

A Comprehensive Review of International Digital Education Governance Research over the Past Decade: Knowledge Graph Analysis Based on WOS Literature from 2014 to 2023

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Abstract: Using Cite Space tool, 406 literatures included in the Web of Science core collection from 2014 to 2023 were analyzed by using the number of publications, authors, keywords and other variables to conduct knowledge graph analysis on foreign digital education governance studies. Over the past decade, there has been a growing focus on integrating information and communication technology (ICT), artificial intelligence (AI), machine learning (ML), big data analytics, and cloud computing in education governance. Through the trend analysis of the number of published documents, it can be seen that the number of foreign digital education governance literature has grown rapidly after 2020, showing greater academic potential. Through core author and collaborative analysis, it is found that the field is in a developing stage, and researchers are still establishing and exploring research directions. Foreign research hotspots on digital education governance mainly focus on the impact of digital technologies such as big data, social media, policy formulation and artificial intelligence on education governance. The analysis provides recommendations for domestic research in the field of digital education governance, including improving the digital literacy of educators and students, integrating a wide range of digital policy tools for data-driven decision-making, exploring innovative digital governance models, and promoting international cooperation.

Keywords: Digital Education Governance; Big Data; Artificial Intelligence; Digital Transformation; Machine Learning; Bibliometric Analysis; Web of Science

1. Introduction

Digital education governance refers to the integration of ICTs into education in the context of a digital governance model and provides a more comprehensive and integrated approach to managing public services and the interaction between the state and its citizens [1]. Digital education governance can be traced back to the integration of information and ICT (communication technology) into education, and as technology advances, the scope of research in this field continues to expand, incorporating complex technologies such as AI (artificial intelligence), ML (machine learning), big data analytics, and cloud computing. The rapid development of digital technology opens a broad prospect for the digital transformation of education, and the innovation of educational governance and the improvement of educational governance level have become the key elements in the process of educational transformation. Transforming the educational governance system, as one of the core tasks of educational digital transformation, is of paramount importance. Utilizing the internet's mode of thinking and technological means, the journey towards digital transformation accelerates the reshaping of the educational governance system [2]. Minister Huai Jinping elucidated the importance of advancing educational governance towards efficiency and precision at the World Conference on Digital Education, emphasizing the necessity of employing advanced technologies such as artificial intelligence and big data for business collaboration, process optimization, structural reshaping, and precise management in education management and services [3]. Professor Yuan Zhenguo posits that digital transformation transcends mere technological issues, deeply involving the enhancement of governance capabilities and levels. Mastering

key technologies and methods of educational digitalization and developing governance capacities and modes adapted to digital transformation are crucial for achieving a profound integration of digital technology with education and shaping the future of education [4]. As a key component of transformation, digital education governance has gradually become a focal point of global attention in the education sector. Currently, scientific bibliometric methods are seldom used in China to analyze research on digital education governance, and existing studies are often based on researchers' intuitive understanding. Therefore, this paper will employ bibliometric methods and utilize the CiteSpace visualization analysis tool to conduct a knowledge map analysis of international digital education governance over the past decade (2014-2023) based on the Web of Science database. By examining the volume of literature, keywords, identifying core authors, and collaborating institutions, this study aims to uncover research hotspots and trends in digital education governance. This comprehensive and systematic evaluation of international research and progress in digital education governance will support the research and practice of digital education governance in China [5].

2. Data Sources and Research Methods

This study is based on the large-scale comprehensive information retrieval system developed by Thomson Reuters, the Web of Science (WoS), utilizing its core collection. The search theme was "digital education governance," with a specified time frame from 2014 to 2023. After filtering and eliminating irrelevant results, a total of 406 valid documents were obtained [6].

To analyze the research landscape of digital education governance, this paper employs bibliometric and scientometric methods, integrating the use of the visualization software CiteSpace for keyword co-occurrence analysis, institutional distribution analysis, and author collaboration analysis. This approach aims to explore the hot topics, evolutionary pathways, and development trends within the field of digital education governance research.

3. Research Results and Analysis

3.1 Analysis of Literature Publication Volume

By observing the trends in the volume of literature over time, we can gain a direct understanding of the development history and the expansion of research scale within a specific field. This not only reflects the evolution of research interests but also reveals the academic community's level of attention and variation in research investments towards a particular topic.

Figure 1 illustrates the volume of literature on digital education governance research in the WOS database since 2014. The graph shows a transition from an initial stable period to a significant growth phase. Beginning in 2017, there was a notable increase in the volume of literature, which surged dramatically after 2020. This trend indicates a continuous rise in the research community's interest in the field of digital education governance, attracting more research and investment. It suggests that the academic development of this field is expected to demonstrate substantial potential beyond 2024.

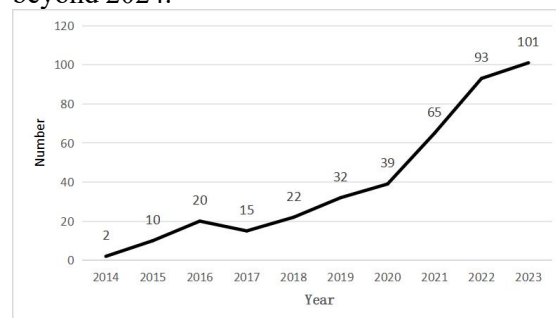


Figure 1. Annual Publication Volume in Digital Education Governance (2014-2023)

3.2 Analysis of Key Authors and Their Collaborative Relationships

By statistically analyzing the publication output of authors from 2014 to 2023 and employing the CiteSpace software to generate a network map of author collaborations (Figure 2), we can distinctly observe the dynamics within the realm of digital education governance, including author collaborations. Investigating the publication trends of pivotal author aids in delineating the developmental trajectory of this field. After standardizing the data, CiteSpace processed the information from the selected sample, covering the period from 2014 to 2023, retaining the top 50 research subjects (Top N=22) for each time

segment, with the analysis focus on "authors." The resulting co-authorship network map for digital education governance research, as shown below, correlates font size with the number of articles published by an author (the more articles, the larger the font), and the lines between nodes represent collaborative relationships between different authors. The network displayed includes 223 nodes (authors) and 148 edges (collaborations), with a network density of 0.006. This low density suggests that, despite some level of collaboration, the overall network of authors within the digital education governance field is relatively sparse, indicating limited collaboration among

internationally significant researchers in this area. From the network map, it is evident that while there are closer collaborations among a few researchers such as Parcerisa, Lluís; Calderon-garrido, Diego; Laaziri, Majida; Anand, Rashmi; and Achenbach, Stephan, forming a significant cluster, other authors either engage in smaller group interactions or publish independently. This pattern suggests that the field may still be in a developmental phase, with researchers exploring and establishing their directions. Over time, it is likely that the collaborative networks among these researchers will become more robust.

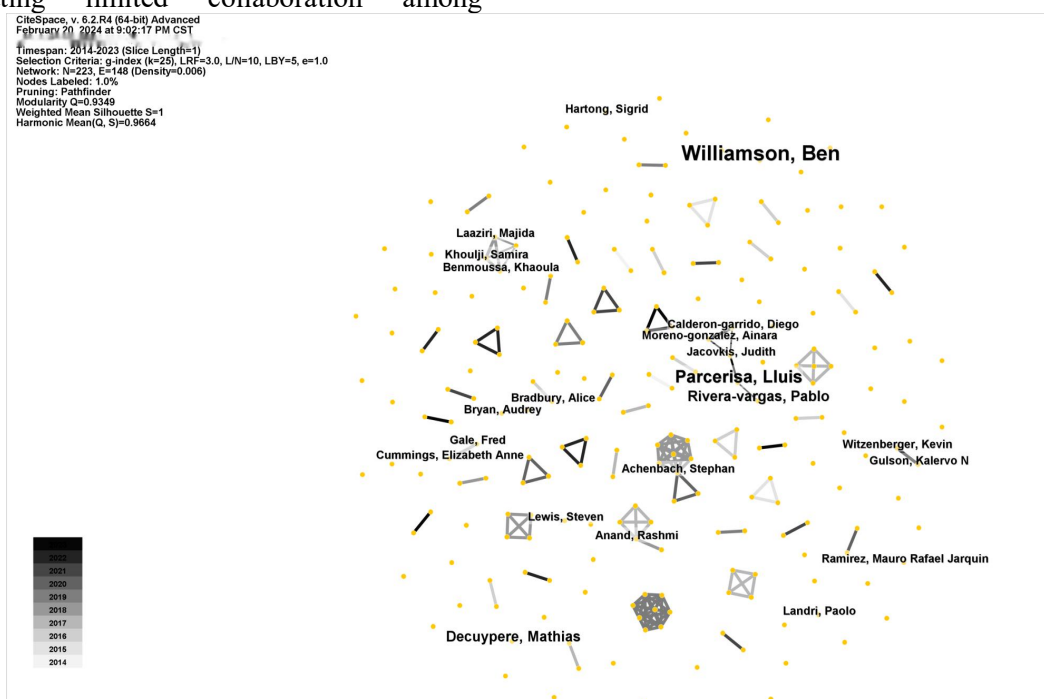


Figure 2. Network Map of Core Author Collaborations

To ensure the accuracy of the data and to prevent the potential overlap in article statistics, this study retained only the first author of each publication during the data compilation and analysis phase. Utilizing the CiteSpace software, the node type was set to 'Author', with a time slice configuration of 1 year. The software's computation revealed a total of 223 publishing authors. Among these, 4 authors had published 3 or more articles, 18 had published 2 articles, and 201 had published a single article. This paper conducts a quantitative analysis of authors based on their publication frequency, as summarized in table 1 below.

As can be seen from table 1, there are more authors studying digital education governance,

and the scientific research team is relatively large, but the level of publication and research intensity of these authors are quite different. There were 22 authors with two or more published papers, accounting for 9.87% of the total number of authors, and 52 published papers, accounting for 20.55% of the total number of published papers. Compared with a small number of authors, these authors published more research papers, indicating that they have a strong production capacity and more research results in the study of digital education governance. A total of 201 authors published less than one paper, accounting for 90.13% of the total number of authors, indicating that most researchers only produced one paper. According to the above analysis, it

can be found that there are great differences in the levels of papers published by authors on digital education governance. Only a few researchers have conducted in-depth discussions and studies on digital education

governance from various aspects, while most researchers have only conducted a single study on a certain aspect, without systematic in-depth discussions and multi-faceted studies, and have not invested enough in this field.

Table 1. Quantitative Analysis of Authors Based on Their Publication Frequency

Publication volume	number of authors	proportion of total authors represented	Proportion of articles published to total articles published
6	1	0.45%	2.37%
4	1	0.45%	1.58%
3	2	0.90%	2.37%
2	18	8.07%	14.23%
1	201	90.13%	79.45%

Table 2 is obtained by further statistics on authors with a large number of publications. It can be seen that Williamson and Ben have published 6 papers in total. The first paper was published in 2015, and after that, they published an average of one paper every year, indicating that they have been paying attention to the development of the field of digital education governance for a long time and have high continuity. Parcerisa, Lluís and Rivera-vargas and Pablo all published their first papers in 2023. Parcerisa and Lluís published four papers in total, while Rivera-vargas and Pablo published three papers in total, indicating that they only started to study this field recently. Mathias Decuyper, with three publications, first contributed in 2016 and added two more articles in 2023, showing a moderate but sustained interest in the field. Authors with two publications have generally started their research in recent years, suggesting that the field is in a developmental phase with researchers still exploring and establishing their investigative directions. As time progresses, collaborations among these researchers are likely to increase, enriching the field further.

3.3 Analysis of Research Hotspots

3.3.1 Co-occurrence analysis of keywords

The co-occurrence analysis of keywords effectively reflects the distribution of research hotspots in digital education governance, thereby summarizing the focal information of studies on digital education governance. This research standardizes the obtained sample data and inputs it into the software CiteSpace, selecting the timeframe from 2014 to 2023. Within each period, it defaults to retaining the top 50 (Top N=50) and chooses "keywords"

for the analysis project, creating a co-occurrence map of keywords related to digital education governance research from 2014 to 2023. Figure 3 shows that the size of nodes is related to the frequency of keyword occurrence (the more frequently a keyword appears, the larger the node), and the connections between nodes represent the co-occurrence frequencies of different keywords. From this, it can be observed that the map consists of 277 nodes and 436 connections, with a network density of 0.0114. In this study, a total of 277 keywords were extracted, accumulating a frequency of 893 occurrences. By summarizing the top twenty keywords from literature data in the WOS core database, as shown in Table 3, centrality measures indirectly reveal their popularity. Centrality indicates the importance of a keyword within the entire co-occurrence network, highlighting the research hotspots and themes in this field over a certain period. Removing outliers, it is evident that in recent years, "governance" has been the keyword with the highest rate of frequency change, followed by "education," "higher education," "technology," "big data," "digital transformation," "policy," "impact," "artificial intelligence," "education policy," "management," "city," "challenges," among others.

These varied research hotspots collectively accelerate the pace of research in the field of digital education governance, thereby enhancing and optimizing the development of this domain.

3.3.2 Keyword clustering analysis

Keyword clustering expands upon the co-occurrence map by summarizing and extracting research themes, thereby visually

presenting the research fields or clustering blocks. Through these blocks, we can discern

the distribution of hotspots within the topic under study.

Table 2. Digital Education Governance Author's Publication Volume

Ranker	Authors	Number	Centrality	Year
1	Williamson, Ben	6	0	2015
2	Parcerisa, Lluís	4	0	2023
3	Rivera-vargas, Pablo	3	0	2023
4	Decuyper, Mathias	3	0	2016
5	Calderon-garrido, Diego	2	0	2023
6	Gulson, Kalervo N	2	0	2022
7	Laaziri, Majida	2	0	2018
8	Bryan, Audrey	2	0	2022
9	Anand, Rashmi	2	0	2017
10	Landri, Paolo	2	0	2018
11	Achenbach, Stephan	2	0	2018
12	Jacovkis, Judith	2	0	2023
13	Moreno-gonzalez, Ainara	2	0	2023
14	Cummings, Elizabeth Anne	2	0	2017
15	Bradbury, Alice	2	0	2016
16	Ramirez, Mauro Rafael Jarquin	2	0	2023
17	Hartong, Sigrid	2	0	2016
18	Lewis, Steven	2	0	2022
19	Gale, Fred	2	0	2017
20	Khoulji, Samira	2	0	2018
21	Witzenberger, Kevin	2	0	2022
22	Benmoussa, Khaoula	2	0	2018

The research involves importing standardized sample data into the software CiteSpace, with the timeframe selected from 2014 to 2023. The top 50 research institutions (Top N=50) are retained for each period, and "keywords" are selected for the analysis. As a result, we obtain Figure 4, a keyword clustering map, which is clustered within the software to produce a

keyword clustering map related to digital education governance research from 2014 to 2023. Backend data shows that the clustering module value of the keyword clustering map is greater than 0.3, indicating that the structure of the clusters is significant; an average silhouette value (S) greater than 0.7 confirms that the clustering results are reliable and credible.

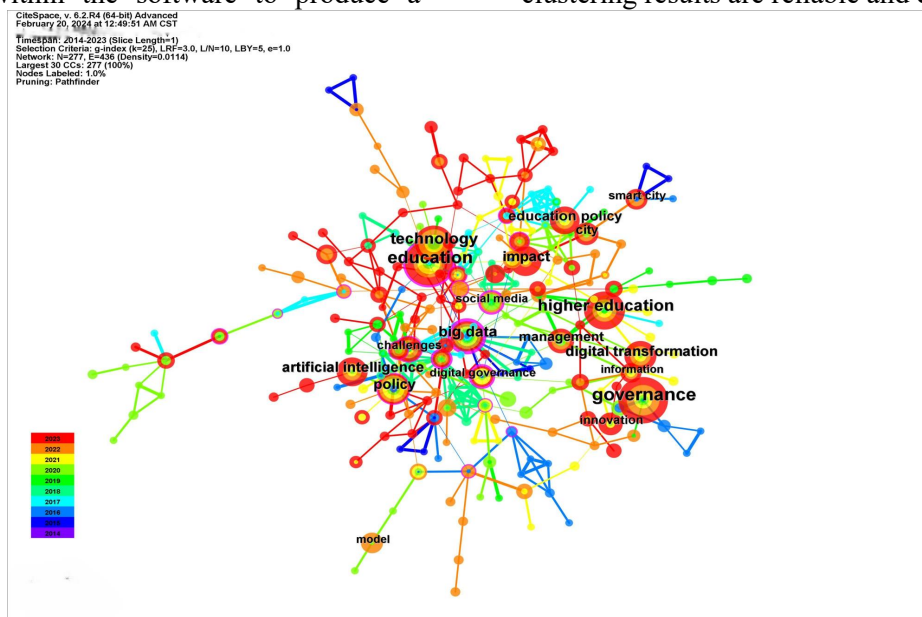


Figure 3. Keyword Co-occurrence Map

Table 3. Keyword Co-occurrence Table

Frequency	Centrality	Year	Keywords
45	0.04	2016	governance
42	0.25	2015	education
31	0.04	2017	higher education
29	0.02	2018	technology
21	0.46	2015	big data
20	0.05	2020	digital transformation
19	0.1	2016	policy
19	0.08	2021	impact
19	0.02	2019	artificial intelligence
16	0.03	2017	education policy
14	0.07	2019	management
13	0.05	2016	city
12	0.12	2016	challenges
11	0.02	2020	innovation
10	0.04	2015	smart city
10	0.29	2018	social media
10	0.27	2015	digital governance
9	0.04	2020	information
9	0.01	2020	model

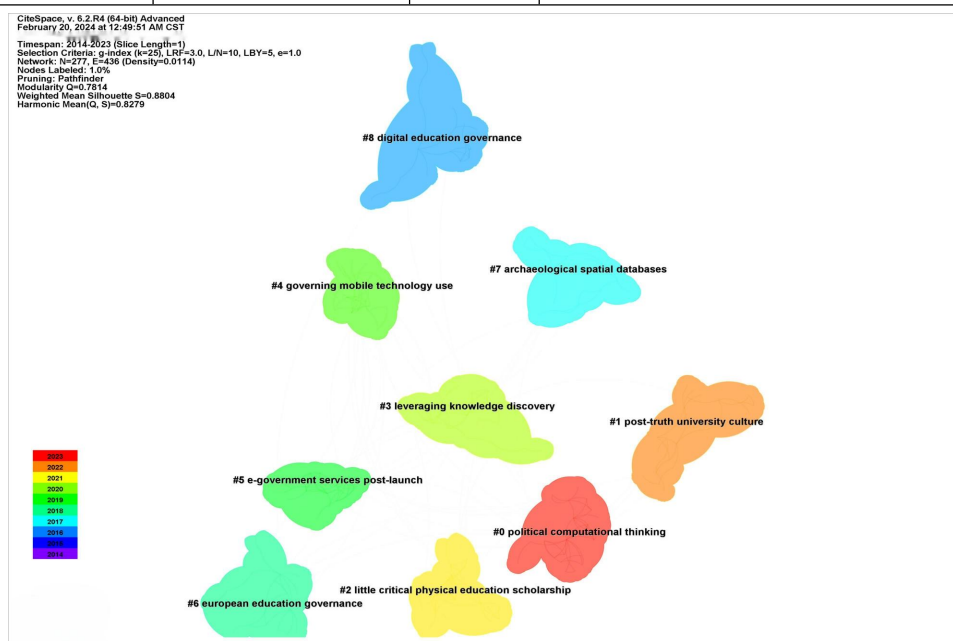


Figure 4. Keyword Clustering Map

Clustering Figure 4 reveals nine major clusters: Political Computational Thinking, Post-Truth University Culture, Little Critical Physical Education Scholarship, Leveraging Knowledge Discovery, Governing Mobile Technology Use, E-Government Services Post-Launch, European Education Governance, Archaeological Spatial Databases, and Digital Education Governance. It's evident that research in digital education governance is intricately linked to political computational thinking, the culture of post-truth in

universities, small-scale physical education scholarship reviews, leveraging knowledge discovery, managing the use of mobile technology, and the governance of digital education. The largest cluster (#0) comprises 23 members (with a silhouette value of $S=0.952$), followed by the second-largest (#1) with 23 members ($S=0.922$), the third-largest (#2) with 22 members ($S=0.936$), the fourth-largest (#3) with 20 members ($S=0.76$), the fifth-largest (#4) with 20 members ($S=0.851$), the sixth-largest (#5) with 20

members (S=0.959), the seventh-largest (#6) with 18 members (S=0.87), and the eighth-largest (#7) with 18 members

(S=0.884).

The primary members of each cluster are listed in table 4 below:

Table 4. Keywords Cluster Analysis Table

Clusters	Members	Silhouette Values	Years	Key Cluster Members
0	23	0.952	2017	political computational thinking (53.32, 1.0E-4); policy network (53.32, 1.0E-4); healthcare environment (47.94, 1.0E-4); assessing readiness (47.94, 1.0E-4); sustaining digital professionalism (47.94, 1.0E-4)
1	23	0.922	2019	post-truth university culture (54.74, 1.0E-4); university scholar (54.74, 1.0E-4); smart cities technologies (50.5, 1.0E-4); education student (42.03, 1.0E-4); experiences observation (42.03, 1.0E-4)
2	22	0.936	2019	little critical physical education scholarship (53.59, 1.0E-4); systematic review (48.23, 1.0E-4); pedagogical innovation (48.23, 1.0E-4); online examination (48.23, 1.0E-4); scalable authentication (48.23, 1.0E-4)
3	22	0.76	2021	leveraging knowledge discovery (49.45, 1.0E-4); knowledge visualization (49.45, 1.0E-4); italian province (49.45, 1.0E-4); developing early career teacher (43.41, 1.0E-4); systematic literature review (43.41, 1.0E-4)
4	20	0.851	2020	governing mobile technology use (48.63, 1.0E-4); australian nursing profession (48.63, 1.0E-4); continuing professional development (48.63, 1.0E-4); regulatory need (45.43, 1.0E-4); governance principle (45.43, 1.0E-4)
5	20	0.959	2018	e-government services post-launch (50.19, 1.0E-4); demographic variable (50.19, 1.0E-4); differentiated urban area (41.7, 1.0E-4); provision protection (33.26, 1.0E-4); digital policy (24.87, 1.0E-4)
6	18	0.87	2019	european education governance (52.33, 1.0E-4); policy innovation labs design (47.51, 1.0E-4); governing method (47.51, 1.0E-4); data science (47.51, 1.0E-4); ed-tech corporations digital educational platform (42.73, 1.0E-4)
7	18	0.884	2019	archaeological spatial databases (46.25, 1.0E-4); indigenous people (46.25, 1.0E-4); platform society (45.44, 1.0E-4); valuing pedagogical autonomy (45.44, 1.0E-4); digital methodologies (42.56, 1.0E-4)
8	18	0.821	2011	digital education governance (44.64, 1.0E-4); predictive analytics (44.64, 1.0E-4); data visualization (44.64, 1.0E-4); european single market (37.61, 1.0E-4); renationalisation resilience (37.61, 1.0E-4)

The cluster analysis reveals that digital education governance encompasses a multidimensional research domain, involving policy formulation, technological application, data processing, and international collaboration. Researchers focus on how to manage and govern educational systems effectively in an increasingly digital and globalized context, as well as how to utilize data analytics tools to enhance the quality and efficiency of educational policies and practices.

4. Analysis of Research Trends

The foregoing discussion employed keyword co-occurrence and clustering maps to illuminate the primary research focal points in digital education governance over the past decade. In order to further explore the internal changes in the popularity of related research topics in the past ten years, the term-based time-line cluster analysis function provided by CiteSpace is used to further and comprehensively explore text information. This tool allows for a more thorough and

comprehensive extraction of textual information, offering insights into the evolution of the digital education governance field over time. Such analysis aids in understanding past research trajectories and formulating more substantiated hypotheses about future research directions. Additionally, CiteSpace offers a feature for identifying emerging keywords that have seen a notable increase in citations within a specific time frame, facilitating the analysis of nascent trends and prominent topics. Figure 5 and figure 6 showcases the timeline progression of the nine most significant clusters and the distribution of the 22 most notable emerging terms.

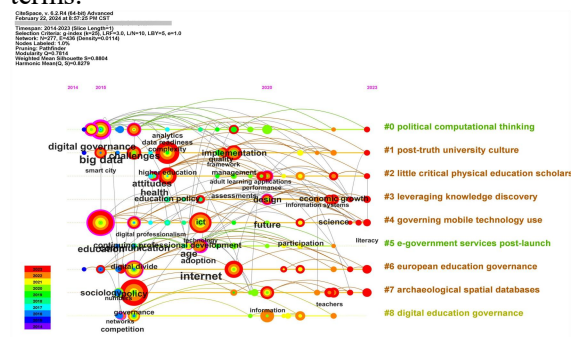


Figure 5. Timeline Progression of the Nine Most Significant Clusters

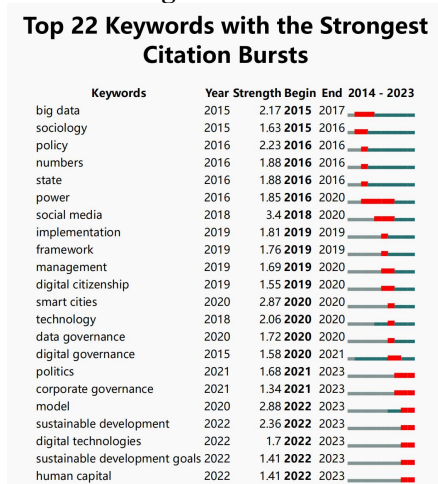


Figure 6. Top 22 Keywords with the Strongest Citation Bursts

The timeline visualization reveals several keyword nodes exhibiting notable surges in activity, distinguished by their red peripheries and substantial yellow cores. This indicates that themes such as "digital governance," "big data," "communication," "education," and "internet" have garnered widespread attention at specific moments in time.

Analysis of trends in digital education governance, derived from timeline graphs and emerging term studies, concentrates on several key areas:

Firstly, big data has garnered widespread attention within the realm of educational governance. For instance, the concepts of "digital governance" and "smart cities" have been explored, notably by Ben Williamson in 2015, who discussed how education is being reimagined as part of smart cities. He introduced the concept of "smart schools," emphasizing the engagement of students in the governance of smart cities through data, software, and programming education [7].

Second, policy formulation becomes the foundation of digital education governance. The term "policy" has seen a significant surge in 2016, reflecting researchers' concern about policy formulation and implementation, such as: Ben Williamson (2015) explores how digital technologies, in particular data visualisation, predictive analytics and real-time 'policy tools', are transforming educational governance, presenting case studies of innovative data systems and highlighting their role in shaping educational policy and practice [8].

Third, social media is increasingly affecting the field of educational governance. The appearance of keywords such as "social media", "communication" and "participation" indicates the importance of social media in educational communication, participation and governance, and indicates that in the digital age, education governance needs to take interaction and participation into account more. For example, Ben Gleason (2018) advocates integrating social media into education to help students improve their ability to navigate online Spaces, engage in constructive conversations, and engage in online activities safely and ethically. In addition, students should be digitally aware, thus preparing them to participate in the digital world [9].

Finally, digital technology is gradually popularized in educational governance, especially the development of emerging technologies in fields such as artificial intelligence and machine learning. Fernando Filgueiras (2023) discusses the transformative impact of AI (artificial intelligence) and big data on educational governance, highlighting the possibilities for improvement and the

emergence of new risks and challenges, and it also highlights the need for new governance practices to address the ethical and practical dilemmas posed by digital technologies in education. In particular, attention should be paid to the impact of social justice [10].

5. Conclusions and Future Outlooks

The governance of digital education abroad has changed significantly over the past decade, especially after 2020, reflecting the growing recognition of the critical role of digital governance in education, driven by advances in ICT, artificial intelligence, machine learning, big data analytics and cloud computing.

Through a visual analysis of international digital educational governance, several recommendations for the domestic sphere are proposed: firstly, enhancing the digital literacy skills of educators and students; secondly, integrating a comprehensive suite of digital policy tools, encompassing a wide range of software, platforms, and technologies into educational governance to support data-driven decision-making, enhance transparency, and facilitate personalized learning; thirdly, exploring and innovating new models of digital educational governance; and fourthly, engaging in international collaboration to draw upon best practices and innovative solutions from abroad, thereby enriching the discourse on digital education governance domestically.

Acknowledgement

Practice Study on Training Professional Quality of Primary School Teachers through College Cooperation in the Post-Epidemic Era.

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