader knowledge networks. Authors with fewer publications but strong citation performance such as Li Zhenhui illustrate that influence is not strictly tied to output volume. The distribution of authors in the table also underscores the field's international scope, with contributions spanning Asia, Africa, and Europe. Overall, Table 4 reflects a diverse authorship landscape shaped by collaborative research practices and expanding global participation in AI-enhanced scientific inquiry.

Journal and Source Analysis

Table 5. Topmost Journals on AI-driven Natural Science Research

Journal	Document	Citation	SJR	H-Index
Eclinical medicine	76	1329	Q1	99
Ebiomedicine	42	1315	Q1	136
Iscience	27	104	Q1	97
The Lancet digital health	19	1401	Q1	85
The Lancet Regional Health-Western Pacific	10	124	Q1	41
Proceedings of Machine Learning Research	8	40	Q1	125
Advances in intelligent systems and computing	8	33	0	81
Lecture notes in network systems	8	3	Q4	48
Nature Communications	6	589	Q1	577
Scientific reports	6	75	Q1	347

The journal ranking outlined in Table 5 highlights the principal publication venues that are influential in shaping research at the intersection of artificial intelligence and natural sciences. High-impact outlets such as EClinical Medicine, Ebiomedicine, and The Lancet Digital Health dominate the list, reflecting the strong intersection between AI methodologies and health-related natural sciences. These journals display substantial citation counts and high SJR and H-index values, confirming their influence and reach within the scientific community. General science platforms such as Nature Communications and Scientific Reports also appear prominently, indicating that

AI-enabled natural science research is not restricted to specialised domains but resonates across broad scientific audiences. The presence of machine-learning-focused outlets, including the Proceedings of Machine Learning Research, highlights the interdisciplinary nature of the field and the integration of computational methods into natural science inquiry. Overall, the table indicates that the most influential journals in this area are those situated at the intersection of AI, medicine, and multidisciplinary science.

Research Question 3: What Collaborative Patterns Exist within This Research Space, and How Do Co-Authorship and Co-Citation Networks Reveal the Structure and Diffusion of Knowledge?

Citation and Co-citation Analysis

Co-citation analysis revealed 1,031 unique cited sources and 133 co-citation links, exceeding the threshold of 23 citations. The most frequently co-cited journals were the New England Journal of Medicine, CA: A Cancer Journal for Clinicians, Nature, The Lancet, and Science.

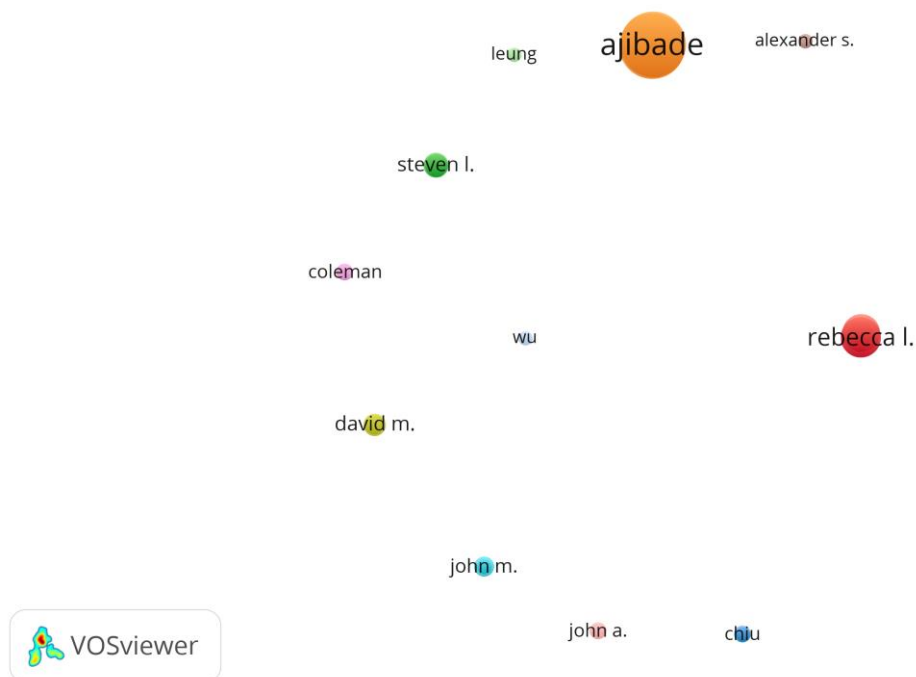


Figure 3. Co-Cited Authors with A Minimum of 5 Citations

Figure 3 illustrates the network of co-cited authors, offering insight into the intellectual structure of AI-driven research in natural sciences. Authors who appear as larger nodes represent those who are most frequently cited together, suggesting foundational or widely referenced contributions. The clustering patterns in the figure reveal distinct thematic groups, in which authors' works converge around shared concepts or methodologies. These clusters indicate the presence of subfields, such as AI-assisted medical diagnostics, machine learning modelling, or computational biology, that anchor the broader research domain. The network's density and connectivity indicate a high degree of intellectual integration, suggesting that researchers consistently draw on a shared body of influential literature. Figure 3, therefore, provides a visual representation of the field's conceptual foundations, identifying key thinkers whose publications shape ongoing developments. This co-citation structure strengthens the understanding of how

scientific ideas are consolidated and how influential authors contribute to shaping research directions.

Co-authorship Network of Authors

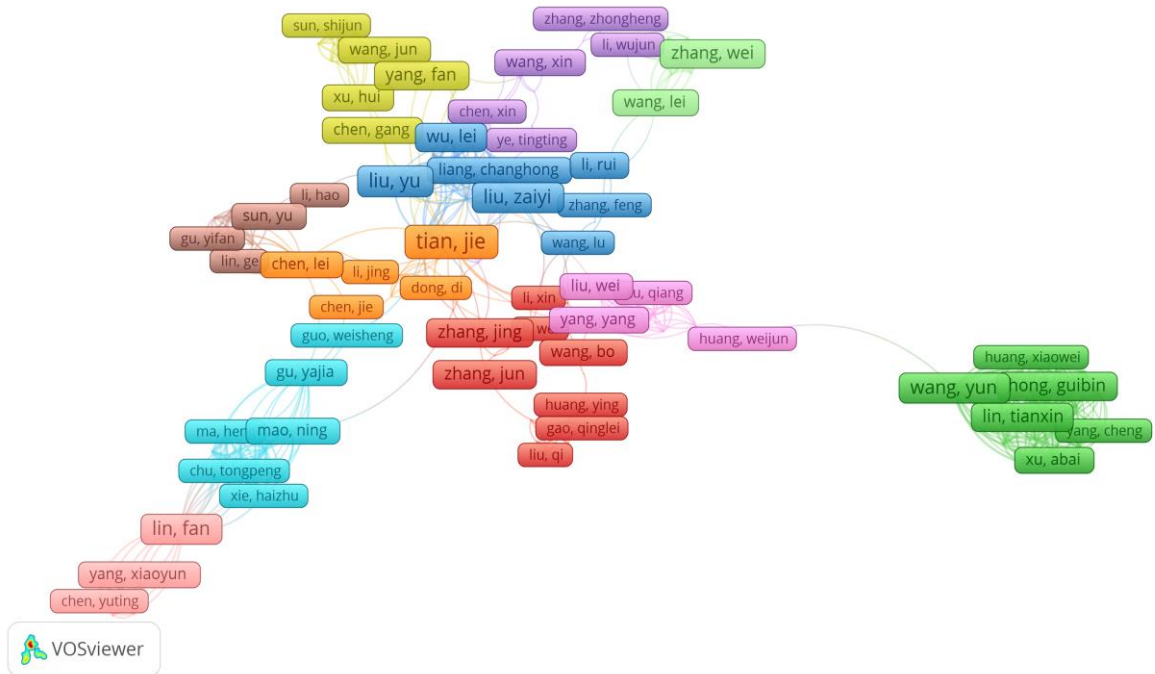


Figure. 4. Co-Authorship Network among Authors

Co-Author Network based on Country

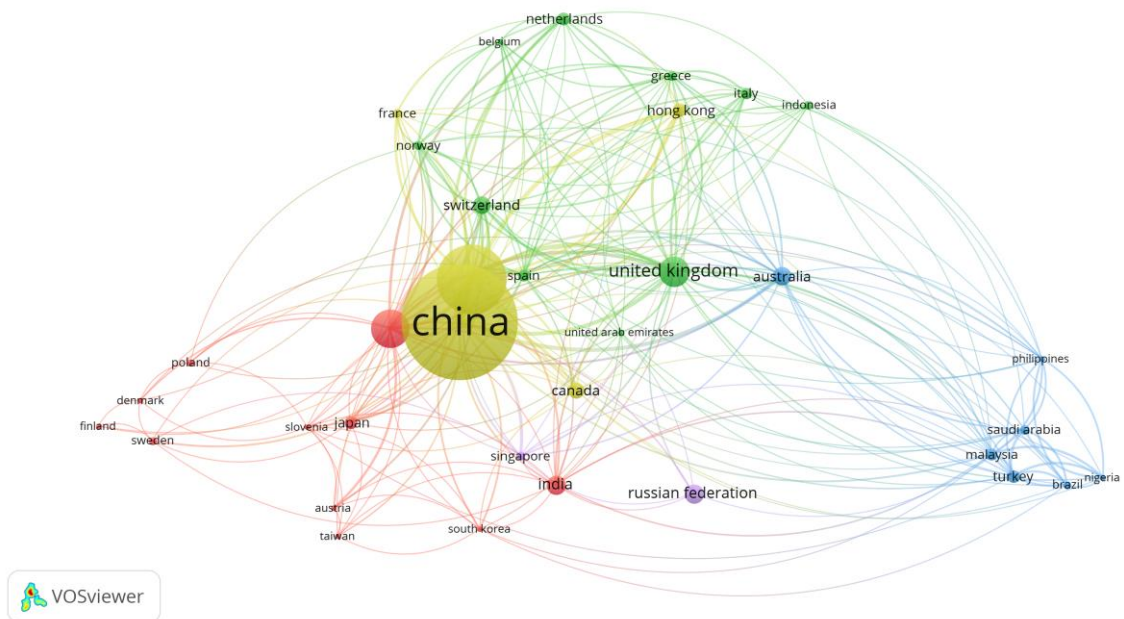


Fig. 5. Co-Authored Network Based on Countries

Figure 5 maps international collaboration patterns by illustrating the co-authorship network across countries. Larger nodes represent nations with higher publication activity or broader participation in multinational research efforts. The network shows strong engagement from countries such as China, the United States, and the United Kingdom, reflecting their leadership in both AI development and natural science research. The connections between countries highlight where scientific partnerships are most active, revealing clusters that may reflect regional proximity, shared research priorities, or historical patterns of collaboration. The presence of cross-continental links demonstrates the field's global character and the extent to which AI-driven natural science research relies on international cooperation. Such networks are crucial for addressing complex scientific questions that require a combination of computational expertise and domain-specific knowledge. Overall, Figure 5 illustrates a highly interconnected research environment in which global partnerships play a crucial role in advancing methodological innovation and scientific discovery.

Research Question 4: How Have Research Themes and Intellectual Linkages Evolved, and What Emerging Frontier Areas Can Be Identified?

Thematic and Conceptual Structure

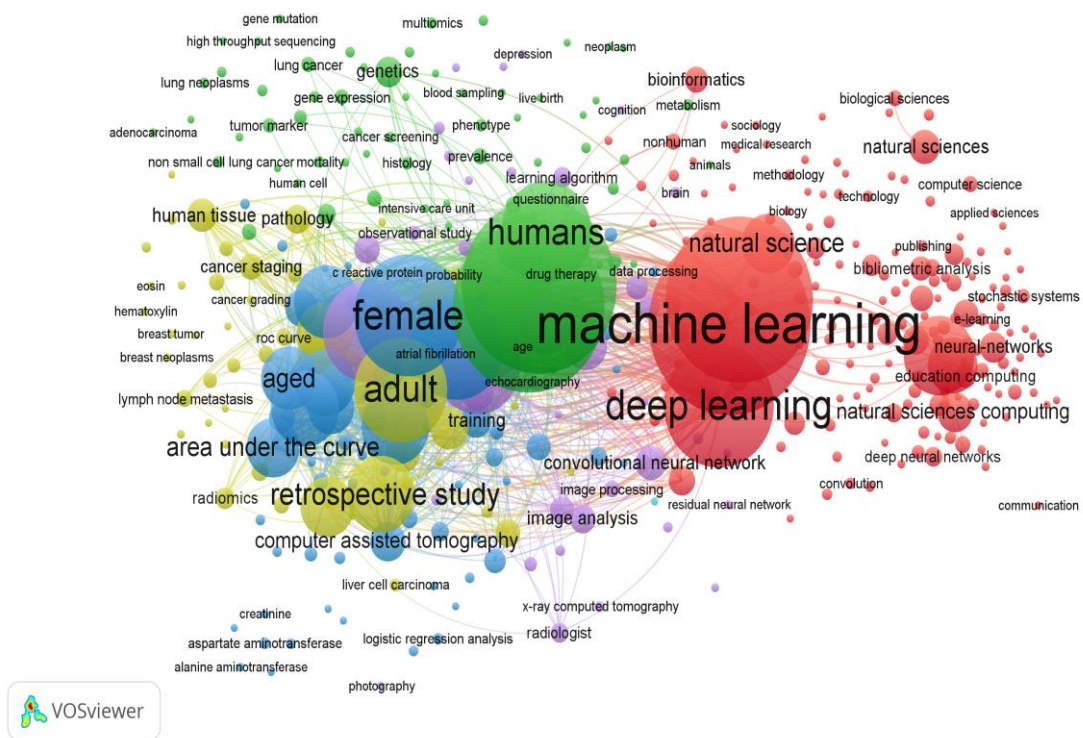


Figure 6. All Keywords

Figure 6 displays the network of all keywords associated with the dataset, providing a comprehensive overview of the thematic landscape. The size of each node represents the frequency of the keyword, while the clustering patterns show how topics group together based on conceptual proximity. The network reveals major themes, including machine learning, deep learning, modelling, prediction, and domain-specific scientific concepts, indicating that AI has been employed broadly across natural science applications. The figure also highlights emerging areas

where AI is increasingly utilised, supported by the presence of newer or more specialised terms. The density of the network reflects the multi-disciplinary nature of the field, where computational methods intersect with multiple branches of natural science. By mapping the full spectrum of keywords, Figure 6 offers insight into both the diversity and concentration of research topics, thereby illustrating how AI methodologies are being embedded across a wide range of scientific practices.

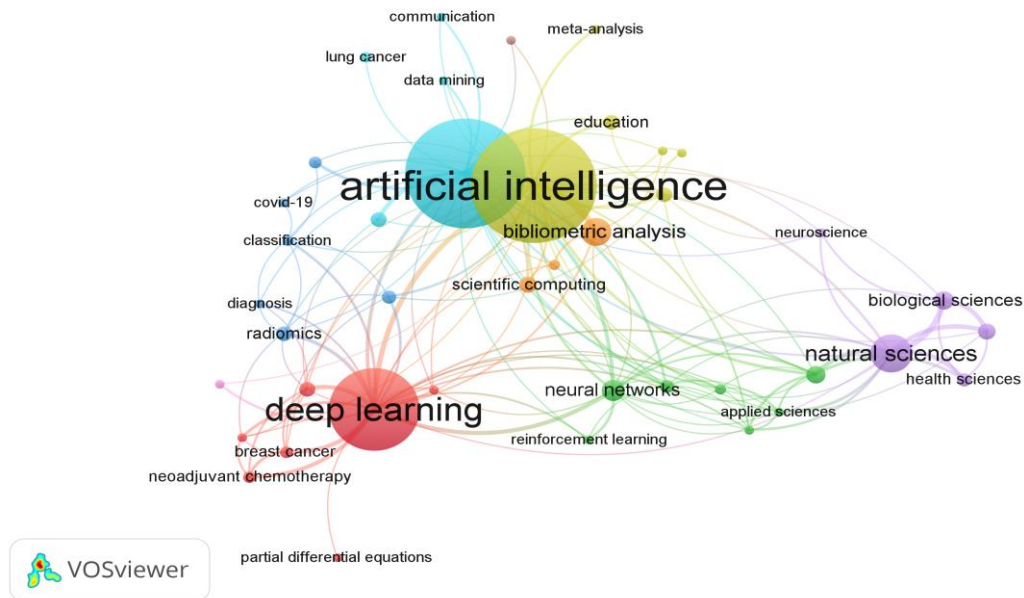


Figure 7. Author Keywords

Figure 7 shows how the authors selected their keywords, giving us a better sense of how researchers frame the main ideas of their work. Author keywords, on the other hand, show intentional choices that point to new trends, methodological preferences, and domain-specific emphasis. The clusters in Figure 7 show different topic areas, such as AI-assisted diagnostics, natural science modelling, predictive analytics, and applications focused on specific fields. The larger nodes highlight high-frequency terms that reveal the community's most pressing research interests. The links between keywords show how themes come together, revealing how different fields are connected. This figure is particularly helpful for identifying emerging research areas, as authors often use new terminology before it becomes widely recognized in databases. It provides insight into how AI-enabled natural science research is being conceptualized, enabling us to identify which topics are gaining prominence.

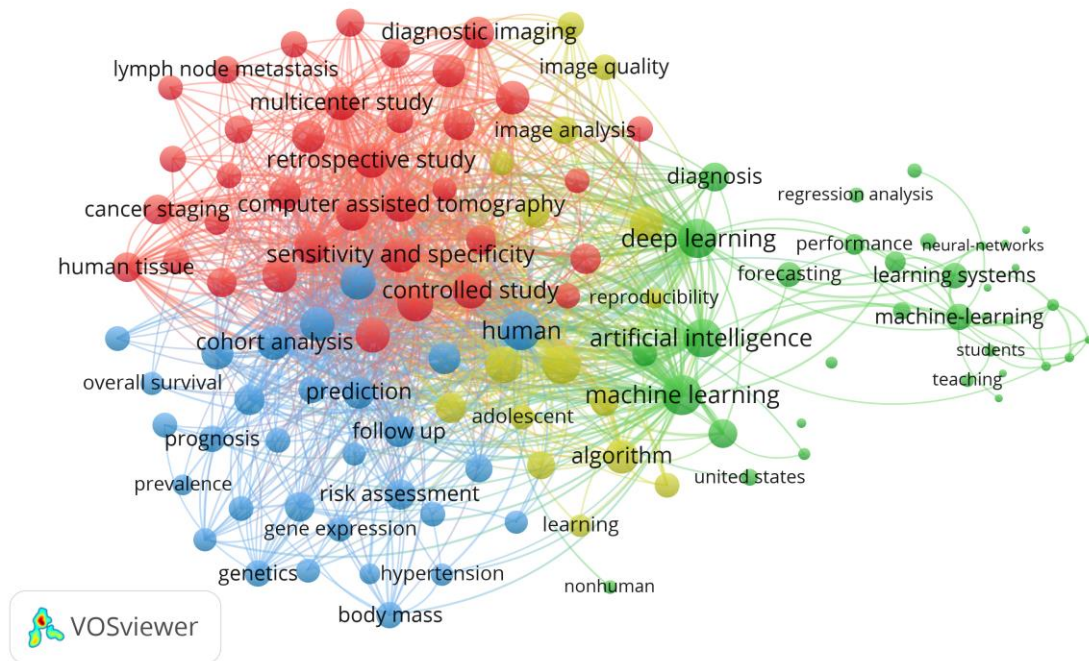


Figure 8. Index Keywords

Figure 8 shows the network of index keywords, which gives a structured view of how scientific databases organise the literature. Index keywords follow controlled vocabularies, which allow publications to be classified consistently. Author keywords do not. The network displays clusters of related terms, illustrating the formal representation of AI-driven natural science research within indexing frameworks. Well-known nodes show terms commonly used in the field, such as artificial intelligence, machine learning, prediction, and modelling. It shows the field's main methodological focus. The clustering shows how computational methods and certain natural science applications are related, indicating that the research is interdisciplinary. This figure also helps find the most important indexing pathways, which affect how future researchers find and read relevant literature. Overall, Figure 8 complements the thematic analysis by providing a standardised perspective on the field's conceptual structure and reinforcing the breadth of AI integration across natural science research domains.

The findings of this study indicate an apparent acceleration in AI-driven natural science research, consistent with earlier reports of rapid growth in AI-related scholarship across scientific domains. The steady increase in publications shown in Figure 2 supports the global growth trends reported by Abanga and Acquah (2024), who found that AI publications grew by 25.93% each year from 2019 to 2023. Similarly, the strong international representation in Table 2 aligns with Hajkovicz et al. (2023), who showed that AI penetration increased from 14% of scientific fields in 1960 to over 98% by 2021. These results support the assertion that AI is now deeply integrated into scientific workflows. The pre-eminence of China and the United States in publication and citation metrics aligns with prior bibliometric studies indicating that these nations are at the forefront of global AI innovation (Xu et al., 2022; Wang et al., 2023).

Nevertheless, our findings indicate a more significant emerging presence from regions including Turkey, Brazil, and Malaysia. This expansion has been less highlighted in prior studies,

which typically concentrated on Western and East Asian research centres. It indicates an expanding democratisation of AI research capabilities.

The thematic clusters delineated in Figures 6–8 correspond with previous research indicating that AI investigations in the natural sciences predominantly focus on predictive modelling, deep learning, diagnostics, and simulation (Zhu et al., 2024; Guo et al., 2023). On the other hand, the data shows a growing diversification toward Earth-system simulation and environmental modeling, corroborating recent research like Dhaka and Sreejeth (2024), which reported a sharp rise in AI applications for environmental analytics and wind forecasting. Erduran et al. (2024) noted that AI-driven scientific procedures tend to promote interdisciplinary and cross-institutional collaborations, which is consistent with the robust collaborative networks depicted in Figures 4 and 5. It is further supported by the dense co-authorship patterns in our findings, which show that integrating domain-specific scientific knowledge with computational competence is crucial for AI-enabled research. According to Cui et al. (2024), bibliometric network mapping can help identify systematically organised research subfields in emerging topics. It is supported by the co-citation clusters in Figure 3, which also reveal a cohesive, developing intellectual structure.

Overall, the findings support previous evidence of rapid expansion and thematic evolution in AI-related research, while adding new insights into its growing global distribution, emerging research hotspots, and strengthened collaborative structures within the natural sciences.

CONCLUSION

This bibliometric review highlights the significant influence of artificial intelligence (AI) on the evolution of scientific workflows within the natural sciences. Utilizing VOSviewer for data visualization and analysis, the study identified notable methodological advancements driven by AI integration. This technological incorporation has optimized existing research processes and facilitated the development of innovative research paradigms. AI fundamentally enhances scientific workflows by automating routine tasks, improving data analysis, and supporting predictive modeling. Its capacity to process extensive datasets surpasses human capabilities, enabling researchers to identify patterns and insights previously unattainable. For example, machine learning algorithms are now routinely employed for data mining, hypothesis development, and experimental design, thereby accelerating research progress and increasing the accuracy and reproducibility of findings. In addition to transforming individual workflows, AI is encouraging new collaborative models among researchers. As such, traditional siloed approaches are gradually giving way to interdisciplinary collaborations that leverage AI's capabilities across various fields.

Furthermore, this bibliometric analysis indicates an increase in co-authorships among researchers from diverse disciplines, reflecting a trend toward integrating AI tools and methodologies. These collaborations often involve partnerships between academia and industry, combining AI expertise with domain-specific knowledge to address complex scientific challenges. Such interdisciplinary efforts are vital for tackling global issues such as climate change, public health crises, and resource management, which require comprehensive, collaborative solutions. The emergence of these new collaboration models has significant implications for the future of scientific enterprise. For instance, as AI continues to influence research practices, the development of more open and collaborative research environments is anticipated. However, integrating AI raises important ethical oversight considerations, including data privacy, algorithmic fairness, and

the reproducibility of AI-generated results. Thus, as the natural sciences adapt to these technological advancements, future research systems should promote interdisciplinary cooperation and uphold ethical standards to ensure responsible and effective scientific progress.

ACKNOWLEDGEMENTS

During the preparation of this manuscript, the author(s) used the VOSviewer App for analysing scholarly publications and their impact comprehensively. The authors have reviewed and edited the output and take full responsibility for the content of this publication.

REFERENCES

- Abanga, E. A., & Acquah, T. (2024). A Bibliometric Analysis of Global Research Trends in Artificial Intelligence from 2019 to 2023. *Asian Journal of Research in Computer Science*, 17(12), 220–233.
- Adewale, S., & Ndwandwe, N. D. (2025). Artificial Intelligence-Driven Leadership in Higher Education: A Bibliometric Analysis of Research Trends and Development. *International Journal of Learning, Teaching and Educational Research*, 24(7), 624–645. <https://doi.org/10.26803/ijlter.24.7.31>
- Creswell, J. W., & Poth, C. N. (2016). *Qualitative inquiry and research design: choosing among five approaches*. New York: Sage Publications.
- Cui, W., Wei, Y., & Ji, N. (2024). Ecotoxicology and Environmental Safety: Global trends of waste-to-energy (WtE) technologies in a carbon-neutral perspective: Bibliometric analysis. *Ecotoxicology and Environmental Safety*, 270(July 2023), 115913. <https://doi.org/10.1016/j.ecoenv.2023.115913>
- Dhaka, P., & Sreejeth, M. (2024). A Survey of Artificial Intelligence Applications in Wind Energy Forecasting. *Archives of Computational Methods in Engineering*, 31(8), 4853–4878. <https://doi.org/10.1007/s11831-024-10182-8>
- Erduran, S., Levrini, O., & Erduran, S. (2024). The impact of artificial intelligence on scientific practices: an emergent area of research for science education. *International Journal of Science Education*, 46(18), 1982–1989. <https://doi.org/10.1080/09500693.2024.2306604>
- Gunadi, R. A., & Robandi, B. (2025). Mapping the intersection of ethics, AI, and higher education: a bibliometric approach. *Jurnal Penelitian Pendidikan Indonesia*, 11(1), 43–53. <https://doi.org/https://doi.org/10.29210/020254242>
- Guo, K., Wu, M., Soo, Z., Yang, Y., Zhang, Y., Zhang, Q., & Lin, H. (2023). Knowledge-Based Systems, Artificial intelligence-driven biomedical genomics. *Knowledge-Based Systems*, 279, 110937. <https://doi.org/10.1016/j.knosys.2023.110937>
- Hajkowicz, S., Sanderson, C., Karimi, S., Bratanova, A., & Naughtin, C. (2023). Artificial intelligence adoption in the physical sciences, natural sciences, life sciences, social sciences, and the arts and humanities: A bibliometric analysis of research publications from 1960-2021. *Technology in Society*, 74(May), 102260. <https://doi.org/10.1016/j.techsoc.2023.102260>
- Ka, K., Cheung, C., Long, Y., Liu, Q., & Yin, H. (2025). Unpacking Epistemic Insights of Artificial Intelligence (AI) in Science Education: A Systematic Review. In *Science & Education* (Vol. 34, Issue 2). Springer Netherlands. <https://doi.org/10.1007/s11191-024-00511-5>

- Liu, J., Wang, C., Liu, Z., Gao, M., Xu, Y., Chen, J., & Chen, J. (2024). A bibliometric analysis of generative AI in education: current status and development. *Asia Pacific Journal of Education*, 44(1), 156–175. <https://doi.org/10.1080/02188791.2024.2305170>
- Mongeon, P., & Paul-Hus, A. (2016). The Journal Coverage of Web of Science and Scopus: a Comparative Analysis. *Scientometrics*, 106(1), 213–228. <https://doi.org/10.1007/s11192-015-1765-5>
- Petticrew, M., & Roberts, H. (2008). *Systematic reviews in the social sciences: a practical guide*. Hoboken, New Jersey: John Wiley & Sons.
- Price, D. J. de S. (1963). *Little Science, Big Science*. Columbia University Press.
- Raji-Afolabi, S., & Osho, A. H. (2025). Mapping the Knowledge Domain: A Bibliometric Review of Instructional Leadership and Student Achievement in Secondary Schools. *Elicit Journal of Education Studies*, 1(1), 1–14.
- Salas-Pilco, S. Z., Xiao, K., & Hu, X. (2022). Artificial intelligence and learning analytics in teacher education: a systematic review. *Educ. Sci.* 12, 1–18. <https://doi.org/10.3390/educsci12080569>
- Small, H. (1973). Co-Citation in the Scientific Literature: A New Measure of the Relationship Between Two Documents. *Journal of the American Society for Information Science*, 24(4), 265–269. <https://doi.org/10.1002/asi.4630240406>
- Tamm, E. P. (2024). Introduction to Guest Section on Neuroendocrine Tumors. *Journal of Computer Assisted Tomography*, 48(4), 509. <https://doi.org/10.1097/RCT.0000000000001650>
- Van Eck, N. J., & Waltman, L. (2010). Software Survey: VOSviewer, a Computer Program for Bibliometric Mapping. *Scientometrics*, 84, 523–538. <https://doi.org/10.1007/s11192-009-0146-3>
- Wang, J., Cheng, L., Feng, L., Lin, K., Zhang, L., & Zhao, W. (2023). Advanced Engineering Informatics: Tracking and predicting technological knowledge interactions between artificial intelligence and wind power: Multimethod patent analysis. *Advanced Engineering Informatics*, 58(September), 102177. <https://doi.org/10.1016/j.aei.2023.102177>
- Xu, D., Liu, B., Wang, J., & Zhang, Z. (2022). Bibliometric analysis of artificial intelligence for biotechnology and applied microbiology: Exploring research hotspots and frontiers. *Frontier in Bioengineering and Biotechnology*, October 1–13. <https://doi.org/10.3389/fbioe.2022.998298>
- Zhu, K., Shen, Z., Wang, M., Jiang, L., Zhang, Y., Yang, T., Zhang, H., & Zhang, M. (2024). Visual Knowledge Domain of Artificial Intelligence in Computed Tomography: A Review Based on Bibliometric Analysis. *Journal of Computer Assisted Tomography*, 48(4), 652–662. <https://doi.org/10.1097/rct.0000000000001585>