

Retraction

Retracted: Summary and Evaluation of the Application of Knowledge Graphs in Education 2007–2020

Discrete Dynamics in Nature and Society

Received 10 October 2023; Accepted 10 October 2023; Published 11 October 2023

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This article has been retracted by Hindawi following an investigation undertaken by the publisher [1]. This investigation has uncovered evidence of one or more of the following indicators of systematic manipulation of the publication process:

- (1) Discrepancies in scope
- (2) Discrepancies in the description of the research reported
- (3) Discrepancies between the availability of data and the research described
- (4) Inappropriate citations
- (5) Incoherent, meaningless and/or irrelevant content included in the article
- (6) Peer-review manipulation

The presence of these indicators undermines our confidence in the integrity of the article's content and we cannot, therefore, vouch for its reliability. Please note that this notice is intended solely to alert readers that the content of this article is unreliable. We have not investigated whether authors were aware of or involved in the systematic manipulation of the publication process.

Wiley and Hindawi regrets that the usual quality checks did not identify these issues before publication and have since put additional measures in place to safeguard research integrity.

We wish to credit our own Research Integrity and Research Publishing teams and anonymous and named external researchers and research integrity experts for contributing to this investigation.

The corresponding author, as the representative of all authors, has been given the opportunity to register their agreement or disagreement to this retraction. We have kept a record of any response received.

References

- [1] Y. Mao, "Summary and Evaluation of the Application of Knowledge Graphs in Education 2007–2020," *Discrete Dynamics in Nature and Society*, vol. 2021, Article ID 6304109, 10 pages, 2021.

Review Article

Summary and Evaluation of the Application of Knowledge Graphs in Education 2007–2020

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Received 26 July 2021; Revised 27 August 2021; Accepted 13 September 2021; Published 28 September 2021

Academic Editor: Ahmed Farouk

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Since 2007, knowledge graphs, an important research tool, have been applied to education and many other disciplines. This paper firstly overviews the application of knowledge graphs in education and then samples the knowledge graph applications in CSSCI- (Chinese Social Sciences Citation Index-) indexed journals in the past two years. These samples were classified and analyzed in terms of research institute, data source, visualization software, and analysis perspective. Next, the situation of knowledge graph applications in education was summarized and evaluated in detail. Furthermore, the authors discussed and assessed the normalization of knowledge graph applications in education. The results show that in the past 15 years, knowledge graphs have been widely used in education. The academia has reached a consensus on the paradigm of the research tool: examining the hotspots, topics, and trends in the related fields from the angles of keyword cooccurrence network (KCN), time zone map, clustering network, and literature/author cocitation, with the aid of CiteSpace and other visualization software and text analysis. However, there is not yet a thorough understanding of the limitations of the visualization software. The relevant research should be improved in terms of scientific level, normalization level, and quality.

1. Introduction

Knowledge graphs provide an extensively applied research tool. Since 2007, many domestic scholars have successfully introduced this tool to study the cooperative research models, hotspots, topics, and trends in their research domains. On June 7th, 2021, our research team found 6,277 Chinese papers with “knowledge graphs” in their titles on CNKI and 3,342 foreign papers with the same words in their titles on the Engineering Index Database. However, the research tool and its supporting software [1] were developed in foreign countries and have not been applied for a very long time. Therefore, the application of knowledge graphs in education and other disciplines generally faces problems like poor research quality and low scientific and normalization levels.

Literature research shows that a handful of scholars discussed the effectiveness [2, 3] and normalized use of knowledge graphs, and some put forward suggestions for

improving and innovating the paradigm of CiteSpace research in Chinese journals [4, 5]. But very few Chinese researchers have systematically reviewed or evaluated the scientific and normalization levels of the domestic papers on the application of knowledge graphs. Tang [6] published “Review and Evaluation of the Empirical Research Essays in Domestic Knowledge Mapping Areas,” which is one of the few papers that deal with the said issue. There is virtually no report on the summary and evaluation of knowledge graph applications in education.

Inspired by Kuhn’s [7] paradigm theory and other scholars’ discoveries [8, 9], following the basic requirements [10–13] on empirical papers of social sciences [14, 15], this paper summarizes the academic papers and graduation theses in CNKI, as well as the published books, which report the application of knowledge graphs in education, under the analysis framework of Tang [6]. On this basis, the authors evaluated the scientific and normalization levels of the knowledge graph applications in CSSCI- (Chinese Social

Sciences Citation Index-) indexed journals in 2019–2020. The purpose is to systematically review the evolution, application state, and future trends of knowledge graph applications in education in China and promote the healthy implementation of the research tool in the field of education.

2. Overview of Knowledge Graph Applications in Education

This paper queries for each of the three types of literature, namely, academic papers, graduation theses, and books, and carries out a comprehensive analysis in terms of the annual distribution of literature quantity, distribution of high-yield institutions, distribution of prolific authors, and distribution of research topics.

2.1. Knowledge Graph Applications in Academic Papers. The authors queried for the existing papers on CNKI about knowledge graph applications in education (query date: June 7th, 2021) and obtained 1,073 records after discrimination and screening. Figure 1 shows the annual distribution of literature quantity.

As shown in Figure 1, Chinese education researchers first studied knowledge graph applications in 2007. The earliest published paper was authored by Peng et al. at the Dalian University of Technology, which is titled “Knowledge Graph Analysis on the Research State of International Entrepreneurship University” [16]. This is the earliest application of knowledge graphs in education. It is only two years later than the first domestic attempt to apply knowledge graphs [17].

From the annual distribution of the quantity of academic papers, it can be seen the number of knowledge graph applications in education has been exploding since 2011, especially in the past three years. More than 200 academic papers were published in each of these three years.

The top 10 high-yield institutions are listed as follows: Shaanxi Normal University published the most academic papers (56), Beijing Normal University (32), Nanjing Normal University (29), Central China Normal University (27), Wenzhou University (23), Henan University (21), Southwest University (20), Liaoning Normal University (19), East China Normal University (17), and Capital Normal University (16). The top-ranking institution published over three times more papers than the institution ranking in the 10th place (as shown in Figure 2).

The top 9 prolific authors are listed as follows: Chen Yulin at Jiaying University (10), Cai Jiandong at Henan University (9), Cai Wenbo at Shihezi University (8), Chang Qinghui at Tiangong Technology (7), Li Yubin at Liaoning Normal University (6), Qi Zhanyong at Shaanxi Normal University (5), Yuan Liping at Shaanxi Normal University (5), Sun Furong at Wenzhou University (5), and Tang Jianmin at Zhejiang Shuren University (5) (as shown in Figure 3).

Finally, the research of knowledge graph applications in education mainly focuses on the following topics: using the knowledge graphs provided by CiteSpace to examine the

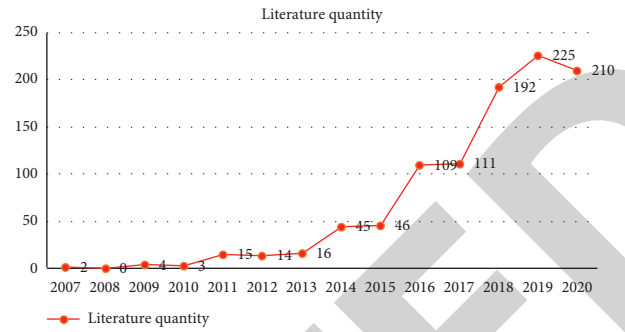


FIGURE 1: Annual distribution of the quantity of academic papers.

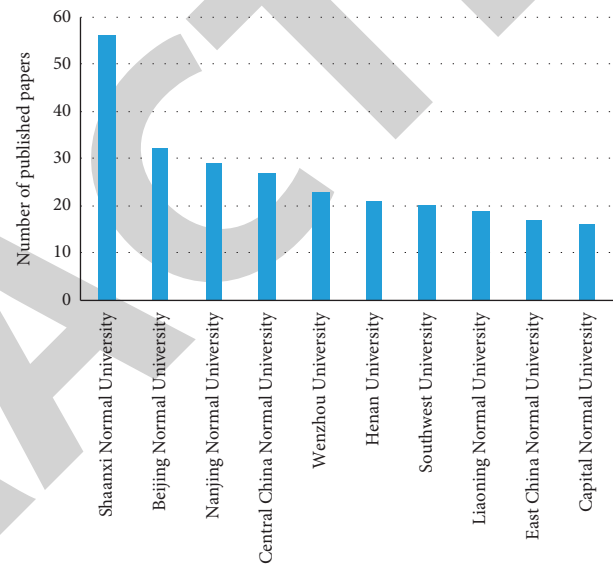


FIGURE 2: Papers published by high-yield institutions.

hotspots (e.g., massive online open course, MOOC, and entrepreneurship education), research frontiers, research status, research topics, research trends, and development trends in the field of education, through visualized analysis, cword analysis, or cluster analysis. Table 1 lists the high-frequency keywords.

2.2. Knowledge Graph Applications in Graduation Theses. The authors queried for the existing graduation theses on CNKI about knowledge graph applications in education (query date: June 7th, 2021), using the Full Text Database of China’s Excellent Master’s Theses and Full Text Database of China’s Doctoral Dissertations. A total of 96 samples were obtained after discrimination and screening, including 94 master’s theses and 2 doctoral dissertations. Figure 4 shows the annual distribution of the graduation theses.

As shown in Figure 4, the earliest graduation thesis written by education masters/PhDs about the application of knowledge graphs was published in 2009. It is a master’s thesis authored by Qu Tianpeng at the Dalian University of Technology. The title reads Knowledge Graphs of the Distribution and Cooperative Network for Natural Science Disciplines in Colleges of Liaoning Province Based on SCI.

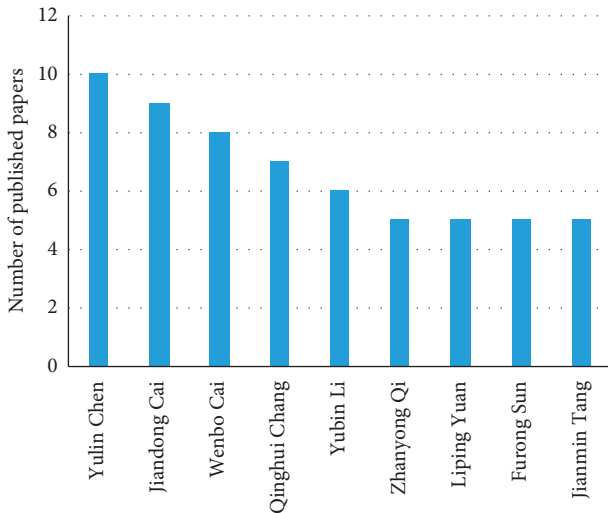


FIGURE 3: Papers published by prolific authors.

TABLE 1: High-frequency keywords.

Keyword	Frequency
Knowledge graphs	826
Research hotspots	199
CiteSpace	167
Visualized analysis	132
Coword analysis	63
Literature metrology	58
Visualization	56
Cluster analysis	35
Bibliometrics	32
Hotspots	31
College students	29
Flipped classroom	28
Entrepreneurship education	28
Research frontiers	27
Scientific knowledge graph	27
Trends	26
Research status	24
Higher education	23
MOOC	21
Social network analysis	21
Research topics	20
Colleges	20
Research trends	18
Development trends	17

Since then, the number of graduation theses has continued to increase. In the last two years, the annual number stabilized at about 20.

The 96 graduation theses were written by masters and PhDs from 57 colleges around China. Minzu University of China and Central China Normal University contributed 6, respectively; Chongqing University and Northwest Normal University contributed 5, respectively; Sichuan Normal University contributed 4; Beijing University of Posts and Telecommunications and Shaanxi Normal University contributed 3, respectively; Bohai University, University of Electronic Science and Technology of China, Northeast Normal University, Harbin Institute of Technology, Henan

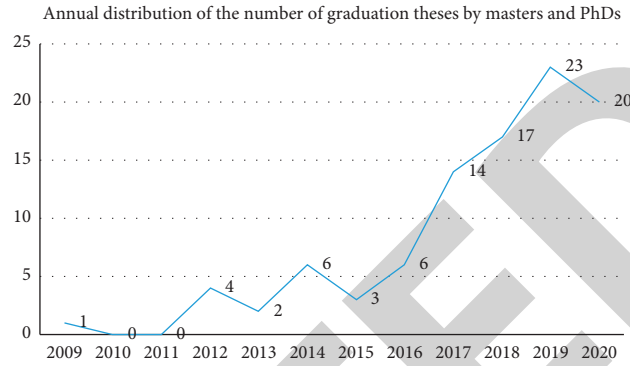


FIGURE 4: Annual distribution of the number of graduation theses by masters and PhDs.

University, Henan Normal University, Hunan Normal University, Tsinghua University, Shanghai Normal University, Wenzhou University, Xi’an University of Technology, Yunnan Normal University, Changsha University of Science and Technology, and Zhengzhou University contributed 2, respectively; every other college contributed only 1.

On research topics, the collected samples mainly utilize software like CiteSpace for visualized analysis on knowledge graphs through coword analysis, citation analysis, and cooperative network, and discuss the research hotspots, frontiers, and progresses of the following fields: individualized learning, education technology, discipline construction, data structure, secondary school students, higher education, learning diagnosis, ontology, education economics, and MOOC.

2.3. Knowledge Graph Applications in Books. The authors queried with the formal title name of the knowledge graph in the Online Public Access Catalog (OPAC), National Library of China (query date: June 7th, 2021). A total of 336 relevant books were found. Through manual screening, 7 books were confirmed to be related to the field of education (Table 2).

The seven books cover multiple fields, namely, international education technology, China’s education technology, China’s education policies, China’s journalism and communication education, China’s curriculum and teaching theories, and China’s educational economics. Overall, there are too few books about knowledge graph applications in education.

It is convenient to search for useful information online. But the search results are not always valuable. To quickly pinpoint the desired information, it is necessary to locate information according to user interests and build a user interest model. To a certain extent, the keyword-based data search and query meet the interests and needs of actual users. Therefore, user preference- or keyword-based data search and query could greatly contribute to the application of knowledge graphs in education, in addition to the above three types of literature.

During the application of knowledge graphs in education, the purpose of forming knowledge graphs is to facilitate

TABLE 2: Books on knowledge graph applications in education.

Lan Guoshuai. Development of International Education Technology Based on Knowledge Graphs (M). Beijing: China Science Publishing and Media Ltd. (CSPM), 2020
Qi Zhanyong. Knowledge graphs of China's educational policies: 1985–2015. (M) Beijing: CSPM, 2019
Deng Guomin. Knowledge map of international educational technology Research; Theory, Technology and Practice. Shanghai: Fudan University Press, 2018
Lu Dan. Knowledge graphs of China's News communication education research: 2000–2014. Wuhan: Wuhan University Press, 2016
Chen Yulin. Construction of visualized knowledge graphs for China's education technology. Chengdu: Sichuan Fine Arts Publishing House, 2016
Jiang Fei. Knowledge graphs of China's curriculum and teaching theories in the New century. Wuhan: Central China Normal University Press, 2015
Huang Wei. A study on the mapping knowledge domains of educational economics in China from 1980 to 2010 based on Multi-methods combination. Beijing: Economic Science Press, 2012

discovery, understanding, communication, and education and to visualize the education discipline. Knowledge graphs in education could provide a panorama of the booming education sector. Through the summary of knowledge graph applications in academic papers, graduation theses, and books, it is concluded that the application of knowledge graphs in China can be divided into an exploratory stage in 2020–2016 and a developmental stage from 2017 till now. In general, knowledge graphs in education are mostly applied to four aspects: intelligent search, in-depth questions and answers (Q&A), social networks, and recommendation systems. The knowledge graphs in education display the search results in the form of knowledge cards, answer user questions in natural languages, and connects people, locations, and things together to support intuitive and precise query. In addition, it is easy to recommend another entity closely related to the target entity with the aid of knowledge graphs.

3. Normative Evaluation

The overview of development reveals the scale, prosperity, and evolution speed of knowledge graph applications in education in China. To understand the internal structure and normative level of these applications, this paper further examines the papers about knowledge graph applications in education, which were published in CSSCI-indexed journals in the past two years.

3.1. Perspectives

Research Institutions. The Chinese colleges offering education courses are either normal colleges or comprehensive colleges. In this paper, the research institutions are divided into two classes: (1) normal colleges; (2) comprehensive colleges. Any college with “normal university” in its name was categorized to class (1), and the other colleges were allocated to class (2).

Data Sources. The data of the academic papers on knowledge graph applications are usually from standard paper databases. In this paper, these databases are categorized into two types: (1) foreign databases and (2) Chinese databases. The former mainly refers to the Web of Science of Information Sciences Institute (ISI), The ProQuest Dissertation and Theses Global (PQDT)

database of graduation theses of doctors and masters, OADDS database of graduation theses, and EI. The latter mainly includes CNKI and CSSCI.

Data Analysis Units. According to the purposes of most papers, this paper defines three data analysis units: (1) the title or keyword of the paper; (2) the authors or their institutions; (3) citations.

Visualization Software. According to the status quo of domestic research, the visualization software fall into three classes: (1) CiteSpace, capable of reflecting the dynamic evolution process; (2) UCInet or Pajek, capable of presenting the internal structure; (3) SPSS or BICOMB, capable of drawing matrix graphs and multidimensional analysis graphs.

Normative Requirements for Empirical Research Papers on Knowledge Graphs. Considering the research purpose, this paper evaluates the normative level of knowledge graph applications in education papers under the analysis framework proposed by Tang [6].

3.2. Data Collection. The authors queried for the papers on the application of knowledge graphs in education 2019–2020 on the website of CSSCI. The query was carried out in the following steps: input “knowledge graphs” into the field of “keywords”, “education” into the field of “discipline type” and “2019–2020” into the field of “years.” A total of 45 records was obtained. After reading each record, the authors found that 18 records are not about knowledge graph applications. Therefore, the remaining 27 papers were adopted for comprehensive analysis and evaluation (Table 3).

3.3. Data Analysis

3.3.1. Simple Classification and Analysis of Sample Structure. As shown in Table 3, the 27 sample papers were published in the following journals: 4 on Educational Research and Experiment; 2 on Research in Higher Education of Engineering, Journal of East China Normal University (Educational Sciences), Modern University Education, Modern Educational Technology, Modern Distance Education, and Distance Education in China, respectively; 1 on Academic Degrees and Graduate Education, Comparative Education Review, University Education Science, Teacher

TABLE 3: Papers on knowledge graph applications in education 2019–2020 from CSSCI database.

Serial number	Title	Journal	Authors
R1	Summary of the research on Educational Internationalization in Recent Decade: Quantitative Analysis of CNKI and WOS Journals, 2010–2019	Comparative Education Review	Yi Hongjun; Zeng Linqin
R2	Progress and Hotspot Comparison of Entrepreneurship Curriculum Research in Colleges: Analysis of Knowledge Graphs Based on CNKI and WOS	University Education Science	Yuan Liping; Yang Yang
R3	Research Methods and Topic Evolution of International Higher Education of Engineering	Research in Higher Education of Engineering	Han Shuangmiao; Xie Jing; Xiao Xiaofei
R4	Characteristics and Trends of Global Interdisciplinary Education: Data Analysis Based on Citespace	Research in Higher Education of Engineering	Zhang Wei; Wei Lina; Qu Chen
R5	Historical Development and Contemporary Mission of Learning Sciences in Chinese Context: Analysis Based on Scientific Paradigm Formation and Knowledge Graph Evidence	Journal of East China Normal University (educational sciences)	Zhao Jian; Yang Xiaozhe
R6	Hot Topics and Frontier Trends of International Hybrid Learning: Empirical Analysis Based on Scientific Knowledge Graphs	Journal of East China Normal University (educational sciences)	Ma Jing; zhou Qian
R7	Academic Right of Speech, Hotspots, and Development Trends of International Teacher Assessment Research: Analysis Based on the Scientific Knowledge Graphs and Contents of SSCI-Index Journals	Teacher Education Research	Zhang Nan; Wang Guangming; Li Yeping
R8	Hotspot Distribution and Development Trend of Multimedia Learning Research for Students with Hearing Disorder in China: Visualized Analysis Based on CNKI Literature 2010–2019	Educational research and experiment	Ren Qiang
R9	Retrospect and Prospect of China's Subjective Education Research in the 40 Years of Reform and Opening-Up: Analysis Based on Knowledge Graphs and Literature Visualization	Educational Research and Experiment	Yue Wei; Xu Yuanyuan
R10	Research Progress in China's Education Historiography in the 40 Years of Reform and Opening-Up: Knowledge Graph Analysis Based on CiteSpace	Educational Research and Experiment	Liu Laibing; Yang Rong
R11	Diversification of Teacher Education: Review and Prospect after 40 Years of Reform and Opening-Up	Educational Research and Experiment	Wu Yuanyue; Yang Yingying
R12	Hotspots and Development Trends of International STEAM Teachers Research: Bibliometric Analysis Based on VOSviewer	Open Education Research	Zhang Nan; Song Naiqing; Huang Xin; Li Yeping
R13	New Century Landscape of PISA Research in China	Social Sciences of Inner Mongolia (Chinese)	Tan Jisheng; zhu Jing
R14	Hotspots of Quality Research on China's Preschool Education Based on Scientific Knowledge Graphs	Social Sciences in Ningxia	Guo Liping; Cai Guoying
R15	Review of the Research Development for Graduate Education Economics in China: Visualized Analysis Based on CSSCI-Indexed Literature, 1998–2019	Tsinghua Journal of Education	Li Fengliang; Wang Yuqi
R16	Hot Topics and Evolution Trends of Chinese Education Research: Bibliometric and Knowledge Graph Analysis Based on CSSCI (1998–2017)	Journal of Xiamen University (Arts and Social Sciences)	Zhu Yu; Cai Wu
R17	Topic Areas and Structural Evolution of International Core Competence Research	Journal of Shandong Normal University (Humanities and Social Sciences)	Bi Hualin; Ye Jianqiang
R18	Dynamic Tracking of Frontier Research on Ideological and Political Education in China: Bibliometric Analysis of CSSCI-Indexed Papers from CNKI since 1998	Studies in Ideological Education	Zheng Bin
R19	Key Authors of Chinese Education Research Papers in International English Journals and Their Coauthor Network	Modern University Education	Li Mei; Su Shuli
R20	Knowledge Graphs of Innovation and Entrepreneurship Education in China's Colleges in Recent Two Decades	Modern University Education	Wu Yiying; Yang Dong

TABLE 3: Continued.

Serial number	Title	Journal	Authors
R21	Differences and Similarities between Domestic and Foreign Smart Campus Research in Research Hotspots and Development Trends	Modern Educational Technology	Li Yiyu; Chen Jinhua
R22	Research Hotspots and Education Application Trends of Deep Learning from the Perspective of Artificial Intelligence: Knowledge Graph Analysis of 20,708 Literature from WOS Database in 2006–2019	Modern educational technology	Zhang hai; cui Yulu; Yu luyao; Ji Mengxue; Wang Yining
R23	Research Landscape and Trends of EEG Technology Education: Knowledge Graph Analysis Based on International Literature 2000–2019	Modern Distance Education Research	Zheng Xudong; Ma Yunfei
R24	Retrospect and Reflection of Rural Education Research in the 70 Years after the Founding of the New China	Modern Distance Education Research	Ouyang xiujun
R25	Review of First-Class Discipline Research: Hotspots, Trends, and Outlook: Visualized Analysis Based on CNKI Keywords	Academic Degrees and Graduate Education	Li Aibin; Du Xiaohong
R26	Evolution and Trend of Smart Teaching Research in China in the Recent Decade	Distance Education in China	Zhang Xiumei; Tian Tian; Tian Mengmeng; Gao Liizhi; Zhang Xuebo
R27	Hotspots and Future Trends in China's Educational Equality Research in the 21st century: Knowledge Graph Analysis Based on Co-Word Matrix	Distance Education in China	Ding Xueyang; Cheng Tianjun

Education Research, Open Education Research, Tsinghua Journal of Education, Studies in Ideological Education, Social Sciences of Inner Mongolia (Chinese), Social Sciences in Ningxia, Journal of Xiamen University (Arts and Social Sciences), and Journal of Shandong Normal University (Humanities and Social Sciences), respectively. 11 were published in 2020 and 16 in 2019.

Following the classification criteria in the research design, the papers in Table 3 were read through and classified (Table 4). The following conclusions can be drawn from the paper contents and the results in Table 4.

- (1) 60% of the authors are from normal colleges, and 40% are from comprehensive colleges. The normal colleges mainly include Central China Normal University, East China Normal University, Tianjin Normal University, Northeast Normal University, South China Normal University, etc., and the comprehensive colleges mainly include Zhejiang University and Southwest University.
- (2) 2/3 of the papers are indexed in Chinese databases, and 1/2 in foreign databases (some papers are indexed in both Chinese and foreign databases, such as R1 [18], R2 [19], R5 [20], and R21 [21]). The Chinese databases mainly refer to CNKI or CSSCI. 18 papers are indexed in ISI's Web of Sciences (13) and Scopus (1).
- (3) On data analysis units, 16, 26, 16, and 7 papers were involved by selecting annual distribution of literature quantity and journal, keywords, authors/institutions/regions, and citations. Hence, keyword analysis is the most important analysis perspective, followed by the annual distribution of literature quantity and journal. On average, each journal has 2.30 analysis

perspectives. That is, there are more than two (two to four) perspectives to analyze these papers, namely, R7 [22], R22 [23], and R23 [24].

- (4) On visualization software, 27 papers utilize CiteSpace, 4 utilize UCInet, 4 utilize SPSS/BICOMB, and 3 utilize VOSviewer. CiteSpace is obviously the most widely used software, taking up 81%. This reflects the immense popularity of CiteSpace among domestic researchers engaging in knowledge graph application in education.

3.3.2. Detailed Classification and Analysis of Sample Structure. To fully understand the research paradigm of the sample papers, this paper further classifies and discusses their structure and trends with an orthogonal view. In other words, the sample papers were observed from two or more angles at the same time. The combined angles include database and research perspective, database and visualization software, year of publication, and visualization software.

- (1) From the angle of database and research perspective, citation analysis is not applicable to knowledge graph visualization of the literature exported directly from domestic databases because the literature thus obtained does not generally contain any reference. As shown in Table 4, citation analysis has been adopted to visualize the knowledge graphs of the sample papers, all of which are exported from foreign databases.
- (2) From the angle of database and visualization software, the papers indexed in domestic or foreign databases both utilize an average of 1.1 visualization software. Detailed analysis shows a certain difference

TABLE 4: Classification statistics of sample paper.

Serial number	Institute		Database		Annual distribution of literature quantity and journal	Perspective		Visualization software				Year of publication
	Normal college	Institute	Chinese	Foreign		Keywords	Authors/ institutions/ regions	Citations	CiteSpace	Unicent/Ucinet	SPSS/Bicomb	
R1	✓			✓	✓	✓	✓	✓	✓		✓	2020
R2	✓			✓	✓	✓	✓	✓	✓			2020
R3		✓	✓	✓	✓	✓	✓	✓	✓		✓	2020
R4		✓	✓	✓	✓	✓	✓	✓	✓			2020
R12		✓	✓	✓	✓	✓	✓	✓	✓		✓	2020
R14		✓	✓	✓	✓	✓	✓	✓	✓			2020
R19	✓			✓	✓	✓	✓	✓	✓		✓	2020
R21	✓			✓	✓	✓	✓	✓	✓			2020
R22	✓			✓	✓	✓	✓	✓	✓			2020
R23	✓			✓	✓	✓	✓	✓	✓			2020
R26	✓			✓	✓	✓	✓	✓	✓			2020
R5	✓			✓	✓	✓	✓	✓	✓			2019
R6		✓	✓	✓	✓	✓	✓	✓	✓			2019
R7		✓	✓	✓	✓	✓	✓	✓	✓			2019
R8		✓	✓	✓	✓	✓	✓	✓	✓			2019
R9		✓	✓	✓	✓	✓	✓	✓	✓			2019
R10		✓	✓	✓	✓	✓	✓	✓	✓			2019
R11		✓	✓	✓	✓	✓	✓	✓	✓			2019
R13		✓	✓	✓	✓	✓	✓	✓	✓			2019
R15		✓	✓	✓	✓	✓	✓	✓	✓			2019
R16		✓	✓	✓	✓	✓	✓	✓	✓			2019
R17		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	2019
R18		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	2019
R20		✓	✓	✓	✓	✓	✓	✓	✓			2019
R24		✓	✓	✓	✓	✓	✓	✓	✓			2019
R25		✓	✓	✓	✓	✓	✓	✓	✓			2019
R27		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	2019

Note. If a paper can be classified by more than one perspective, only the most important perspective is adopted for classification.

TABLE 5: Evaluation criteria and questions.

Serial number	Question	Reasons for setting this criterion
Q1	Does the paper clearly specify the visualization software?	There are various visualization software programs, each of which has its unique features.
Q2	Does the paper clearly specify the size and features of samples?	The size and intrinsic structure of the samples directly determine the feasibility of knowledge graphs.
Q3	Does the paper clearly specify the thresholds?	Different thresholds lead to different graphs.
Q4	Does the paper clearly specify the basis for determining the thresholds?	Different thresholds lead to different graphs. This calls for scientific determination of thresholds.
Q5	Does the paper take the knowledge graphs as the main strategy?	Knowledge graph provides only one research tool. Normally, it should be combined with other methods to draw comprehensive conclusions.
Q6	Does the paper clearly specify the limitations of conclusions?	Knowledge graphs have many limitations, namely, the unstable and incomplete clustering and the conflict between the large data volume and the limited space.

Data source: Tang [5].

in the use frequency of different software facing different databases. Among the three papers adopting VOSviewer, two utilize foreign databases. Among the four papers adopting SPSS/BICOMB, three utilize domestic databases (R1 utilizes both domestic and foreign databases simultaneously). Among the five papers without adopting CiteSpace, four utilize a domestic database. Among the four papers adopting UCInet, three utilize domestic databases. Relatively speaking, CiteSpace is often coupled with foreign databases, while other software like UCInet is often coupled with domestic databases.

- (3) From the year of publication and visualization software, the number of CiteSpace-based knowledge graph analyses is even throughout the period (11 in 2019 vs. 11 in 2020); the papers using BICOMB for knowledge graph analysis were all published in 2019, so were those using UCInet. The papers using VOSviewer were all published in 2020. To a certain extent, the data reflect the preference for visualization software of researchers engaging in knowledge graph applications in education. Overall, CiteSpace and VOSviewer are the favorite choices of the researchers.

3.4. Normative Evaluation. Another important purpose of this paper is to evaluate the scientific and normative levels of papers. Table 5 shows the normative evaluation criteria and questions of the sample papers. With these questions in mind, the researchers carefully read each paper and evaluated each paper against every question. The evaluation results are recorded in Table 6. Each positive answer is denoted as *Y*, each negative answer is denoted as *N*, and each ambiguous answer (the paper only partially conforms to the criterion) is denoted as *C*; the number of papers with *Y*, *N*, and *C* is denoted as *EY*, *EN*, and *EC*, respectively.

The following conclusions can be drawn from Table 6.

- (1) The predominant majority (25 out of 27) of the sample papers clearly specify the visualization software.

TABLE 6: Normative evaluation results.

Serial number	Q1	Q2	Q3	Q4	Q5	Q6
1	Y	Y	N	N	N	N
2	Y	Y	N	N	N	N
3	Y	Y	N	N	N	N
4	Y	Y	N	N	N	N
5	Y	Y	N	N	N	N
6	Y	Y	N	N	N	N
7	Y	Y	N	N	N	N
8	Y	Y	N	N	N	N
9	Y	Y	N	N	N	N
10	Y	Y	N	N	N	N
11	Y	Y	N	N	N	N
12	Y	Y	N	N	N	N
13	Y	Y	N	N	N	N
14	Y	Y	N	N	N	N
EN	2	0	22	27	27	26
15	Y	Y	Y	N	N	N
16	Y	Y	N	N	N	N
17	Y	Y	N	N	N	N
18	Y	Y	Y	N	N	N
19	Y	Y	N	N	N	Y
20	Y	Y	Y	N	N	N
21	N	Y	N	N	N	N
22	Y	Y	N	N	N	N
23	Y	Y	Y	N	N	N
24	N	Y	N	N	N	N
25	Y	Y	Y	N	N	N
26	Y	Y	N	N	N	N
27	Y	Y	N	N	N	N
EY	25	27	5	0	0	1
EC	0	0	0	0	0	0

- (2) Only five sample papers specify the threshold of each component of the similarity vector for knowledge graph plotting. 80% of the samples do not mention “threshold” during the preparation of knowledge graphs.
- (3) None of the papers derive conclusions solely from the plotted knowledge graphs. Instead, knowledge graphs are combined with bibliometric methods, such as quantitative text analysis or qualitative word

frequency statistics. Some papers cross-validate the knowledge graphs drawn by multiple software programs to ensure research accuracy (R3) [25] or verify the bibliometric results based on knowledge graphs through detailed qualitative tests (R5) [20]. Of course, the qualitative text analysis is not well integrated with the empirical and quantitative knowledge graphs.

- (4) Only five papers (R15 [26], R18 [27], R20 [28], R23 [24], and R25 [29]) clearly specify the threshold values, yet without providing the basis. Compared with Tang's work [6] in 2013, the lack of a detailed explanation of threshold setting is a long-lasting problem. The main reason for the problem is that most education scholars mainly engage in the research of liberal arts. They know how to apply knowledge graphs to their research domains but do not know the mechanism behind the application of the tool.
- (5) All papers introduce the sample collection process and roughly report the internal features of the samples. This is a major progress compared with Tang's work [6] in 2013. The researchers must have noticed the significant influence of internal features on the overall state and bibliometric results of the knowledge graphs.
- (6) Only one paper (R19) [30] clearly specifies the limitations of conclusions. From the perspective of research normalization, this is not at all surprising. It is a must for a normalized research paper to summarize its limitations along with the conclusions. Most education experts only know how to use knowledge graphs in research. They are, after all, not designers of the bibliometric methods. It is impossible for them to make professional reflections on the research tool, not to mention providing improvement suggestions.

4. Conclusions

Fifteen years has passed since knowledge graphs were introduced to the field of education in 2007. During these years, the research tool has been applied to increasingly extensive domains. After reviewing the development and analyzing the current state, the sample papers were classified and normatively evaluated. Based on the results, the following conclusions can be drawn:

- (1) With the elapse of time, knowledge graphs are being increasingly applied to education, indicating the applicability of the tool to education.
- (2) The research paradigm has already taken shape. By carefully deconstructing the research samples, this paper finds that academia has reached a consensus on the paradigm of the research tool: examining the hotspots, topics, and trends in the related fields from the angles of keyword cooccurrence network (KCN), time zone map, clustering network, and literature/

author cocitation, with the aid of CiteSpace and other visualization software and text analysis.

- (3) The research quality is yet to be improved. Firstly, there are relatively few high-quality papers, as evidenced by the papers indexed in the CSSCI database and master/PhD's graduation thesis databases and the published books on the relevant field. Second, the existing studies are defected in scientific and normalized levels. According to our normative evaluation, most papers ignore the importance of threshold settings to the plotting of knowledge graphs and do not have a widely recognized and feasible standard for threshold setting. Besides, few papers reflect on the limitations of research.

In the future, education researchers should try to master the principle of knowledge graphs and carry out refined research on the application of this tool. The improvement of knowledge graph applications will surely promote the research level in the field of education.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Acknowledgments

This paper is phased achievement of the project of China Vocational Education Society in Zhejiang Province (ZJCV2021B31).

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