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Mapping the Integration of Artificial Intelligence in Higher Education: A Visual and Bibliometric Analysis (2010-2024)

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Abstract: This study employs VOS Viewer and the R programming language to conduct a visual analysis of the application of artificial intelligence (AI) in higher education, aiming to reveal research hotspots, frontier dynamics, and development trends. Using the Web of Science (WOS) database as the data source, we reviewed and analyzed the literature on the application of AI in higher education from 2010 to 2024. The results show that AI technologies have significantly impacted core educational domains, reshaping the structure, processes, and objectives of modern education. The integration of higher education and AI has shown initial success, but further exploration is needed in intelligent teaching systems and educational governance.

Keywords: Higher Education; Artificial Intelligence; Visual Analysis; Personalized Learning; Digital Transformation.

1. Introduction

The rapid development of Artificial Intelligence (AI) has sparked a new round of global technological revolution. In particular, the emergence of generative AI, such as ChatGPT, is reshaping the ecosystem and structural order of education and teaching with unprecedented intensity [1]. The report of the 20th National Congress of the Communist Party of China pointed out that it is necessary to deeply implement the strategy of revitalizing the country through science and education, comprehensively improve the quality of independent talent cultivation, accelerate the construction of a high-quality education system, and speed up the realization of connotative development to enhance adaptability to the new era. How to deeply integrate the new generation of AI with undergraduate education has become a topical issue of great concern in undergraduate institutions. In this context, this paper employs the VOS Viewer software to review the relevant literature on AI-empowered undergraduate teaching in China. It aims to present the overall framework and basic developmental trajectory of research in this field from a quantitative and comprehensive perspective, to distill and display the research characteristics, focal points, and evolutionary process of the field, and to provide a reference for subsequent in-depth research and practical applications.

2. Data Sources and Methods

2.1. Data Sources and Search Strategy

Bibliometrics is a systematic method proposed by Alan Pritchard for the quantitative analysis of academic literature to identify research characteristics. Initially applied in library and information science, bibliometrics has now been widely used in various fields to measure scientific progress. The application of bibliometrics usually focuses on the publication time, authors, journals, and the distribution structure of hot issues in a particular research field. Bibliometric analysis is a powerful and valuable information visualization tool [2], which scholars use to capture research performance and growth trends in global scientific literature in specific fields or topics. Bibliometrics also provides a comprehensive macro-overview of influential academic literature in specific fields or topics from the perspectives of major authors, journals, institutions, and countries.

In this study, bibliometric analysis is combined with scientific mapping methods to measure research growth trends by providing quantitative and qualitative insights into specific fields. The Web of Science (WoS) is considered a major quality-oriented database globally and contains more standardized records for retrieving global scientific literature across multidisciplinary fields and research areas. Therefore, this study selects WoS as the scientific data source for bibliometric analysis.

This paper uses the Web of Science (WOS) Core Collection to search for the subject range of keywords. Keywords are combined using the Boolean operator “OR”. The search range is from January 1, 2010 to December 31, 2024. By carefully reading the titles and abstracts of each document and excluding as many irrelevant documents as possible, we manually selected 242 publications that fit the research topic.

2.2. Statical Analysis

Many software tools are available for bibliometric analysis. VOSviewer was chosen for this study over CiteSpace due to its advantages in several aspects, making it particularly suitable for specific bibliometric analysis scenarios:

1. User-Friendliness and Intuitive Visualization: VOSviewer is easier to operate and features a more intuitive interface, allowing beginners to get started quickly without the need for complex parameter adjustments. The network maps generated by VOSviewer are typically clearer and more aesthetically pleasing, with better automatic layout optimization of nodes and labels to avoid overlaps and support dynamic interactions (such as zooming, dragging, and clustering highlights).

2. Data Processing Flexibility:

Compatibility with Multiple Data Sources: In addition to Web of Science, VOSviewer supports a wider range of data sources, including Scopus, PubMed, Dimensions, and Crossref, and can directly import formats such as RIS and

CSV.

Data Cleaning Tools: It features built-in term merging capabilities (e.g., synonym handling) to simplify data preprocessing steps.

3. Specific Analytical Functions:

Co-Authorship Network Analysis: VOSviewer provides more intuitive clustering in the visualization of co-authorship, co-institution, and co-country networks.

Density View: Its unique heatmap mode allows for quick identification of research hotspots.

Timeline Evolution: Although not as detailed as CiteSpace's time slicing, VOSviewer's "Overlay Visualization" can intuitively display the evolution of topics over time.

4. Performance and Stability:

Efficiency in Handling Large-Scale Data: VOSviewer processes large datasets (such as tens of thousands of documents) more quickly and with lower memory usage.

Stability: CiteSpace may crash during complex network analysis due to improper parameter settings, while VOSviewer is relatively more stable.

Despite these advantages of VOSviewer, CiteSpace remains irreplaceable in the following scenarios:

Temporal Evolution Analysis: CiteSpace's time slicing and burst detection functions are more powerful.

Betweenness Centrality Analysis: It is more accurate in identifying key nodes (e.g., pivotal documents).

Complex Network Metrics: CiteSpace offers a wider range of topological parameters (such as modularity and silhouette values).

This software can generate visualized networks, such as co-citation, bibliographic coupling, and co-occurrence networks, which can effectively assess the relationships among publications, institutions, and authors.

3. Results

3.1. Number of Published Articles

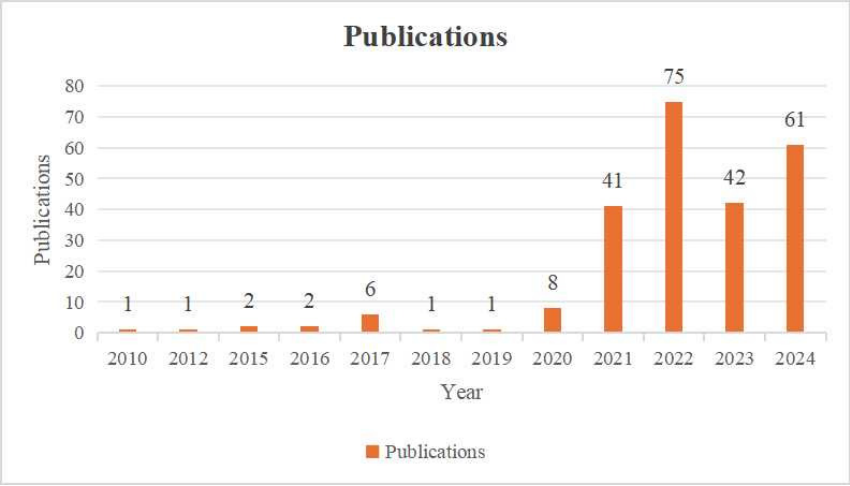

Figure 1. The Changes in Publications

Figure 1 illustrates the trend of research article output on artificial intelligence in higher education. The Web of Science (WoS) database retrieved 242 research articles on artificial intelligence in higher education published between 2010 and 2024. In the first nine years, the growth of research on the selected topic was slow over time [3]. Subsequently, the number of research papers gradually increased, attracting significant attention from numerous scholars in the scientific community.

By statistically analyzing the number of papers and country information, a graph showing the changes in the number of publications by country over time was constructed, as shown in Figure 2. It can be seen from the figure that China's publication output has been increasing year by year since 2020.

3.2. The Analys of Countries

3.2.1. Number of Articles by Countries

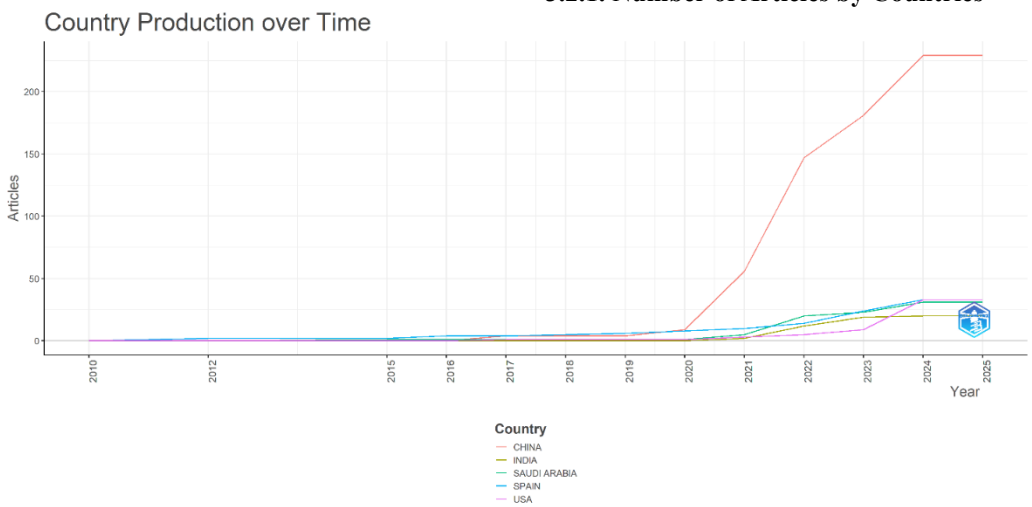

Figure 2. Publication Output of Countries Over Time

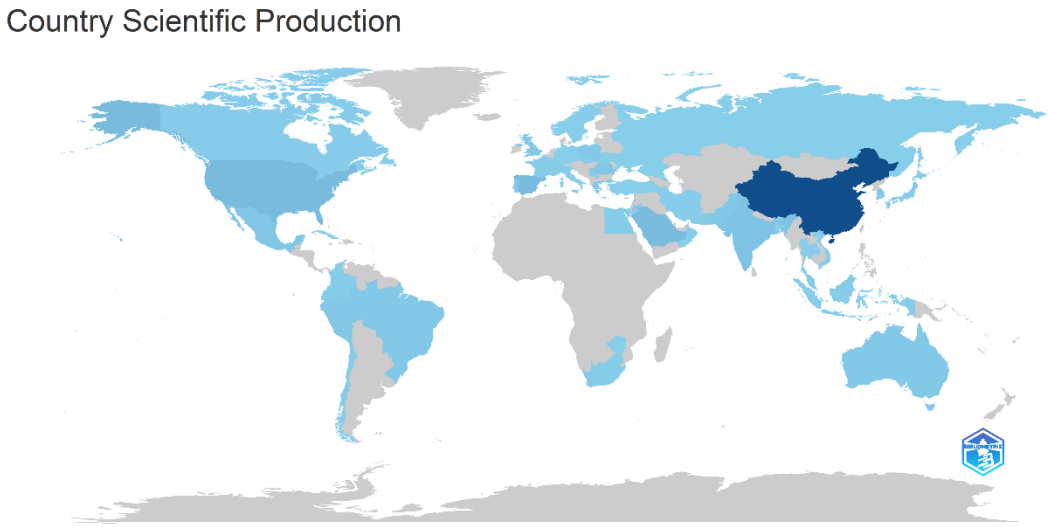

Figure 3. The scientific Production of countries

Figure 3 presents a map of publication output by country, where the intensity of the color corresponds to the number of publications [4]. Among these papers, China has the highest number of publications in this field, taking the leading position.

3.2.2. Co-authorship among Countries

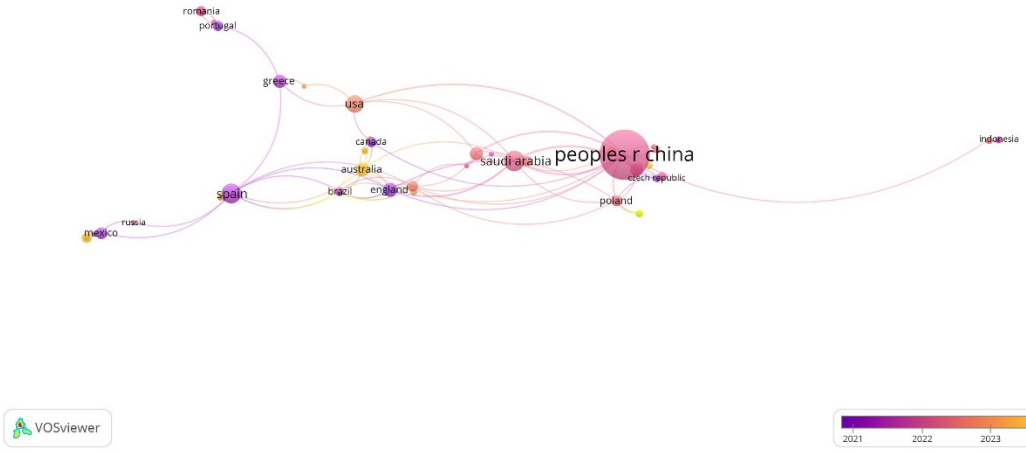

Figure 4. International Collaboration: A Network Analysis

Figure 4 illustrates the co-occurrence of international collaboration, highlighting 52 countries. It reflects the extent of communication and cooperation among authors from different countries in the field of personalized teaching. The strength of the connections is determined by the size of the nodes[5]. Generally,the larger a country's node,the more extensive its collaboration and cooperation with researchers in personalized teaching from other countries. China has played a pivotal role in this research topic, closely collaborating with various countries and having the largest node and the most connections in the co-authorship map.The results of the co-authorship analysis also indicate that Saudi Arabia has a higher link strength than other countries.

This study reveals that the United Kingdom, Spain, and Canada began researching the application of artificial intelligence in teaching relatively early, with the main output of publications occurring around 2021. In contrast, China's main output of publications was around 2022.

3.3. Co-authorship among Organizations

Figure 5. Research cooperation network among institutions

Figure 5 illustrates that Academic institutions from various countries have participated in the research on personalized teaching, with a significant number of these institutions being from abroad. This information provides crucial insights for new levels of research at the institutional level and offers a basis for a deeper understanding of the impact and collaborative patterns of institutions.

3.4. The Analys of Journals

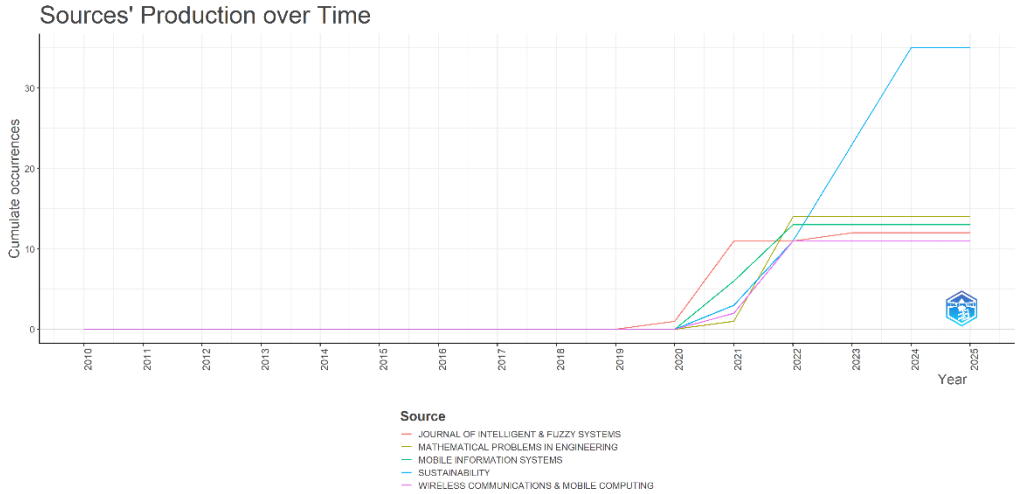

Figure 6. Sources' Production Over Time.

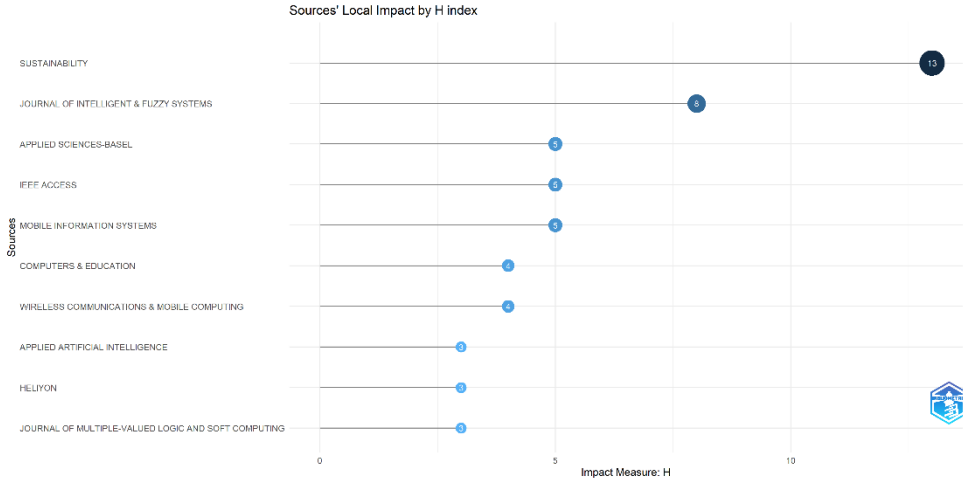

Figure 7. Sources' Local Impact by H index

Figure 6 shows the annual number of papers published in the top five journals on artificial intelligence in teaching from 2010 to 2024. The number of articles in these journals follows a general trend: the figures were relatively low from 2010 to 2020. However, from 2021 to 2022, the number of publications continued to grow and then stabilized. "Sustainability" ranked first in terms of the number of publications.

Figure 7 presents the top 10 scientific journals ranked by the number of publications, which highlights the journals most interested in this topic. The H-index is a comprehensive indicator used to assess the quantity and quality of a journal's academic output in a specific field[7]. A higher H-index indicates that the journal's articles are more relevant to the research area. Among them, "Sustainability" has an H-index of 13.

3.5. Keywords Clustering Analysis

In the literature, keywords play a significant role in understanding research and its direction, aiding in the identification of research gaps. Keywords that frequently appear indicate research hotspots [7]. In this section, a co-occurrence analysis of keywords was conducted to systematically identify connections between different themes across three defined periods. The results of the keyword analysis show that the conceptual evolution of research topics is interconnected through clusters of keywords. Out of 866 eligible keywords, we selected 55. As shown in Figure 7, the association between "Artificial intelligence" and "higher education" is particularly strong, with 41 (43) links and a total link strength of 106 (105).

In this study, the frequent occurrence of keywords is crucial for ensuring the visibility of articles in relation to current and past research issues. Thick connecting lines indicate a close relationship between two items, while a large node size signifies a high frequency of occurrence for the item.

4. Summary

By conducting bibliometric and visual analysis of domestic research literature on artificial intelligence in teaching, this paper reveals the current development status, research hotspots, evolutionary trends, and research frontiers in this

field. The main conclusions are as follows:

1) The field is developing rapidly, with research maintaining stable attention in recent years.

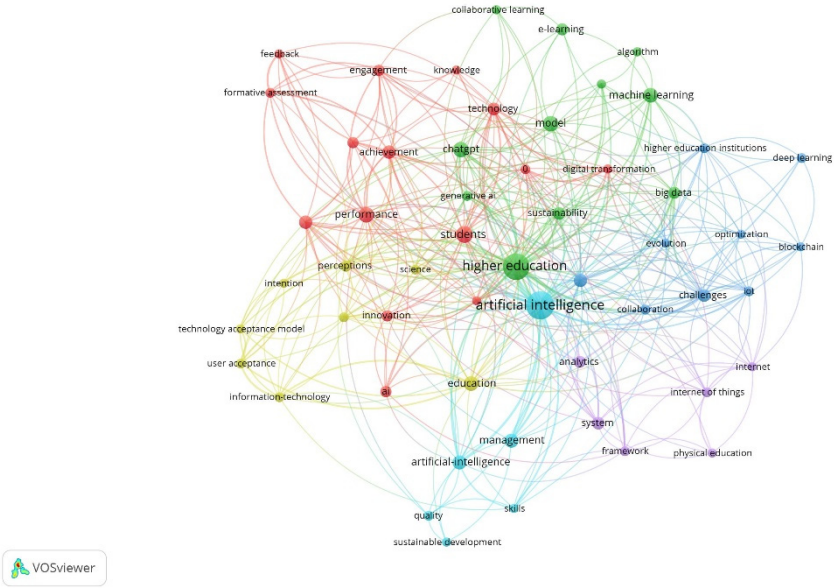

Figure 8. Keywords Analysis

2) Institutional cooperation is relatively loose, and a stable scientific research cooperation network has not yet been formed. Scholarly collaboration is relatively limited, showing small-scale characteristics. Judging from the publication output of scholars, a group of scholars with high scientific research productivity has not yet been formed. In the future, inter-institutional exchanges and cooperation should be further strengthened, scholars should be encouraged to collaborate across fields and institutions, broaden their research horizons, and enhance overall scientific research capabilities.

3) The trend of research evolution is evident. With the continuous maturation of technology and the deepening of applications, research content has gradually shifted from initial conceptual exploration to in-depth integration and reflection, focusing on the actual effects and potential problems of artificial intelligence technology in the application of higher education teaching.

Acknowledgments

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