# Research on Building Library-Empowered Smart Education Service Systems: A Bibliometric Review of Current Status and Future Prospects

**Authors:** He Cong, Yang Jing

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## Abstract

[Purpose/Significance] Against the backdrop of the official launch of the "Smart Education First Year," this study reveals the current status and development trends of research on library-empowered smart education, clarifies the academic ecological characteristics of this field, and provides references for constructing a library knowledge service system adapted to smart education development. [Method/Process] Selecting Chinese and English literature related to libraries and smart education from CNKI, Wanfang, and Web of Science databases, this study comprehensively employs bibliometrics, scientific knowledge mapping, and comparative research methods, utilizing software such as CiteSpace and VOSviewer to conduct multi-perspective, cross-lingual visual analysis and interpretation from dimensions including temporal distribution of literature, collaborative networks of prolific authors, institutional-regional output patterns, keyword clustering, and thematic evolution. [Results/Conclusion] Research on library-empowered smart education has experienced rapid development since 2020 and is currently in an active phase, with higher education institutions serving as the main arena. Significant differences exist between domestic and international research in terms of literature output rhythm, institutional and regional distribution, and keyword themes. Domestically, research focuses on eastern coastal regions and education-strong provinces (municipalities), emphasizing adaptation to local educational scenarios; internationally, it is led by China and the United States, primarily involving Asian countries, and focuses on technology-driven and cross-domain ecological expansion research. However, both face deficiencies and key challenges in collaborative depth and practical transformation. Finally, prospects are offered from four dimensions: collaborative mechanism optimization, technology fusion innovation, practical scenario expansion, and evaluation system reconstruction, proposing the construction of a library smart education service system that meets contemporary needs,

thereby facilitating the high-quality development of the smart education ecosystem and the rapid intelligent transformation of libraries.

## Full Text

# Research on the Construction of Library-Empowered Smart Education Service Systems: A Bibliometric-Based Review of Current Status and Future Prospects

**He Cong, Yang Jing**
Beijing Institute of Technology Library, Beijing, 100081

**Abstract:** [Purpose/Significance] Against the backdrop of the official inauguration of the "Smart Education First Year," this study reveals the current state and development trends of research on library-empowered smart education, clarifies the academic ecosystem characteristics of this field, and provides references for constructing a library knowledge service system adapted to smart education development. [Methods/Processes] We selected Chinese and English literature related to libraries and smart education from CNKI, Wanfang, and Web of Science databases. Using bibliometrics, scientific knowledge mapping, and comparative research methods, and employing software such as CiteSpace and VOSviewer, we conducted multi-perspective, cross-linguistic visual analysis and interpretation from dimensions including temporal distribution, high-productivity author collaboration networks, institutional-regional output patterns, keyword clustering, and thematic evolution. [Results/Conclusion] Research on library-empowered smart education has experienced rapid development since 2020 and is currently in an active phase. Higher education institutions serve as the primary front, with significant differences between domestic and international research in terms of publication rhythm, institutional-regional distribution, and keyword themes. Domestically, research concentrates in eastern coastal provinces and education-strong municipalities, focusing on adapting to local educational contexts. Internationally, China and the United States lead, primarily among Asian nations, emphasizing technology-driven and cross-domain ecological expansion research. However, both face deficiencies and key challenges in collaboration depth and practical transformation. Finally, we propose constructing a smart education service system for libraries that meets contemporary needs from four dimensions: collaborative mechanism optimization, technology integration innovation, practice scenario expansion, and evaluation system reconstruction, thereby facilitating high-quality development of the smart education ecosystem and accelerating library intelligent transformation.

**Keywords:** library; smart education; bibliometrics; visual analytics; knowledge service system

**Classification Codes:** G251.5, G353.1

## 1 Introduction

Smart education is recognized as the advanced stage of digital education development and the target form of educational digital transformation, representing the future development direction of new technology-driven educational change. It embodies the core concerns for future education in the knowledge economy society and artificial intelligence era, and is becoming a common strategic vision for the international community to address key challenges in the digital age and achieve sustainable educational development goals. There is no consensus among domestic and international academia and industry regarding when the concept of "smart education" was first proposed. Domestic scholars[1] and the *Encyclopedia of China* suggest that contemporary smart education in an information-based environment can be traced back to Qian Xuesen's advocacy of "Da Cheng Wisdom Studies" as early as 1997. During the same period, the American psychology community proposed that schools should teach for wisdom. In 2008, IBM first introduced the concept of "Smart Planet" in its report *Smart Planet: The Next Leadership Agenda*, which quickly extended to education and other domains. English literature generally considers this landmark international event as the starting point of smart education.

On May 16, 2025, at the World Digital Education Conference, the *White Paper on Smart Education in China* was officially released. This marked China's first white paper on "smart education," explicitly proposing that 2025 is the first year of smart education[2], signaling that the era of smart education has officially begun.

For the library community, the "first year of smart education" actually arrived before 2021. Public libraries, university libraries, and specialized library systems have all identified smart services and smart libraries as important future development directions[3-4]. Against the backdrop of China's vigorous promotion of educational digitalization and the construction of a lifelong learning society, learning powerhouse, and education-strong nation, libraries should actively consider how to "make contributions" and strive for "a rightful place" during their intelligent transformation process. Therefore, this study systematically reviews and visually analyzes literature related to libraries and smart education using bibliometric methods, attempting to reveal the research characteristics, existing problems, and key challenges of the current library smart education service system, and to identify directions for subsequent theoretical framework and practical path innovation, thereby providing a theoretical foundation and reference for libraries to continuously empower high-quality development of smart education and future research.

### 1.1 Data Sources

This study selected CNKI and Wanfang Data as Chinese literature retrieval platforms. In CNKI's professional search, we used the expression SU=('smart education' + 'smart learning' + 'smart teaching') * 'library' to search for library-

related content on smart education, smart learning, or smart teaching themes. We selected academic journals as the document type with unlimited time span, retrieving on June 5, 2025, and obtained 80 Chinese documents. In Wanfang Data's professional search, we used the expression theme:("smart education" or "smart learning" or "smart teaching") and ("library") with journal articles as the document type and unlimited publication time, retrieving on June 5, 2025.

We deduplicated and screened data from the two databases. After software deduplication and manual removal of duplicate literature, conference announcements, news reports, and interviews, we included 171 qualified Chinese documents. For English literature, we selected the Web of Science (WOS) database, specifically the WOS Core Collection. In WOS advanced search, we used TS=(Smart education OR Smart Learning OR Smart teaching) AND TS=Library as the search expression to find library-related content on smart education, smart learning, or smart teaching themes, with unlimited time span, retrieving on June 5, 2025. We retrieved 444 English documents. After manually selecting Articles and Review Articles and screening out duplicate literature and documents unrelated to libraries or smart education, we obtained 258 qualified English documents.

### 1.2 Research Methods

We converted Chinese literature from CNKI and Wanfang into formats recognizable by analysis software. Using CiteSpace (6.4.R2) and VOSviewer (1.6.20), we conducted visual analysis of the literature data, performing statistical and visual analysis of authors, institutions, keywords, and other node types to generate corresponding network maps and explore research 脉络, hotspots, and directions in library and smart education research. We used NoteExpress (V3.2) and Excel to record, sort, deduplicate, and statistically analyze overall literature output, publishing journals, and annual distribution characteristics.

## 2 Results

### 2.1 Annual Publication Volume Characteristics

Analysis of temporal distribution characteristics of literature output is shown in Figure 1 [FIGURE:1]. The results indicate that Chinese literature accounts for 39.9% of total publications, while English literature accounts for 60.1%. The cumulative annual publication volume of both Chinese and English literature shows a year-by-year growth trend, with English literature generally predominant. English literature first appeared in 2004[5], while Chinese literature first appeared in 2010[6], reflecting that international academia's attention to the library-smart education connection slightly preceded domestic interest. Before 2019, research on libraries and smart education experienced slow growth with low annual publication volumes, indicating that smart education received limited attention in the library community during this early exploratory stage. Starting in 2020, literature on libraries and smart education has grown rapidly, with significant increases in both Chinese and English annual publications, peak-

ing in 2024 (2025 data only includes publications up to June 5). Although fluctuations occurred, possibly due to shifting academic trends and research funding directions, the overall research 热度 remained high, reflecting rapidly growing research demand and sustained attention to library-empowered smart education both domestically and internationally. This trend may have been influenced by the global COVID-19 pandemic and driven by the continuous advancement of smart education in the education sector, as well as libraries' internal drive to seek service transformation and expand service connotations under the background of new-generation information technology transformation, prompting accelerated development and entering an active research phase.

A-annual cumulative number of published Chinese and English literature, B-number of Chinese and English literature published each year, 2025 data as of June 5.

Figure 1 Distribution Characteristics of literature production time

### 2.2 Journal Distribution

When exploring the development status of a research field, journal publication distribution is a key dimension for insight into the field's development ecosystem. We compiled and statistically analyzed the publishing journals for Chinese and English literature on libraries and smart education. Chinese literature was published in 128 journals, while English literature was published in 181 journals. The top 15 Chinese and English journals are shown in Figure 2 [FIGURE:2] and Table 1 , where journal database indexing, impact factors, JCR quartiles, and Chinese Academy of Science quartiles are based on the latest information obtained from relevant databases at the time of retrieval.

The top 15 Chinese journals exhibit distinct "library science + educational technology" integration characteristics. In terms of journal type, library science professional journals dominate, such as AMI-indexed journals like *University Library and Information Science Journal*, *Henan Library Science Journal*, and *Library Science Journal*, as well as CSSCI and Peking University Core journals like *Library Journal*, *Library Science Research*, and *Library and Information Service*, which collectively account for more than half of publications. This reflects that domestic research heavily relies on library science journal venues, focusing on professional practice exploration of library services in educational scenarios. Meanwhile, educational technology journals like *China Information Technology Education* and *Modern Educational Technology* are also frequently involved, demonstrating that "library-empowered smart education" requires interdisciplinary collaboration with educational technology to explore integration paths for smart learning and teaching models. Regarding database indexing, AMI database serves as the core support, with 80% of the top 15 Chinese journals indexed by AMI (authoritative, core, repository, extended). CSSCI (including extended edition) and Peking University Core journals also account for more than one-third, indicating that Chinese research results concentrate in

journals within the domestic humanities and social sciences evaluation system, with academic dissemination and evaluation relying on the domestic database ecosystem.

The top 15 English journals demonstrate multidisciplinary cross-disciplinary characteristics and convergence on high-impact international platforms. Disciplinary coverage is broader, including not only Library and Information Science (*Electronic Library*, *Library Hi Tech*, *Global Knowledge Memory and Communication*, *Information Development*, *Libri-International Journal of Libraries and Information Studies*, *Journal of Academic Librarianship*), but also computer science (*IEEE Access*, *IEEE Internet of Things Journal*, *International Journal of Advanced Computer Science and Applications*, *Expert Systems with Applications*, *Intelligent Automation and Soft Computing*), medicine (*Journal of Medical Internet Research*), environmental science and ecology (*Sustainability*), and comprehensive journals (*SENSORS*, *Applied Sciences-Basel*). This reflects that international research on library-empowered smart education is deeply integrated into the interdisciplinary ecosystem of "smart technology + educational services," expanding research boundaries through multi-domain journals. Regarding database indexing and impact, SCIE and SSCI international authoritative databases dominate, with high-quartile (Q1, Q2) journals accounting for over 70%. This indicates that English literature research results highly rely on high-impact international journals, with academic dissemination and evaluation embedded in the global academic system, more likely to receive broad international attention, and reflecting that cutting-edge research in this field is deeply bound to top multidisciplinary platforms.

Figure 2 Top 15 Chinese (A) and English (B) journals in terms of publication number

Table 1 Information of top15 published journals in Chinese or English

### 2.3 High-Productivity Author Collaboration Network Characteristics

High-productivity authors and their collaboration networks within a research field are important windows for insight into academic community interaction, research inheritance, and innovation. We statistically analyzed authors from Chinese and English literature, identifying 304 Chinese authors and 947 English authors. Using Price's Law formula m=0.749√nmax, where nmax represents the maximum number of publications by any author in the statistical period, authors with more than m publications are considered high-productivity authors[7]. Calculations yielded m=1.3 for Chinese authors and m=1.8 for English authors; both rounded to integers, we considered authors with $ $2 publications as high-productivity authors. Using VOSviewer for collaboration network analysis of high-productivity authors, we generated co-occurrence maps shown in Figure 3 [FIGURE:3].

The Chinese literature network includes 22 nodes (authors), with the largest connected component containing only 4 nodes, exhibiting a "small groups scattered,

weak overall connections" characteristic. Some authors formed local collaboration circles, such as small groups like "Hu Hongpu-Chen Quan-Chen Yongxin-Lei Xingyun" and "Han Jincen-Zhang Cheng-Ren Qi," reflecting collaboration within the same research team or institution. However, most high-productivity author nodes are isolated with low total connection strength (some at 0), indicating that cross-team collaboration has not yet formed scale in Chinese research, with insufficient overall synergy in the academic community. Temporally, Chinese high-productivity authors first appeared across large year spans—for example, early authors (Wang Changming, Rong Zhengtong in 2012) and recent authors (Wang Jing, Bai Rujiang in 2024) did not form continuous intergenerational collaboration, suggesting that research inheritance and relay mechanisms need improvement. This "scattered small groups" pattern may be influenced by domestic university and institutional research evaluation orientations and dispersed research resources, limiting cross-team wisdom aggregation and hindering systematic research advancement in the field.

The English literature network includes 23 nodes (authors), with the largest connected component containing only 5 nodes, exhibiting a "local clustering emerging, shallow cross-domain collaboration" characteristic. Although small-scale clusters centered on "Khan, Shakeel Ahmad" and "Khan, Asad Ullah" exist with relatively higher total connection strength than Chinese literature (mostly 8), all values are below 15, reflecting that the overall network has not formed a tight, large-scale collaborative ecosystem. The openness of international academic exchange and the interdisciplinary nature of smart education have not been fully transformed into tight cross-domain collaboration advantages, indicating that international research in this field remains in the exploratory stage regarding author collaboration network construction, requiring breakthroughs from local clustering to expanded collaboration breadth and depth.

Figure 3 Cooperation network of highly productive authors in Chinese (A) and English (B) literature

Table 2 Information of top15 authors in Chinese or English literature

### 2.4 Institutional and National Distribution Characteristics

The institutional and national/provincial publication distribution in a research field can reflect geographical clustering of academic research, resource investment, and development differences. Using CiteSpace software with Node Types set to Institution and Top N% set to 100, we identified 173 institutions from Chinese literature and 518 from English literature. All Chinese institutions except one from the Philippines are located in China, while English literature institutions come from 73 countries. The top 15 institutions for Chinese and English literature are shown in Table 3, while the top 15 provinces for Chinese literature and top 15 countries for English literature are shown in Table 4 .

These institutions include comprehensive universities, science and engineering institutions, vocational and technical colleges, and Islamic characteristic uni-

versities, with higher education institutions occupying the absolute dominant position, indicating that universities are the main front for library and smart education research both domestically and internationally. Among Chinese institutions, only Shanghai Jiao Tong University has published 3 related papers since 2012; other universities have generally low publication volumes of only 1-2 papers, indicating that universities and research institutions have not yet formed sustained, concentrated research output, lack "benchmark institutions" with long-term deep cultivation in this field, and have insufficient academic influence consolidation. The top 15 Chinese provinces exhibit a characteristic of "eastern coastal agglomeration and education-strong province leadership," with Jiangsu, Shandong, Guangdong, Beijing, Zhejiang, Fujian, and Shanghai—all eastern coastal provinces or education resource-rich regions—accounting for over 50% of publications. These areas have dense university concentrations, urgent educational digitalization needs, and good foundations for library smart service practices (such as smart library construction and online education support), driving related research.

Among the top 15 English institutions, 13 are Asian universities (covering China, South Korea, Pakistan, Saudi Arabia, and Iran), accounting for over 85% of institutions. This reflects the positive response of Asian regions to library-empowered smart education, possibly related to the advancement of Asian educational digitalization strategies (such as smart campus construction and online education popularization). However, small differences in publication volumes between institutions (mostly 2-5 papers) indicate no obvious core leading institutions, and low publication volumes from top European and American universities (such as Georgia Institute of Technology) suggest that Asian universities are currently the main force in international research, with participation from global top research forces needing improvement and cross-regional institutional collaboration networks remaining immature. English publication countries exhibit a characteristic of China-US leadership with diverse participation from Asian and Islamic countries. China (64 papers) and the United States (47 papers) are far ahead, reflecting the dual advantages of resource investment and demand-driven research in the world's two largest education and technology nations. Pakistan (19 papers), Saudi Arabia (18 papers), and Malaysia (9 papers) follow closely, with Asian and Islamic countries accounting for over 60% of publications. These countries have urgent educational digitalization needs (such as library services for religious education and distance education) and concentrated research output influenced by international educational aid and digital infrastructure advancement. However, lower-than-expected publication volumes from traditional European and American education and academic powers (such as the UK and Germany) reflect uneven research 热度 distribution among countries.

Table 3 Information of top15 institutions in Chinese or English literature

Table 4 Information of top 15 provinces in Chinese and top 15 countries in English literature

### 2.5 Keyword Analysis

**2.5.1 Co-occurrence Network Analysis** Keywords in literature are highly condensed expressions of authors' main ideas and standardized vocabulary of paper themes. Analyzing literature keywords enables deep exploration of a field, and high co-occurrence frequency helps scholars identify research hotspots[8]. Using VOSviewer software to analyze keywords from Chinese and English literature, we merged and deduplicated synonymous keywords such as "智慧型图书馆" and "智慧图书馆," "高校" and "高等学校," "information-science" and "information science," "web 2" and "web 2.0." After merging, Chinese literature yielded 375 keywords; we selected 68 high-frequency keywords with occurrence frequency $ $2 for co-occurrence network analysis. English literature yielded 1,512 keywords; we selected 73 high-frequency keywords with occurrence frequency $ $4 for co-occurrence network analysis, with results shown in Figure 4 [FIGURE:4].

We present the top 15 keywords by frequency and first appearance year in Table 5 . Chinese literature research centers on the "smart education" core, deeply bound to library application scenarios. Library science-specific concepts such as "高校图书馆" (41 occurrences), "智慧图书馆" (23), and "图书馆" (18) co-occur frequently and are strongly associated with "智慧教育" (32), "智慧学习" (10), and "未来学习中心" (12), demonstrating that domestic research focuses on "how libraries embed into the smart education ecosystem," exploring scenario-based empowerment paths such as smart collections, smart learning spaces, and knowledge services (e.g., "智慧学习空间" with 9 occurrences, "智慧服务" with 11). Meanwhile, emerging technology keywords such as "元宇宙" (5 occurrences, first appearing in 2022) and "人工智能" (5, first appearing in 2023) show weak association with "智慧教育," reflecting that domestic research on applying cutting-edge technologies remains in its initial stage, with insufficient depth in technology-education scenario integration. The overall network presents a structure of "library scenarios as the foundation, educational ecosystem as the framework, and technology application as supplementation," focusing on local educational needs (e.g., "信息素养" or "信息素养教育" with 11 total occurrences) but requiring expanded breadth and depth of interdisciplinary technology integration.

English literature research centers on technologies such as "machine learning" (46), "artificial intelligence" (22), and "internet of things" (23), radiating toward global educational common issues. Technology keywords like "education" (21) and "smart libraries" (related terms) are strongly bound, reflecting that international research emphasizes "how technology reconstructs library educational services," exploring technology-driven paths such as machine learning-empowered service optimization (e.g., "classification" with 14 occurrences), IoT reshaping collection management (e.g., "management" with 13), and big data-supported decision-making (e.g., "big data" with 20). Additionally, public health event keywords such as "covid-19" (related terms) are embedded in the network, reflecting international research attention to educational emergency scenarios (such as library pandemic online services), demonstrating the driving force of global educational common challenges on research. The English network presents a

structure of "technology as the core, educational scenarios as the target, and global issues as the mirror," deeply integrating multidisciplinary technologies to respond to universal smart education needs, but paying insufficient attention to library science local characteristic scenarios (such as university library-specific services).

Figure 4 High-frequency keyword co-occurrence network map of Chinese literature (A) and English literature (B)

Table 5 Top 15 high-frequency keywords in Chinese or English literature

**2.5.2 Cluster Analysis** Cluster analysis of Chinese and English keywords enables better observation of research direction distribution within a field. More keywords under a cluster indicate more nodes within the cluster module, making the cluster larger and more important. Cluster module value (Q-value) and cluster average silhouette value (S-value) can determine clustering effectiveness; generally, Q>0.3 and S>0.5 indicate the mapping results have significant reference value[9-11]. Using CiteSpace software to import Chinese and English literature information for keyword clustering, the resulting cluster maps are shown in Figure 5 [FIGURE:5]. The Q-values for Chinese and English literature maps are 0.7398 and 0.8957, respectively, and S-values are 0.9277 and 0.9552, respectively, indicating significant and reasonable keyword clustering structures with high reference value.

From the Chinese literature keyword cluster map, research forms nine core clusters covering themes such as "smart education," "smart learning," "smart service," and "future education," presenting three major characteristics. First is scenario-based empowerment dominance, with clusters focusing on "library embedding into smart education scenarios," such as "#6 smart learning" and "#8 smart classroom" linking to learning scenarios, "#4 smart service" and "#7 smartification" focusing on service models, and "#0 smart education" and "#1 future education" anchoring the educational ecosystem. This demonstrates that domestic research is driven by "educational scenario needs," exploring libraries' functional upgrading from resource provision to smart services. Second is technology-literacy synergy, with "#2 linked data" and "#5 information literacy" clusters highlighting the dual logic of technological support and literacy cultivation—linked data provides the resource foundation for smart education, while information literacy empowers teachers and students to adapt to smart services, reflecting domestic research attention to the "technology application + literacy cultivation" collaborative path. Third is local scenario adaptation, with the "#3 vocational colleges" cluster demonstrating research attention to scenario adaptability in vocational education, responding to domestic vocational education digital transformation needs, and showing that Chinese research emphasizes differentiated empowerment for local educational stratification and classification (such as vocational colleges and regular higher education institutions).

From the English literature keyword cluster map, research forms twenty core

clusters covering themes such as “smart library,” “machine learning,” “internet of things,” and “data science,” which can also be summarized into three characteristics. First is technology-driven core, with clusters centered on technologies such as “#1 head-mounted display use,” “#5 manufacturing cloud,” “#7 neural network model,” and “#17 computer vision,” radiating to cross-domain applications such as “#9 additive manufacturing,” “#12 using smart home technologies,” and “#19 public library setting.” This demonstrates that international research emphasizes “technology reconstructing educational service boundaries,” exploring how libraries integrate into the global smart ecosystem (such as manufacturing, smart home, and urban contexts) through technology, breaking through traditional educational service scopes. Second is system-culture synergy, with “#6 warning system,” “#15 smart culture,” and “#16 datastream classification” clusters highlighting “smart culture + smart governance” synergy, reflecting international research attention to the “soft environment” (cultural cultivation, governance systems) of library-empowered smart education, rather than focusing solely on technology application, demonstrating deep integration into the global educational governance ecosystem. Third is global issue response, with “#10 heart failure” and “#11 health care” clusters echoing global common issues such as public health and health management, indicating that international research focuses on libraries’ roles in emergency education and global health governance, demonstrating the driving force of global issues on research directions.

Figure 5 Keyword clustering maps of Chinese literature (A) and English literature (B)

**2.5.3 Timeline Analysis** Keyword cluster timelines can clearly observe each cluster’s temporal span and keyword distribution within clusters, vividly displaying the research logic, thematic associations, evolution 脉络, and research foci of a field[8]. Using CiteSpace software for keyword cluster timeline analysis of Chinese and English literature on library and smart education research, the results are shown in Figure 6 [FIGURE:6]. The timeline’s horizontal axis represents years, the vertical axis represents clustering results, and color changes from inner to outer nodes represent temporal evolution.

The Chinese literature keyword timeline presents an evolution logic of “smart education as the foundation, scenario-based expansion as the 脉络,” rooted in local educational needs, gradually deepening from basic concepts to layered scenarios and technology integration. Core characteristics can be divided into three periods: embryonic foundation period (before 2010s), scenario deep cultivation period (2010s–2020s), and frontier exploration period (after 2020s). The embryonic foundation period focused on basic concepts of “smart education” and “smart learning,” laying the research foundation for library-empowered smart education, reflecting early domestic librarians’ understanding of smart education. The scenario deep cultivation period expanded along the “smart education” mainline to diverse scenarios: first, educational stratification scenarios,

deriving "#3 vocational colleges" and "#8 smart classroom" clusters to respond to vocational education and classroom digitalization needs; second, technology integration scenarios, adding "#2 linked data" and "#5 information literacy" clusters to explore data-driven services and literacy cultivation paths; third, service model scenarios, expanding "#4 smart service" and "#7 smartification" clusters to promote libraries' transformation from resource provision to smart services. The frontier exploration period introduced information technology keywords such as "5G," "blockchain," "metaverse," "artificial intelligence," and "digital twin," attempting integration into the "#1 future education" framework, reflecting domestic exploration of new technology-empowered education forms, but still focusing on local educational scenarios (such as higher education institutions) with technology integration depth requiring breakthrough.

The English literature keyword timeline presents an evolution logic of "technology as the core, cross-domain ecosystem construction as the 脉络," relying on technological advantages to expand from educational scenarios to cross-domain ecosystems such as healthcare, governance, and emergency response, constructing a global research network. Core characteristics can be divided into three periods: technology foundation period (before 2010s), technology deep cultivation period (2010s–2020s), and frontier exploration period (after 2020s). The technology foundation period focused on basic associations of "academic libraries," "library," and "education," initially introducing technical concepts such as "artificial neural networks" and "#8 neural network model," laying the foundation for technology-driven research and reflecting early international attention to technology empowerment. The technology deep cultivation period rapidly expanded along the "technology integration" mainline to cross-domain ecosystems: first, intelligent technology scenarios, deriving keywords such as "machine learning," "artificial intelligence," "big data," "internet of things," and "blockchain," deeply embedded in cross-domain scenarios like "activity recognition," "#8 smart healthcare system," "agriculture," and "art"; second, global governance scenarios, adding clusters and keywords such as "#15 smart culture," "air pollution," "management," "system," and "model" to explore libraries' roles in cultural governance, public management, and services; third, emergency response scenarios, introducing clusters and keywords such as "#11 health care," "covid-19," "event-based systems," and "#6 warning system" to respond to public health event-driven educational service innovation. The frontier exploration period expanded information technology clusters and keywords such as "#1 head-mounted display use," "#2 bibliometric perspective," "#5 manufacturing cloud," "virtual reality," "digital twin," and "data mining algorithms," attempting to construct deep integration of "technology-education-global ecosystem," reflecting international research's sustained attention to technology-driven global educational ecosystem reconstruction.

Figure 6 [FIGURE:6] Timeline of keyword clustering results of Chinese literature (A) and English literature (B)

# 3 Discussion

## 3.1 Research Status Assessment and Conclusions

Through bibliometrics, scientific knowledge mapping, and comparative research methods, using tools such as CiteSpace and VOSviewer, this study conducted visual analysis and interpretation of journal literature on libraries and smart education from CNKI, Wanfang, and Web of Science databases. Examining publication timelines, high-productivity author collaboration networks, institutional and regional distribution, keyword co-occurrence and clustering, and timeline analysis, we presented the research 脉络 and current status characteristics of library-empowered smart education research across multiple dimensions, while also reflecting existing deficiencies and challenges. The main conclusions are as follows:

(1) From the temporal distribution of literature output, both domestic and international research have experienced a process from embryonic exploration to rapid growth. Chinese literature started slightly later but demonstrated stronger explosive growth in later stages, reflecting domestic research advantages under smart education strategy promotion. English literature explored earlier, with more volatile development influenced by diverse academic environments, reflecting frontier iteration and direction dispersion in international research. This difference reflects different response models between domestic and international academic ecosystems and educational digitalization needs.

(2) Keyword co-occurrence and cluster analysis shows that Chinese research focuses on "library service scenarios + educational ecosystem" integration, emphasizing adaptation to local educational contexts. English research is based on "technology-driven + global educational commonalities," emphasizing technology reconstruction of educational services. This reflects the divergence between domestic and international research on the demand and supply sides, providing guidance for the library community to further promote the construction of a more dynamic smart education research ecosystem and service system driven by the dual wheels of "scenarios + technology."

(3) Current research faces challenges in literature output: although Chinese literature grows rapidly, the proportion of high-quality, high-impact achievements needs improvement, while English literature pays insufficient attention to local educational scenarios (such as library practices). Author collaboration exhibits a "local clustering, overall dispersion" pattern, with most authors in isolated research states, weak deep collaboration across institutions, generations, and regions, making it difficult to sustain research inheritance and innovation chains.

(4) Future research faces challenges in transforming theory to practice, with unclear transformation paths from research results to library smart ed-

ucation service practices. The role positioning of libraries in smart education scenarios, service models, and technology application implementation mechanisms need clarification. Academic ecosystem collaboration faces challenges, with immature collaborative networks among domestic and international academic communities, institutions, and regions, and insufficient release of knowledge sharing and innovation synergy, making it difficult to support the diverse needs of interdisciplinary and cross-scenario smart education research at a high level.

### 3.2 Future Research Directions and Prospects

The current status review of library-empowered smart education service system research reveals structural characteristics and development bottlenecks in collaboration networks, technology application, and practice scenarios. These findings not only expose key challenges facing current service system construction but also indicate directions for subsequent theoretical framework and practical path innovation. Based on the above analysis of current research status, this study explores systematically constructing a library-empowered smart education service system that meets contemporary needs, focusing on collaborative mechanism optimization, technology integration innovation, practice scenario expansion, and evaluation system reconstruction, to provide forward-looking thinking for promoting the theoretical construction and practical implementation of library smart education service systems.

**3.2.1 Optimizing Collaboration Mechanisms: Circle Integration and Dimensional Expansion** Libraries have accumulated diverse collaboration models and cross-system alliance cooperation mechanisms in their service innovation practices that can serve as references for smart education service systems[12-13]. From a cross-circle synergy perspective, we need to break inherent boundaries of "local small groups" and "international local clustering." Domestically, promote the construction of provincial and national library science research alliances, such as those led by university libraries and jointly established with public libraries and vocational college libraries, to conduct collaborative research on "smart education resource co-construction and sharing," integrating practical experiences from different library types in smart education services to form research results covering all educational stages. Internationally, promote organizations like IFLA to launch a "Global Library Smart Education Collaboration Plan" to conduct transnational joint research on common challenges such as "library empowerment for educational equity under the digital divide," promoting global flow of academic resources and practical experience. For cross-dimensional synergy, strengthen multidimensional integration of "discipline-scenario-technology." Form research teams comprising multidisciplinary experts from library science, education, computer science, psychology, etc., focusing on "user behavior analysis and service optimization in smart education," using educational psychology theories to analyze user smart learning needs, computer science technologies to construct service models, and library

science methods to implement practical solutions. Simultaneously, expand research scenario boundaries beyond traditional campus contexts to community education and lifelong learning scenarios, exploring how libraries empower smart education in non-formal education systems, such as how community libraries use smart terminals to provide digital literacy education services for elderly populations.

**3.2.2 Innovating Technology Integration: Emerging Technologies and Traditional Services Coexistence** With the revolutionary progress of digital technologies such as 5G/6G, artificial intelligence, cloud computing, IoT, blockchain, and metaverse, traditional learning and lifestyle patterns in the digital intelligence era demonstrate powerful transformation potential[14-15]. For artificial intelligence technology, conduct research on "library smart education service intelligent agents." Develop intelligent systems with functions such as knowledge recommendation, learning companionship, and service scheduling. Based on user profiles and learning trajectories, accurately push collection resources and online courses for learners in smart education scenarios, and assist teachers in designing personalized teaching plans. Simultaneously, explore intelligent agents' applications in library smart reference consultation and subject services to enhance the intelligence level and response efficiency of smart education services. For metaverse technology, construct "metaverse smart learning spaces." Create virtual library smart education scenarios enabling virtual collection resource roaming, immersive learning activities, and cross-regional learner interaction, breaking through physical space limitations and expanding the temporal and spatial dimensions of smart education services[16-17]. For big data technology, deepen "library smart education data governance and application." Establish smart education data platforms covering user data, resource data, and service data, using data mining and visual analysis technologies to analyze demand patterns, resource utilization efficiency, and service effectiveness evaluation in smart education services. Based on data insights, optimize library smart education resource allocation, such as dynamically adjusting collection construction and digital resource push strategies according to resource demand preferences of users in different regions and educational stages.

**3.2.3 Expanding Practice Scenarios: Layered Progress and Cross-domain Full Coverage** China has built the world's largest educational resource center, the "National Smart Education Public Service Platform"[15,18], which can fully utilize existing application scenarios and refine research granularity in layered educational scenarios. For higher education, focus on differences between "double first-class" universities and local institutions, researching how top university libraries can build smart education research support systems relying on high-quality academic resource advantages to serve top innovative talent cultivation, and exploring how local university libraries can create industry-education integration smart education service platforms combining regional industrial needs to assist applied talent cultivation. For basic education,

focus on primary and secondary school libraries (rooms), conducting research on "primary and secondary school library empowerment for student core competency cultivation in the context of smart campuses," exploring models for using library spaces to conduct project-based learning and information literacy training in smart education activities, strengthening libraries' roles in basic education smart transformation. In cross-domain educational scenarios, expand service boundaries. For lifelong education, construct a "library + elderly university + community" smart education collaborative service model, developing aging-friendly smart education resources and services such as large-font digital resource databases and voice-interaction learning platforms to meet elderly populations' smart learning needs. For special education, research appropriate transformation of library smart education services, using VR and AR technologies to create barrier-free smart learning spaces for visually and hearing-impaired populations, providing personalized resources and services to promote equitable and inclusive smart education development.

**3.2.4 Reconstructing Evaluation Systems: Multi-dimensional Architecture and Dynamic Mechanism Construction** Scientific and complete service evaluation systems are crucial for libraries to optimize smart education service quality and achieve long-term development. Especially as new-generation information technologies such as artificial intelligence and metaverse increasingly integrate with educational behaviors, educational evaluation scenarios have undergone significant transformation[19-21]. For library smart education service systems, explore constructing multi-evaluation indicators of "process + results." Process evaluation covers collaboration network activity (such as cross-institution collaboration frequency and intergenerational inheritance effectiveness) and technology application depth (such as innovation points of emerging technology integration into services and user participation). Results evaluation includes practical transformation effectiveness (such as number of cases where service models are referenced and promoted by other libraries and data on improved smart education teaching effectiveness) and academic influence (such as highly cited papers and international academic dialogue participation). Combining qualitative and quantitative indicators comprehensively measures the value of library-empowered smart education research and practice. Establish dynamic evaluation mechanisms that adjust evaluation indicators timely according to smart education development stages and technology iteration rhythms. For example, in the initial application stage of metaverse technology, focus on evaluating scenario construction innovation and user experience; when technology matures and promotes, emphasize evaluating educational teaching effectiveness and social value. Simultaneously, introduce user participatory evaluation, allowing smart education service users (students, teachers, lifelong learners, etc.) to participate in evaluation processes through questionnaires and user experience interviews to obtain authentic feedback and optimize evaluation results, ensuring evaluation system scientificity and practicality, and providing basis for continuous improvement of library-empowered smart educa-

tion service systems.

## 4 Conclusion

With the official inauguration of the smart education first year and the background of library intelligent transformation, the construction of library-empowered smart education service systems has entered a rapid development stage. However, the current academic ecosystem in the library and smart education research field presents a status of "local collaboration, overall dispersion," constrained by factors such as research evaluation, resource allocation, and regional culture, while also reflecting insufficient adaptation between research models and interdisciplinary, cross-scenario needs. Yet this also provides entry points for libraries to optimize smart education service systems—through building multi-dimensional collaboration platforms, improving evaluation mechanisms, and strengthening intergenerational inheritance, research forces can be transformed from dispersion to synergy, from local clustering to full-domain linkage.

In the future, with maturing collaboration networks, upgraded technology empowerment, expanded practice scenarios, and innovative evaluation systems, library-empowered smart education research will enter a new stage: breakthroughs in interdisciplinary integration depth to create more precise and immersive service solutions for smart learning and teaching; expanded breadth of cross-regional synergy to gather global experiences and help libraries play core hub roles in educational equity and digital transformation. Especially university libraries, as dual subjects of research and practice, need to deeply integrate into this development process, driving continuous upgrading of library smart education services with dual identities as "academic collaborative innovators" and "practice service leaders," injecting abundant momentum into smart education ecosystem construction, truly making libraries key engines for knowledge dissemination, innovation cultivation, and equity assurance in the smart education era, and providing solid library science support for achieving the strategic goal of becoming an education-strong nation.

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## Figures

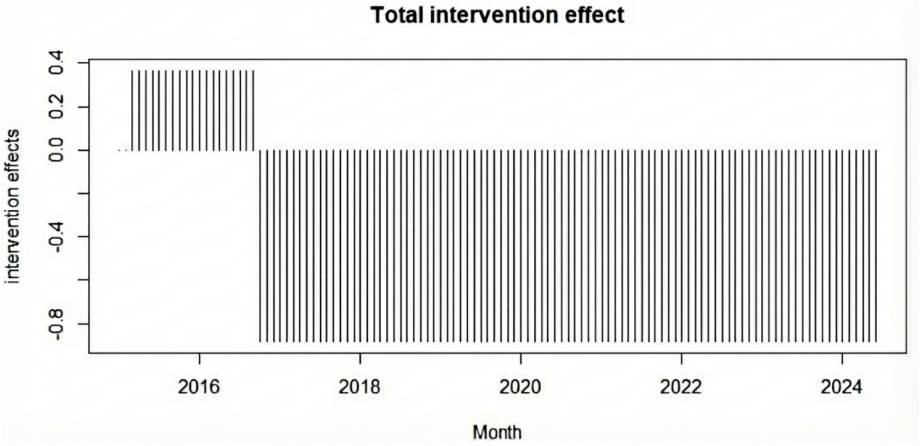


Figure 1: Figure 8

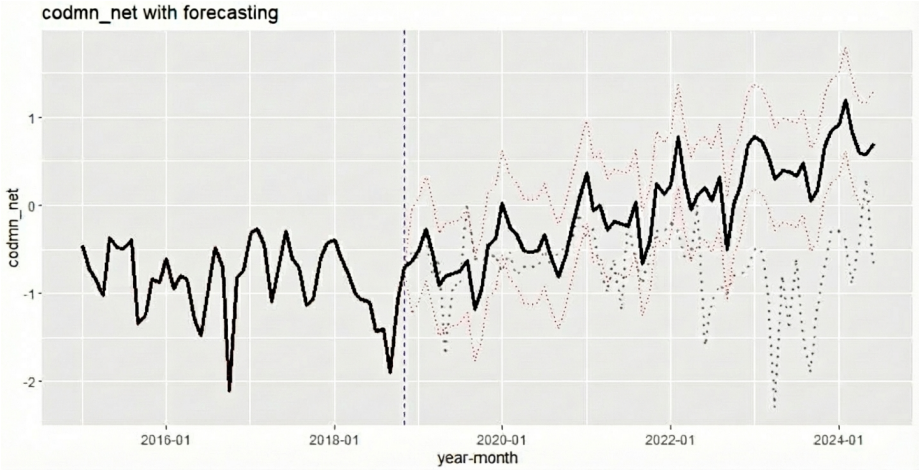


Figure 2: Figure 9