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Progress, hot spots and findings of the research on curriculum knowledge graph in China—Based on CiteSpace CNKI literature analysis in the past 13 years

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Abstract: By using visualization software CiteSpace 6.2R6, the literature on curriculum knowledge graph in China National Knowledge Network (CNKI) from 2010 to 2023 was measured and analyzed in terms of the annual number of publications, research institutions and authors, and research topic clustering. It is found that the core research institutions are Central China Normal University, Yunnan Normal University, Huazhong University of Science and Technology, etc., and the exchanges and collaboration between the research institutions and scholars in the academic field are not close enough. The hot research topics include flipped classroom, learning path, entity recognition, data structure, etc., which can be summarized into three theme areas: "teaching", "personalized learning" and "technical support". The future unified research trend is not clear, and resource recommendation is one of the trends in the study of curriculum knowledge graph in China.

1. Introduction

With the rapid development of artificial intelligence technology and the steady progress of digital campus construction, internet education is moving into a new stage of intelligent education development. As an important branch of artificial intelligence technology, knowledge graphs have gradually been widely applied in the fields of education, healthcare, finance, etc. China's New Generation Artificial Intelligence Plan points out that advanced technologies, such as knowledge processing, deep search, and visual interaction, should be utilized to continuously improve the efficiency of artificial intelligence. According to different needs, information should be quickly, accurately collected, analyzed, inferred, and displayed from different fields, disciplines, and data, thus forming a knowledge graph covering hundreds of millions of entities. [1]

Taking the field of education as an example, a knowledge graph is a technical method that describes things and their relationships, which can represent the relationships between various

knowledge points and resource entities in a graphical form.[2] Curriculum knowledge graphs are gradually refined based on disciplinary and professional knowledge graphs, targeting the construction of a knowledge structure for a specific course, involving all knowledge points in the disciplinary field and the relationships between knowledge points, in order to better deduce the correlation between knowledge points and learning paths.[3]

To quickly grasp the progress, hot spots, and characteristics of curriculum knowledge graph research in China, this paper uses CiteSpace software for visual analysis of literature on curriculum knowledge graphs published on the CNKI platform, hoping to provide valuable ideas for subsequent research and construction of curriculum knowledge graphs.

2. Research Design

2.1. Data Source

This paper takes the China National Knowledge Infrastructure (CNKI) as the information source, selects the theme words "curriculum" and "knowledge graph," with a time span from 2010 to 2023, and retrieves 546 documents including journal articles, dissertations, and conference papers. After data cleaning, excluding non-academic papers such as social comments and conference notices, as well as supplements, a total of 308 valid records were obtained, including 194 journal articles and 114 master's and doctoral dissertations.

2.2. Research Design and Method Selection

This paper combines quantitative and qualitative research organically, using bibliometric and word frequency analysis methods for quantitative analysis of related literature, supplemented by qualitative research.

The research tool selected is CiteSpace 6.2 R6, launched by Professor Chen Chaomei and his team from Drexel University in Philadelphia, USA. This software can visualize literature information such as keywords, research institutions, and authors, making it clearer to understand the research status and latest dynamics in a certain field, and explore the evolution and research frontiers of disciplinary knowledge fields.

The article focuses on the basic characteristics of selected papers, such as the analysis of the distribution of publication times, core authors, and core research institutions; followed by the analysis of hot spots and trends in curriculum knowledge graph research in China.

3. Research Process and Results

3.1. Literature Publication Shows a Feature of Thick Accumulation and Thin Eruption in the Past 6 Years

With the advancement of information technology， New technologies such as artificial intelligence and big data provide support for the construction of knowledge graphs, curriculum knowledge graphs have gradually attracted widespread attention from Chinese researchers. Figure 1 shows the change in the number of research papers on curriculum knowledge graphs published in the China Academic Network Publishing Total Database (CNKI) over the years. According to the chart, the first research paper was published in 2010, and from 2010 to 2017, the number of published articles was relatively small, not exceeding 10, with a small fluctuation in the number of publications. However, as time progressed, there was a significant increase starting in 2018, especially between 2021 and 2023, when the number of published articles exceeded 60, reaching a

peak of 69 in 2023.

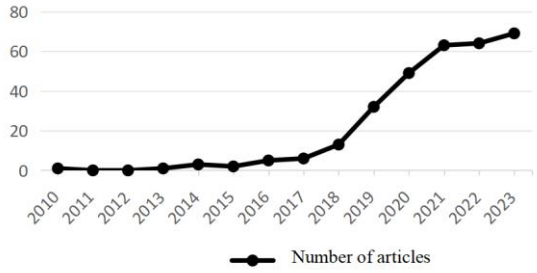

Figure 1 Number of Publications per Year.

3.2. Research Institutions Show a Scattered State, with the Central China Normal University Team Leading

By counting the number of papers published by authors' research institutions from 2010 to 2023, the results show that Central China Normal University (16 papers), Yunnan Normal University (10 papers), Huazhong University of Science and Technology (7 papers), Inner Mongolia Normal University (7 papers), and Wuhan University (7 papers) are in the top five, having a significant influence and representation in curriculum knowledge graph research. Jilin University (6 papers), East China Normal University (5 papers), Harbin Institute of Technology (5 papers), Nanjing University of Science and Technology (5 papers), and Northeast Normal University (5 papers) are ranked sixth to tenth, contributing to the research on knowledge graphs to some extent.

Through the visualization analysis of cooperation and influence among academic institutions between 2010 and 2023 using CiteSpace, we obtained an institution co-occurrence map with TOP N=50, 142 nodes, 45 lines, and a density of 0.0045. From the generated map, it can be seen that the nodes of Central China Normal University and Yunnan Normal University are relatively large, and the larger the node, the more papers published, indicating that these two institutions have published more papers and have stronger academic research capabilities in curriculum knowledge graph research in China. However, it can be seen from the map that there are fewer lines between nodes, and the number of lines represents the connection between nodes. The more lines, the closer the connection between nodes. It can be known that the current cooperation is mainly within institutions or teams, belonging to the exchange of knowledge and resources within the same college or team, and the connection between different institutions is not very obvious and extensive.

3.3. Research is Still in the Emerging Stage, and Core Team Leaders are Ready to Go

Using CiteSpace and setting the node type to authors, we obtained an author co-occurrence map with 197 nodes, 114 lines, and a density of 0.0059. From the figure, it can be seen that the size of each author node is similar, which is because their publication volume is 2 papers and below, and there are no obvious high-output authors. Due to mutual exchanges and cooperation, several author sub-network structures have been formed in the map, such as the network structure composed of Ma Teng, Zhou Zili, Gao Shulin, Ni Ruikang, Li Yanru, and Wang Yanbing. However, there is no obvious core figure in each network structure, and no core group of cooperating authors has been formed. This indicates that although curriculum knowledge graphs have gradually attracted widespread attention from scholars, the research is still in the emerging stage, and there is no core author with a leading role that has an important guiding significance for non-core academic researchers. Moreover, scholars' academic exchanges and cooperation in curriculum knowledge graphs are not close enough, and there is an urgent need to strengthen the awareness of

communication and cooperation.

3.4. Research Themes and Hotspots Show a Gradually Gathering State, Focused on Keywords Such as "Learning Path"

Research hotspots can be seen as the core of a discipline, helping us better understand and analyze the research content of the field. Keywords are a general expression, a summary and refinement of each paper, and a high frequency of keywords in a certain field reflects the research hotspots of that field.[4] Keyword clustering analysis is a process that simplifies many complex keywords into fewer, more explicit classifications based on keyword co-occurrence analysis, making it clear at a glance.[5] This paper will use this method to delve into the research hotspots of curriculum knowledge graphs in China, in order to obtain more valuable information. Running CiteSpace and setting the node type to keywords, with the same parameters as the institution parameters, based on the high-frequency keyword co-occurrence visualization map, using the LLR algorithm, we obtained a keyword clustering network map as shown in Figure 2. The map shows 8 clusters: "knowledge graph," "learning path," "entity recognition," "big data," "data structure," "resource recommendation," "data structure" and "quality education," reflecting the research hotspots in the field of curriculum knowledge graphs in China.

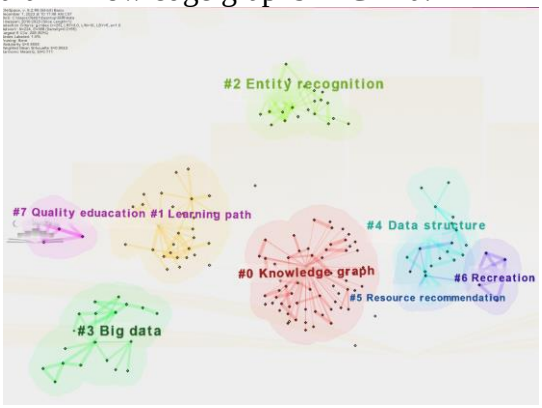

Figure 2 Map of Keywords Clustering.

Based on the keyword clustering map, through the log-likelihood ratio analysis, we obtained a keyword co-occurrence network clustering table (see Table 1).

Table 1 Keyword Co-occurrence Network Clustering Table (Limited by space, only the top 5 clusters are presented.)

cluster	size	Contour value	Average year of publication	Tag word
0	64	0.975	2020	Knowledge graph, learning path, graph database, new engineering, data structure
1	29	0.908	2020	Learning paths, artificial intelligence, collaborative filtering, recommendation algorithms, data mining
2	25	0.913	2020	Entity recognition, deep learning, relationship extraction, web programming, learning elements
3	21	0.971	2018	Big Data, teaching, MOOCs, Knowledge graph, Flipped classroom
4	19	0.893	2020	Data structure, Applied research, ontology, educational resources, preemptive relations

Through the analysis of the keywords in each cluster, it is found that there is an overlap in the research content of each cluster. Therefore, the research on curriculum knowledge graphs in China

can be summarized into three thematic areas: "teaching," "personalized learning," and "technical support." Details are as follows:

1) "Teaching" research theme. The "teaching" field includes keywords such as "knowledge graph" and "flipped classroom." The construction of curriculum knowledge graphs is ultimately to serve education and teaching. From existing literature, we are pleased to find that many scholars have explored teaching optimization methods based on knowledge graphs for specific disciplines or courses, such as "Construction and Application of Curriculum Knowledge Graph Teaching Platform for 'Ventilation Engineering' Course" [6] and "Systematic Application of 'Knowledge Graph' in Tourism Management Discipline Course Teaching" [7]. From the perspective of educational levels, the practice of applying knowledge graphs to teaching is mainly concentrated in the higher education stage, and there are also attempts in other educational stages, such as "Research on Personalized Learning Resource Recommendation System for Junior High School Mathematics Based on Knowledge Graph" [8] and "Design and Application of Python Teaching Case for Secondary Vocational Education Based on Knowledge Graph" [9]. However, the existing literature mainly builds knowledge graphs for science and engineering courses, and there are not many documents for humanities and social science courses. The current status of curriculum knowledge graph construction at Tongji University also reflects this point. Among the schools that have built curriculum knowledge graphs, the top three in terms of the number of courses built are the School of Aerospace and Mechanics, the School of Mathematical Sciences, and the School of Medicine, and the School of Transportation Engineering (tied for third), all of which are science and engineering colleges. It is speculated that there are two reasons for this: First, the differences in courses themselves, some science and engineering courses have a large number of knowledge points and complex interrelationships, making it difficult for students to quickly and accurately grasp them, thus requiring a visual and intuitive knowledge graph for guidance; second, the differences in teachers' knowledge reserves, teachers of different disciplines should have a comprehensive and in-depth understanding of their own professions and courses, however, teachers of humanities and social science may not have the technology and methods to build knowledge graphs on their own, and need to rely on external support and help, which to some extent hinders the construction of knowledge graphs for humanities courses.

2) "Personalized Learning" research theme. The "personalized learning" field includes keywords such as "knowledge graph," "learning path," "educational resources," and "prerequisite relationships," focusing more on how to apply after the construction of the knowledge graph. In the era of information explosion, learners often face a vast amount of information. Researchers, from the perspective of learners, try to use knowledge graphs to filter out suitable learning content from a large volume of learning resources, allowing learners to follow personalized learning paths, master knowledge points from easy to difficult one by one, and thus improve overall learning effectiveness. For example, Li Ba Ke and others have developed a personalized learning resource recommendation system based on knowledge graphs, which can recommend learning resources that meet the needs of different students according to their own knowledge reserves and course knowledge graphs. [10] Some scholars have also focused on the online education platform "MOOC." As a new educational model, MOOC has a large amount of educational resources but also has problems such as lack of guidance for learners and lack of feedback on learning situations. In this context, Zhang Boya proposed a learning path planning method based on knowledge graphs for the MOOC platform. [11]

3) "Supporting Technology" research theme. The "supporting technology" field includes keywords such as "graph database," "data mining," "entity recognition," and "relationship extraction," focusing on the construction process of knowledge graphs. Building a complete knowledge graph requires the use of various key technologies, including establishing an effective

basic framework, accurately identifying entities, extracting the relationships between entities, and integrating this information.[12] Most of these studies have proposed different curriculum knowledge graph design schemes, such as Yan Bo, based on HanLP keyword extraction and syntactic analysis, converting the text information of professional courses into a graph form for knowledge graph construction[13]; Zhu Jiale completed the curriculum knowledge graph system design based on Neo4j, etc..[14] In addition, some studies start from the cultivation of a new generation of applied talents and the improvement of knowledge graph construction capabilities, clarifying the teaching objectives, content, methods, and assessment methods of knowledge graph courses in artificial intelligence majors, allowing students to have a comprehensive understanding of knowledge graphs and improve practical capabilities. [15]

3.5. Research Trends are Not Yet Clear, and the Demand for Intelligent Resource Recommendation is Relatively High

Burst words refer to keywords that are cited frequently within a certain period and can reflect the research trends of that period. In this regard, to further explore the development trends of curriculum knowledge graph research in China, CiteSpace was run, and the "Burstness" was selected to obtain a keyword burst map (see Figure 3).

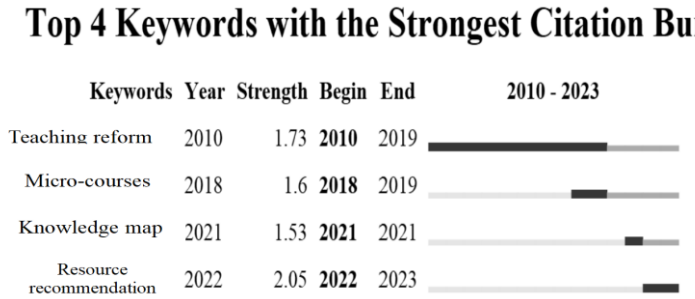

Figure 3 Map of Keywords Burst.

From the map, it can be seen that the burst words from 2010 to 2019 are "teaching reform"; the burst words from 2018 to 2019 are "micro-courses"; the burst word for 2021 is "knowledge map"; and the burst words for 2022-2023 are "resource recommendation." Among them, the burst rate of "resource recommendation" has continued to this day, indicating that the current research on curriculum knowledge graphs mainly stands from the perspective of learners, with the goal of screening and pushing high-quality and accurate learning resources. In addition, the burst intensity of the four keywords is relatively low, indicating that scholars have chosen a more dispersed entry point in the research on curriculum knowledge graphs, and no large-scale common research trend has been formed.

4. Outlook and Suggestions

Taking "curriculum knowledge graph" as the theme, and the literature published on CNKI from 2010 to 2023 as the research object for bibliometric and visualization analysis, the following conclusions can be drawn:

1) The literature publication shows a feature of thick accumulation and thin eruption in the past 6 years. Judging from the current number of research papers on curriculum knowledge graphs, the total number of papers published is increasing year by year, and the number of papers published has gradually increased since 2018, indicating that the research on curriculum knowledge graphs is gradually receiving attention.

2) Research institutions show a scattered state, with the Central China Normal University team leading. According to the research institutions, except for Central China Normal University, the gap in the number of papers published by other institutions is relatively small, and the number of connections between institutions is relatively small, indicating that most institutions are conducting research independently and lack the necessary cooperation. In the future, institutions should strengthen their sense of cooperation and actively share cooperative experiences to promote the progress and efficiency of curriculum knowledge graph research.

3) Research is still in the emerging stage, and core team leaders are ready to go. From the main author group, there is no obvious high-output author, and there is little cooperation between them, indicating that researchers lack the awareness of active cooperation, and the research field is relatively dispersed. Scholars should further strengthen cooperation to enable the research field of curriculum knowledge graphs to intersect and integrate with each other, promoting the development of curriculum knowledge graph research to be more integrated and systematic.

4) Research themes and hotspots show a gradually gathering state, focusing on keywords such as "learning path." The research on curriculum knowledge graphs in China mainly revolves around teaching, personalized learning, and supporting technology themes, and the prerequisite for personalized learning—resource recommendation—has been a significant focus from burst to the present, indicating that these aspects are existing and need to be paid attention to in curriculum knowledge graph research. Therefore, attention should be paid to the application of curriculum knowledge graphs in teaching in the future, providing necessary conditions and technical support for the construction of knowledge graphs, gradually building a comprehensive knowledge graph that includes disciplines such as humanities and social sciences, helping students establish a clear and complete knowledge framework; outlining learner portraits, formulating personalized learning paths, pushing suitable learning content and questions for them, and timely checking the effectiveness of learning outcomes; continuously exploring the possibilities of knowledge graph construction in technology, improving construction efficiency and feasibility; optimizing the design of knowledge graph courses in artificial intelligence majors, and enhancing students' practical capabilities to cultivate reserve talents for the construction and research of knowledge graphs.

5) Research trends are not yet clear, and the demand for intelligent resource recommendation is relatively high. This requires researchers to focus more on the effectiveness and timeliness of resource push to meet the growing and diversified needs of learners.

In summary, as a key enabling technology for the application of artificial intelligence in education, the long-term development of curriculum knowledge graphs cannot be separated from two driving forces: one is technical support, and the other is educational care. The development of technology provides the possibility for knowledge graphs to "show their strength" in the field of education, and the care of education integrates the traditional and wise concept of "teaching students according to their aptitude" into the pursuit of large-scale personalized learning. If we can adhere to the original intention of "running education for people," resolve technical difficulties one by one, we can promote the construction and research of curriculum knowledge graphs in China to move forward, ultimately serving the majority of teachers and students, and benefiting many seekers of knowledge.

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