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Artificial Intelligence in Libraries, A Multifaceted Analysis of Integration, Impact, and Collaboration Dynamic

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ABSTRACT

This study investigates the centrality and density of the 'Artificial Intelligence' cluster within interdisciplinary research networks, contrasting it with thematic clusters like 'prediction' and 'library.' The research aims to assess AI's impact on education and services compared to other thematic clusters. To achieve this, we employed Python analysis tools on a dataset of 587 articles from the Web of Science Core Collection, examining centrality measures and collaboration dynamics. The methodology includes systematic data collection, centrality analysis, and advanced visualisation techniques. The findings indicate AI's high centrality and moderate density, underscoring its pivotal role in driving interdisciplinary research. Comparative analysis reveals AI's broader application potential and influence compared to other clusters. Additionally, insights into country collaborations and centrality measures within clusters illuminate network dynamics and key nodes. Visualisations, such as scatter and box plots, offer comprehensive insights into centrality distribution and relationships within the collaboration network. These results contribute significantly to understanding AI's role in interdisciplinary research, informing strategic planning and resource allocation for future advancements. The broader implications of findings suggest potential practical applications and directions for future research in leveraging AI's influence across various domains.

Keywords: Artificial intelligence; Collaborative networks; Centrality measures; Library science; Centrality and density

1. INTRODUCTION

The integration of AI in libraries offers significant potential for improving information management, retrieval, and analysis. Over time, AI has evolved from basic automation tools to sophisticated systems that personalize user experiences and enhance search algorithms. Early applications of AI in libraries focused on automating cataloging processes, but modern AI systems now drive more complex tasks. Adewojo, A.A., & Dunmade, A.O[1]. like personalised recommendations and advanced data analytics.Key milestones in AI development include the advent of machine learning, the rise of big data, and the recent advancements in natural language processing. Duan, Y., Edwards[2]. These innovations have progressively transformed how libraries operate, enabling more efficient information access and greater user engagement. This study examines the 'artificial intelligence' cluster's role in research, particularly its centrality and density compared to other thematic clusters such as 'prediction' and 'library.' The study aims to explore how AI's high centrality and moderate density influence its integration across diverse domains. Also, it assesses AI's impact on 'education' and 'services' relative to clusters like 'prediction,' 'challenges,'. By understanding these dynamics, the research provides insights into AI's critical role in driving interdisciplinary research, fostering technological advancements, and supporting global collaborations in the digital age.

2. LITERATURE REVIEW

The existing literature on AI applications across various fields shows significant promise but also reveals critical gaps in empirical validation and practical implementation. For instance, Ng[3], *et al.* reviewed AI in nursing care, emphasising documentation and predictive analytics, but highlighted the lack of randomised controlled trials, revealing a gap in robust empirical evidence. Lantada[4] ,et al. explored AI in designing microtextured surfaces for biomedical applications but did not consider its broader implications in material science, leaving a gap in understanding its full impact. In library science, Lund[5], *et al.* examined librarians' perceptions of AI adoption, which revealed varied attitudes but did not explore how these perceptions affect AI implementation, indicating a gap in practical application. Ridley and Pawlick-Potts[6] focused on algorithmic literacy in libraries but lacked empirical data on the effectiveness of programs, pointing to a gap in educating library staff and patrons on AI. Al-Aamri and Osman[7] discussed AI in library knowledge management, identifying challenges but

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lacking a critical analysis of implementation issues, suggesting the need for more detailed studies. Yordy[8] explored AI-generated prior art in patent law, focusing on innovation but not its effects on patent system efficiency, highlighting a gap in understanding AI's broader legal implications. Taha[9], *et al.* reviewed AI in liver diseases and surgery, noting the benefits but overlooking limitations and ethical concerns, while Van Dieren[10], *et al.* demonstrated AI's potential in melanoma diagnosis but did not address challenges in clinical adoption, revealing gaps in translating AI research into practice. In manufacturing, Garois[11], *et al.* proposed an AI model for predicting hardness profiles but did not explore practical implications or scalability, highlighting a gap in real-world industrial applications. Potnis[12], *et al.* classified public library innovations but failed to analyse their long-term impact, while Ekstrand and Strandberg[13] provided an overview of technological trends in Swedish medical libraries without addressing integration challenges, pointing to gaps in practical implementation. Bryant[14], *et al.* emphasised digital literacy in England's NHS for AI-driven healthcare but lacked empirical evidence on the effectiveness of these initiatives.

Collectively, these studies underscore AI's transformative potential while highlighting significant gaps in empirical validation and implementation. This research builds upon these findings, aiming to fill these gaps by providing a critical analysis of AI applications in libraries and offering insights into their practical implementation.

3. METHODOLOGY

The methodology initiated with a search on the Web of Science Core Collection to identify articles on "Artificial Intelligence in Libraries." The criteria included articles published between January 1, 2014, and December 31, 2023, focusing on those relevant to AI in library science. The search yielded 587 articles in RIS format. Also, the methodology had some limitations, such as excluding non-English studies and limiting the scope to articles, potentially omitting valuable research from other formats or databases. For the analysis, data preprocessing was performed by importing the RIS data into a structured dataframe using the Biblioshiny package in RStudio. Python was also used for further analysis within the PyCharm Integrated Development Environment. The Pandas library was crucial for data manipulation, enabling the conversion of raw data into a more usable format. Visualisation of data was conducted using Matplotlib and Seaborn, which provided the necessary tools for creating scatter plots and box plots to represent centrality measures and collaboration dynamics effectively. NetworkX was employed for network analysis, allowing for an in-depth exploration of the relationships and interactions within the dataset. The dataset included 31,868 references, with 1,419 Keywords Plus and 2,384 Author's Keywords highlighting the main themes. The involvement of 2,739 authors and the fact that 29.75 % of collaborations were international underscore the global scope of the research. The study builds on prior research by Ng et al. (2022) and Lantada et al. (2020), addressing gaps in the understanding of AI's specific applications in library science. This comprehensive analysis aims to guide future research, strategic planning, and resource allocation within the field.

4. RESEARCH QUESTIONS

Artificial intelligence (AI) is becoming increasingly central to various research fields, influencing technological advancements and interdisciplinary collaborations. To understand its impact comprehensively, we explore key aspects of AI's role within research networks.

Key Terms

- **Centrality:** A measure of the importance or influence of a node (in this case, the 'artificial intelligence' cluster) within a network.
- **Density:** A measure of how tightly connected the nodes within a cluster are.
- **Impact:** The overall influence of a cluster, often gauged by citation metrics and the reach of its contributions.
- **Betweenness centrality:** Measures the extent to which a node lies on the shortest paths between other nodes, reflecting its role as a connector or broker in a network.
- **Closeness centrality**: Measures how quickly a node can reach all other nodes in the network, indicating its overall accessibility and proximity to others.

RQ1: How do the high centrality and moderate density of the 'artificial intelligence' cluster influence the development and integration of AI technologies in various research fields, compared to other clusters such as 'prediction' with centrality and density or 'library' with centrality and high density?

RQ2: How does the high impact and centrality of the 'artificial-intelligence' cluster, particularly in the contexts of 'education' and 'services,' influence advancements in these fields compared to other clusters such as 'prediction' and 'challenges' or 'drug discovery' with varying levels of impact and centrality?

RQ3: What are the key determinants influencing the intensity and directionality of country collaborations, as evidenced by the frequency and geographic distribution of collaborative relationships among nations?

RQ4: How do the centrality measures (Betweenness, Closeness, and PageRank) of nodes within different clusters affect the structure and cohesiveness of the collaboration network?

5. DATA ANALYSIS AND DISCUSSION

5.1 High Centrality and Moderate Density of the 'Artificial Intelligence' Cluster: Implications for Development and Integration Across Research Fields.

The dataset analysis visualised the relationship between Callon Centrality and Callon Density across various clusters. The generated scatter plot in Fig. 1 provides insightful visualisation, allowing for easy identification of patterns and outliers among the clusters.

To validate RQ1, data analysis focuses on centrality and density across clusters. Visualisation emphasises their significance, with key clusters highlighted in red. The 'artificial intelligence' and 'prediction' clusters are pivotal, connecting network parts, while the 'library' clusters maintain internal cohesion. Variability in centrality and density indicates diverse cluster roles, from bridging to internal connectivity. This visualisation offers insights into network structure, identifying key clusters based on centrality and density.

- Callon Centrality measures the importance of a cluster within the research network by quantifying how well-connected it is to other clusters.
- Callon Density assesses the internal cohesion of a cluster by evaluating the strength of connections within the cluster itself.
- The 'artificial intelligence' (AI) cluster stands out with the highest Callon Centrality (8.59), indicating its crucial role as a hub for interdisciplinary collaboration within the research network. Its moderate density (49.50) suggests a balanced internal structure, supporting AI's broad adoption and influence. In contrast, the 'prediction' cluster has lower centrality (6.23) and slightly higher density (54.41), reflecting strong but less influential integration. The 'library' clusters, with low centrality and high density, indicate strong internal collaboration but limited interdisciplinary impact, highlighting AI's unique role in driving diverse research and technological advancements.

These findings justify the research question's focus on understanding AI's unique development and integration across various domains, informing strategic planning and resource allocation for future advancements. The 'artificial intelligence' (AI) cluster stands out with the highest Callon Centrality (8.59), indicating its crucial role as a hub for interdisciplinary collaboration within the research network. Its moderate density (49.50) suggests a balanced internal structure, supporting AI's broad adoption and influence. In contrast, the 'prediction' cluster has lower centrality (6.23) and slightly higher density (54.41), reflecting strong but less influential integration. The 'library' clusters, with low centrality and high density, indicate strong internal collaboration but limited interdisciplinary impact, highlighting AI's unique role in driving diverse research and technological advancements. These findings justify the research question's focus on understanding AI's unique development and integration across various domains, informing strategic planning and resource allocation for future advancements

5.2 Impact of 'Artificial Intelligence' Cluster in Education and Services: A Comparative Analysis with other Clusters

Figure 2 presents a scatter plot generated using Python code to illustrate the relationship between centrality and impact across various clusters. In this plot, the x-axis represents centrality, the y-axis represents impact, the size of the points indicates frequency, and different clusters are distinguished by colour. Each point is labelled accordingly. This visualisation addresses the research question by comparing the artificial intelligence cluster's impact and centrality in the domains of education and services with other clusters, such as prediction, challenges, and drug discovery. The scatter plot reveals how AI's significant impact and centrality in education and services contribute to transformative changes, improved efficiencies, and

Table 1. Cluster analysis metrics

Cluster	Callon centrality	Callon density	Rank centrality	Rank density	Cluster frequency
prediction	6.229884986	54.41347552	29	15	274
impact	2.524729151	56.73380463	27	16	62
library	1.727436444	72.54166667	26	24	83
cohort	0.5	75	22.5	26	6
model	4.083486853	48.69218474	28	2	158
artificial-intelligence	8.590311959	49.50115203	30	3	320
de-novo design	0.25	75	21	26	8
inhibitors	1.608333333	60.546875	25	18	26
assist	0	66.66666667	9.5	21.5	6

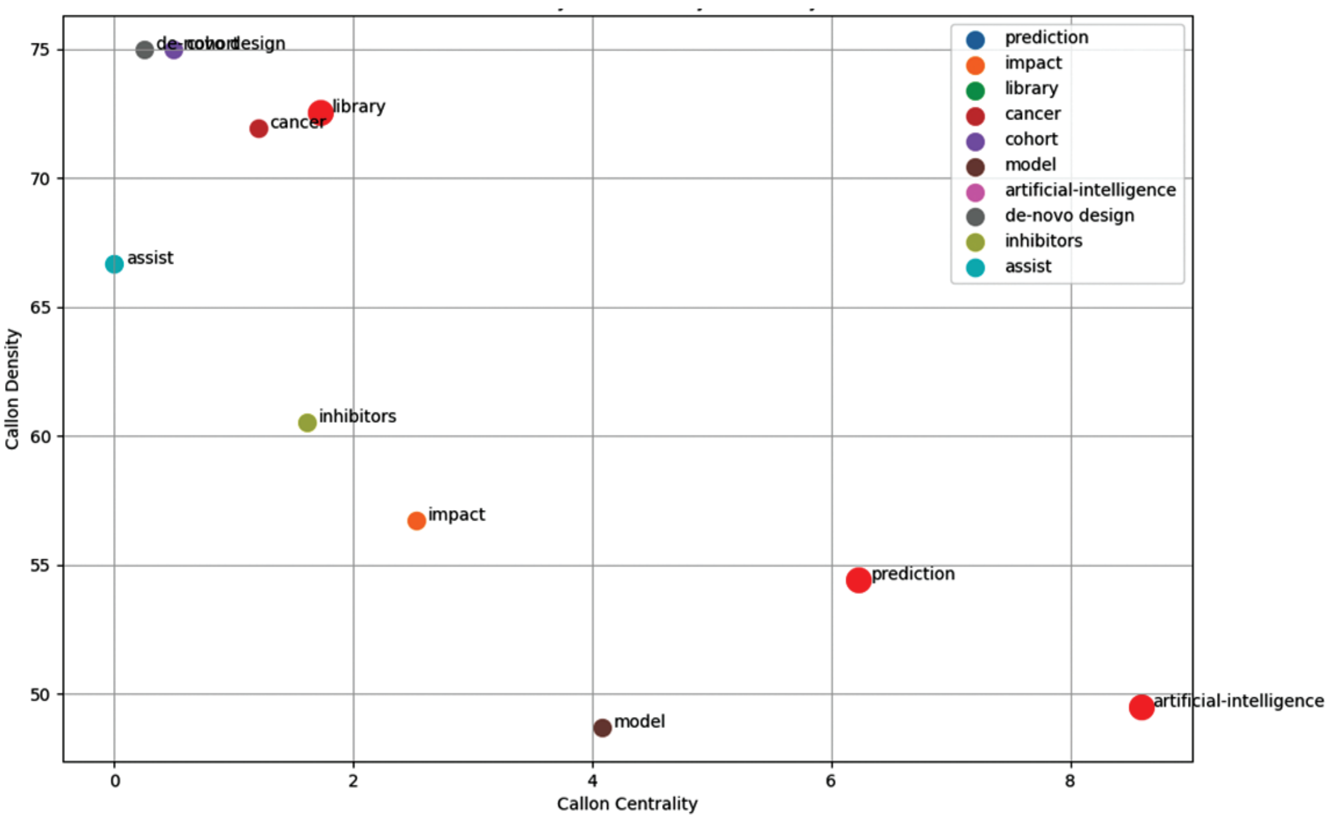

Figure 1. Cluster analysis: centrality vs. density.

innovative solutions. By comparing AI's role with other clusters, the plot helps to understand AI's influence on learning outcomes, service delivery, and emerging challenges. This analysis provides insights into AI's unique strengths and limitations compared to other thematic clusters, enriching the understanding of AI's role across various fields. Thus, Fig. 2 directly supports the research question by highlighting how AI's centrality and impact in key areas differentiate it from other clusters.

5.3 Determinants of Country Collaborations: Frequency and Geographic Distribution Analysis

Figure 3 presents a comprehensive analysis of country collaborations, highlighting several key determinants. Notably, high collaboration frequencies are observed between major research powerhouses such as the USA and China. Most collaborations occur infrequently, with many countries engaging in only 1 or 2 collaborative efforts. Higher collaboration frequencies often indicate stronger and more sustained research relationships. For

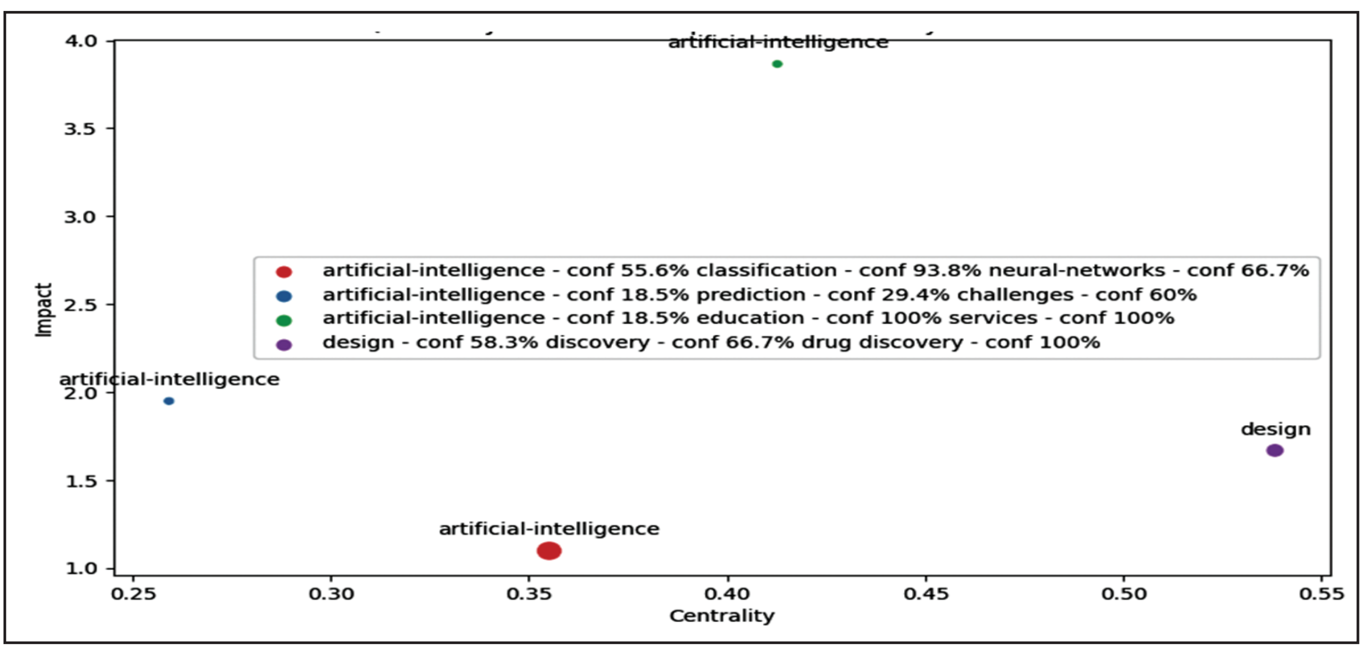

Figure 2. Impact and centrality in different clusters.

instance, collaborations between continents-such as those between North America and Asia (e.g., USA-China, USA-Germany)-highlight global research ties. Conversely, regional clusters, influenced by factors such as geographical proximity, historical ties, or economic connections, are also evident. Collaborations between neighboring countries can have significant geopolitical implications. Significant collaborations, especially those involving major economic players like the USA and China, stand out due to their frequency and strategic importance. The increasing number of collaborations involving China, in particular, signals a shift in global research dynamics. By recognising emerging trends and key partnerships, it can better anticipate future developments in global research collaborations and identify strategic areas for expansion and collaboration.

5.4 Impact of Centrality Measures on Collaboration Network Structure.

Tables 2 and 3 offer insights into centrality measures within Cluster 1. Nodes like ‘cox am’, ‘liu d’, ‘liu y’, and ‘wang f’ have zero betweenness centrality, indicating no bridging role, while ‘huang y’ has a high betweenness centrality of 113.20, highlighting its critical network role. Clusters 8 and 9 show strong internal connectivity with a closeness centrality of 1.00. Clusters 3, 4, and 2 exhibit the highest betweenness centrality, emphasising their bridging functions. Variations in PageRank across clusters reflect differing node influence. These measures offer a detailed understanding of the network’s structure and dynamics.

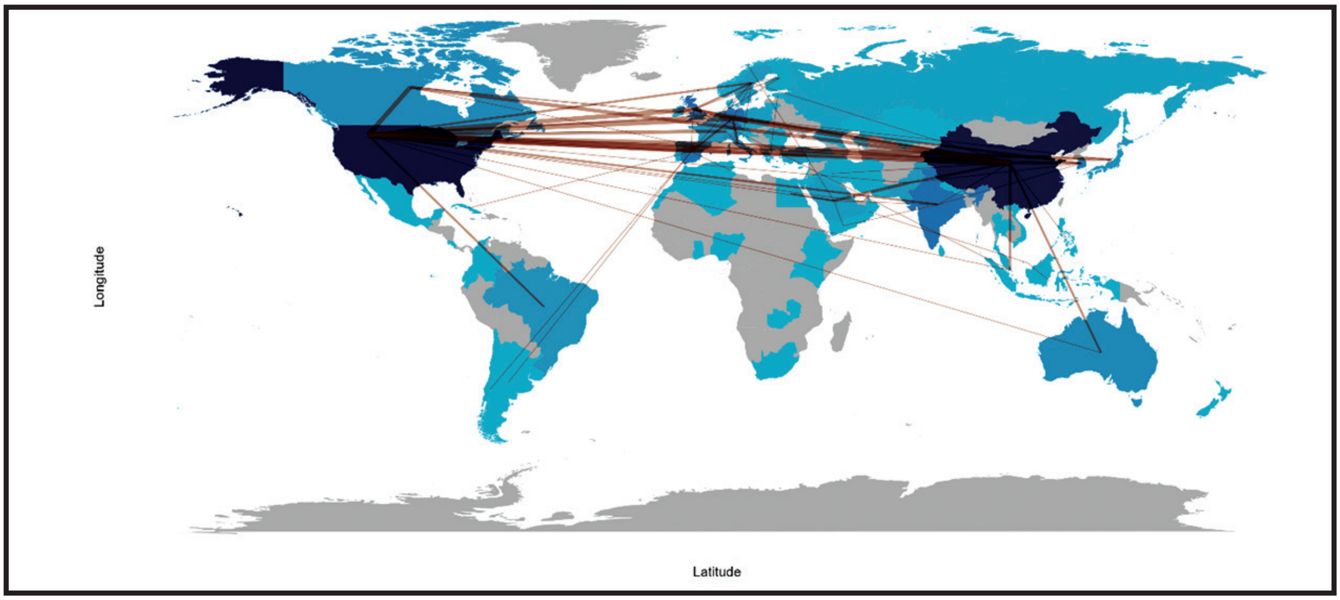

Figure 3. Country collaboration map.

Table 2. Centrality measures of nodes in cluster 1

Node	Cluster	Betweenness	Closeness	Page rank
cox am	1	0.000000	0.006623	0.008315
huang y	1	113.204762	0.008929	0.035166
liu d	1	0.000000	0.007634	0.017331
liu y	1	0.000000	0.006061	0.008430
wang f	1	0.000000	0.006623	0.008315

Table 3. Centrality measures by cluster

Cluster	Betweenness	Closeness	Page rank
1	29.864286	0.007301	0.017923
2	49.341403	0.008294	0.020801
3	64.299236	0.009221	0.026794
4	62.180728	0.009217	0.026294
5	16.333333	0.006321	0.015631
6	21.633477	0.008666	0.022960
7	27.087798	0.007976	0.020933
8	0.000000	1.000000	0.022222
9	0.000000	1.000000	0.022222

Figure 4 summarises centrality measures (Betweenness, Closeness, and PageRank) across clusters in the collaboration network. The plots display centrality score distributions, with the median marked by a central line and the interquartile range (IQR) capturing the middle 50 %. Wider distributions indicate greater variability in node importance, while higher median values suggest stronger connectivity. PageRank plots identify influential nodes, and correlation matrices reveal relationships between centrality measures, offering insights into the network’s structure and dynamics.

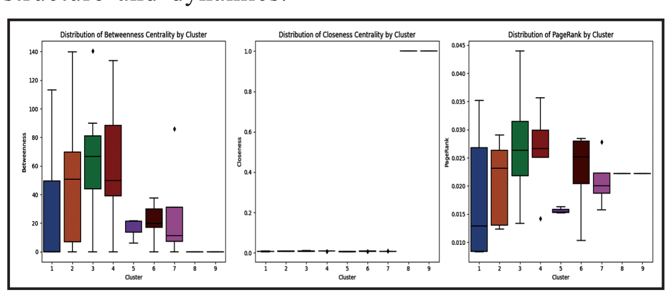

Figure 4. Distribution of betweeness, closeness and page rank by cluster.

6. CONCLUSION

The analysis reveals that the 'artificial intelligence' (AI) cluster plays a crucial role in research and technological advancements. With the highest centrality among clusters, AI significantly influences various research domains, fostering integration and innovation. Its moderate density reflects adaptability and ongoing field diversification. When compared with clusters like 'prediction' and 'library,' AI demonstrates broader application potential and greater influence. The study of AI's impact on education and services highlights its transformative role in critical areas. Insights into country collaborations reveal diverse global dynamics and implications for authors. Centrality measures within clusters clarify network structure, identifying key nodes essential for optimisation. Visualisations, including scatter and box plots, provide detailed views of centrality distribution and network relationships, aiding strategic planning. However, the study's reliance on the Web of Science Core Collection may omit relevant literature from other databases. Future research should broaden the dataset and include qualitative studies to further explore AI's impact across various fields. The findings underscore AI's importance in advancing interdisciplinary research and guiding future directions.

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