Analysis of the Forefront of Intelligent Classroom and Educational Informatization in China

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Abstract. With the rapid development of information technology, the informatization of education has become an inevitable trend in modern education. As a crucial manifestation of educational informatization, smart classrooms are gradually changing traditional teaching methods and learning models. In recent years, thanks to the continuous development of technology, research on smart classrooms has made significant progress in various academic fields and yielded fruitful results. This paper uses bibliometrics and CiteSpace visual knowledge map analysis tools to analyze China's research on educational informatization and smart classrooms, including the number of papers published, authors, co-occurrence maps of keywords, keyword clustering maps, and keyword temporal distribution maps. The results indicate that active institutions in the research of smart classrooms in China include South China Normal University, Northeast Normal University, and others. Active authors include Liu Bangqi and Xie Yueguang. The research hotspots of smart classrooms are "Theory and Practice of Smart Classrooms," "Technology Application and Teaching Model Innovation," "Core Literacy and Learning Framework," and "Smart Campus and Industry-Education Integration." Finally, based on the analysis results, several insights are proposed for the development of smart classrooms in China.

Keywords: Educational Informatization; Smart Classroom; Intelligent Technology; Smart Learning.

1 Introduction

The smart classroom utilizes the latest generation of information technology to revolutionize the classroom, creating an informational and intelligent learning environment. In China, the development of smart classrooms is closely linked to government educational policies. Since the beginning of the 21st century, China has started to explore educational informatization. Post-2010, the Ministry of Education in China has placed greater emphasis on the application of information technology in the field of education, promoting the Educational Informatization 2.0 strategy. The development of smart classrooms is not only limited to digital teaching resources but also extends to the integrated use of technologies like cloud computing, big data, and artificial intelligence. In recent years, government documents have emphasized the use of informatization to

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promote the modernization of education and accelerate the innovative pace of smart classrooms. At the current stage, smart classrooms focus more on using technology to improve the quality and efficiency of education, achieving personalized and intelligent teaching. Overall, the progress of smart classrooms in China is a result of technological development and the direction of educational policy, reflecting the trend of concurrent development of educational informatization and modernization. Currently, researchers from disciplines like pedagogy, management, and engineering are conducting smart classroom analysis studies from various perspectives, involving multiple fields, including the theoretical construction of smart classrooms, smart curriculum technology, smart classrooms, instructional design, and evaluation of smart classroom teaching. The related literature in this research field is abundant and features a diverse and complex knowledge structure. To more comprehensively explore the current status, hotspots, and development trends of smart classroom research, this study uses the CNKI database as a data source, utilizing scientometrics to visually present the knowledge structure of existing literature, thereby providing a reference and an overall view for scholars in the field. This paper investigates the progress of smart classrooms by answering the following three questions: (1) Which individuals and institutions in China are researching smart classrooms? (2) What are the hot topics in smart classroom research? (3) What are the future research trends for smart classrooms?

2 Data and research methods

To thoroughly analyze the research trends and themes in the field of smart classrooms, this study selected the China National Knowledge Infrastructure (CNKI) database as the literature retrieval platform, due to its extensive and comprehensive coverage in China. Using the advanced search function of CNKI with "smart classroom" as the keyword, and limiting the source type to "Core Journals," "CSSCI," and "CSCD" to ensure the quality and comprehensiveness of the retrieved data. This study did not set a specific time limit to gather as wide a range of literature data as possible. Through this method, a total of 444 documents were retrieved. Each document record includes information such as the title, authors, institutions, abstract, keywords, publication medium, and date, excluding the main text and references. To ensure the accuracy and relevance of the research, a manual selection method was used to eliminate irrelevant documents, such as foreign language literature, conference news, and review articles, etc. Finally, 420 documents were determined as the research sample.

In the area of data mining and visual analysis, this study employed the advanc ed scientific literature mining and visualization tool — CiteSpace6.1.6 software, a iming to deeply explore the annual development trends, thematic distribution, and knowledge structure of smart classroom research. CiteSpace is a scientometric vis ualization software developed by Professor Chaomei Chen's team at Drexel Unive rsity in the USA, based on the Java platform. In recent years, it has been widely used in bibliometric analysis.[1]

3 Results Analysis

3.1 Publication Volume Analysis

Looking at the annual publication volume (see Figure 1), from 1997 to 2015, the cumulative number of published documents in this field was 46, showing a slow growth trend. However, since 2015, the research momentum in this field has clearly strengthened. Between 2016 and 2020, the volume of literature published significantly rose to 223, with an average annual publication rate of about 47. Particularly in 2020, the annual publication volume reached a peak of 80 papers. Entering the period from 2021 to 2023, although the annual publication growth rate has slowed down, the total number still maintains at 151, with an average annual publication rate of about 50. Overall, the volume of literature published in the field of smart classrooms demonstrates a clear increasing trend.

3.2 Distribution of Research Institutions and Prolific Authors

Between 1997 and 2023, nine research institutions in China participated in smart classroom research. Among them, the School of Educational Information Technology at South China Normal University, the School of Information Science and Technology at Northeast Normal University, the School of Information and Software Engineering at Northeast Normal University, the School of Open Learning at East China Normal University, the Faculty of Education at Shandong Normal University, the iFlytek Education Technology Research Institute, the Digital Learning Technology Support Center of the Ministry of Education, the School of Educational Technology at Northwest Normal University, and the Faculty of Education at Beijing Normal University are the prolific institutions. These institutions are mainly concentrated in disciplines such as pedagogy, management, and engineering. In terms of individual contributions, Liu Bangqi, Xie Yueguang, Tang Yewei, Pang Jingwen, and Zhong Shaochun are prolific authors. However, overall, there is still a need for enhanced communication and collaboration among researchers in this field.

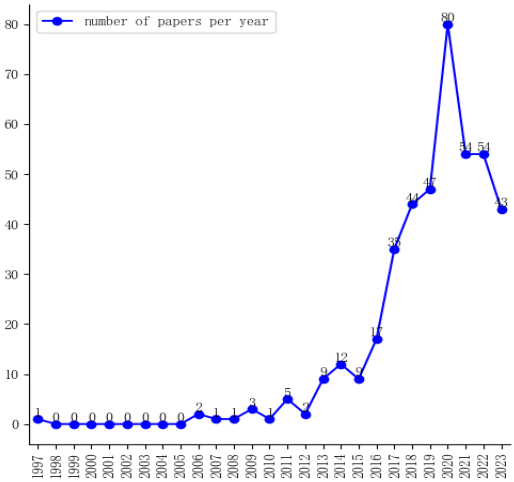

Fig. 1. Number of publications on the theme of Smart Classroom from 1997 to 2023.

3.3 Knowledge Evolution Analysis

Using Category as the node type, a threshold of Top N=50 was selected, setting Slice=1, and the Pathfinder network pruning method was chosen to generate Figure 2. Based on the node distribution and the color of the connections in Figure 2, the progress of smart classroom research can be divided into three stages. From 1997-2015, the primary keywords were "smart classroom," "information age," "real-time teaching," "diverse curriculum," "classroom teaching," "smart classroom," "smart education," "information technology," "teaching model," "teaching strategy," "smart learning," etc., focusing on applying information technology in the field of education to enhance quality and efficiency. From 2016-2020, the main keywords were "instructional design," "cloud teaching," "flipped classroom," "big data," "artificial intelligence," "vocational education," "intelligent era," "deep learning," "intelligent technology," "human-computer collaboration," "conceptual map," "online education," "human-computer interaction," etc., focusing on the further development and application of educational technology. From 2021-2023, the main keywords were "learners," "future schools," "cultivation mechanism," "precision teaching," "integration of industry and education," "synchronous classroom," "classroom interaction," "teaching interaction," etc., focusing on learner-centered educational methods, educational innovation, the improvement of cultivation mechanisms, integration of industry and education, synchronous classrooms, in-class interactions, and the development of teaching interaction.

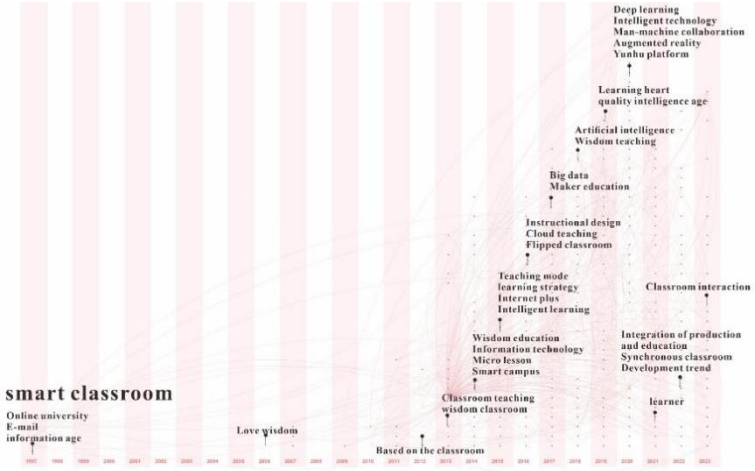

Fig. 2. Time Zone Analysis of Keywords in Smart Classroom

3.4 Research Hotspots Analysis

1)Keyword Analysis

Using Keywords as the node type, with a threshold set at Top N = 50 and oth er parameters at default values, the keyword co-occurrence knowledge map obtain ed through Citespace metric analysis is as shown in Figure 3. The analysis reveal ed 677 nodes and 1,529 connections, with a network density of 0.0067. The speci fic data on keyword frequency and centrality are presented in Table 1., the keyw ords that rank in the top 13 in both frequency and intermediary centrality include smart classroom, smart education, artificial intelligence, teaching model, deep lear ning, core literacy, big data, teaching strategy, smart teaching, instructional desig n, Flipped Classroom, information technology. These terms have become substant ial nodes or critical hubs within the research network of smart classrooms, playin g a significant role in the research of smart classrooms.

Table 1. Frequency Distribution of Keywords for Smart Classrooms (1997-2023)(TOP12)

Number	Frequency	Intermediary centrality	Year	Keywords
1	250	1.14	1997	smart classroom
2	26	0.07	2014	Smart Education
3	16	0.03	2018	artificial intelligence
4	13	0.00	2015	teaching model
5	11	0.00	2020	deep learning
6	11	0.01	2019	core literacy
7	10	0.01	2017	core literacy
8	10	0.01	2015	teaching strategy
9	10	0.02	2018	smart teaching
10	8	0.01	2016	instructional design
11	8	0.01	2016	Flipped Classroom
12	8	0.04	2014	Information technology

2)Keyword Clustering Analysis

To further analyze and refine the research hotspots in the field of smart classro oms, this study conducted a clustering analysis based on Figure 3, resulting in a keyword clustering map as shown in Figure 3. CiteSpace provides module value (Q) and silhouette value (S) based on network structure and clarity of clustering, with Q > 0.3 indicating a significant cluster structure, and an S value of 0.7 sugg esting that the clustering is efficient and convincing; if it's above 0.5, the clusteri ng is generally considered reasonable. The map indicates Q = 0.6705 and S = 0.9 746, suggesting that the results of the clustering analysis are ideal and credible. T his analysis identified 20 clusters, with 9 clearly presented, including #0 smart cla ssroom, #1 smart education, #2 core literacy, #3 smart campus, #4 teaching mode l, #5 instructional design, #6 artificial intelligence, #7 smart teaching, and #8 lear ning architecture.

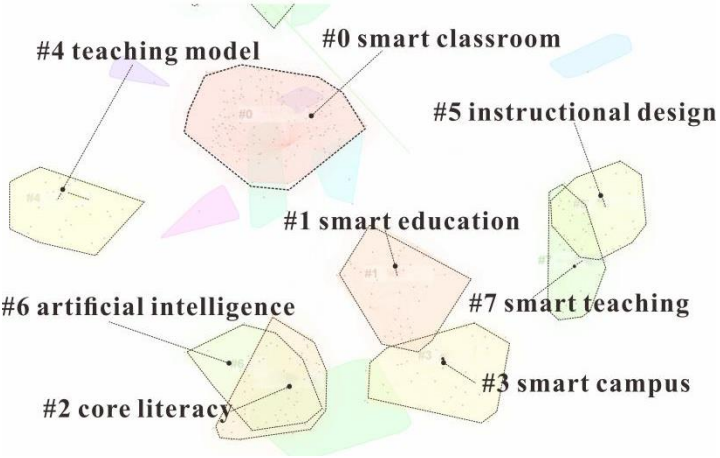

Fig. 3. Cluster Map of Smart Classroom Keywords

Table 2. Classification of Co-occurring Keyword Clusters in Smart Classrooms

Research Theme	Cluster number name	Cluster size	Clustering Tags (LLR algorithm)
Theory and Practice of Smart Classrooms	#0 smart classroom	147	Wisdom classroom; Intelligenteducation; Implementation strategy;Cloud teaching;Artificial intelligence;
	#1 smart education	46	Intelligent education; Classroominteraction; Higher vocational colleges; Grounded theory; Practice framework;
	#7 smart teaching	31	Intelligent teaching; Intelligent learning; Strategy; Structural analysis; "Rainclassroom" teaching;

Technological Application and Innovation in Teaching Models	#4 teaching model	38	Teaching mode; Educational-technology; Intelligent technology; Design; Classroom wisdom;
	#5 instructional design	35	Teaching design; Teaching evaluation; Colleges and universities; Dataanalysis; The idea of harmony;
	#6 artificial intelligence	34	Artificial intelligence; The Age of intelligence; Application design; Production andeducation; Teaching subject;
Core Competencies and Learning Architecture	#2 core literacy	35	Core literacy; Smart classroom; Groupwork; Full participation, ldeologicaland political teaching;
	#8 learning architecture	30	Learning architecture; Deep learning; Flexibility; Artificial intelligence empowerment; Key ability training;
Smart Campus and Industry-Education Integration	#3 smart campus	39	Smart campus; Jiangsu Province; Intelligent;

3)Research Hotspot Analysis

By synthesizing the cluster labels for in-depth exploration, the researcher categ orized the research hotspots in this field into four directions (as shown in Table 2): theory and practice of smart classrooms, technological application and innovati on in teaching models, core literacy and learning architecture, and smart campus with industry-education integration.

a) Theory and Practice of Smart Classrooms.

This direction focuses on "#0 smart classroom," "#1 smart education," and "#7 smart teaching." The cluster labels include smart classroom, smart education, clas sroom interaction, smart teaching, smart learning, etc. Under this direction, resear chers mainly discuss how to use modern technological means such as artificial int elligence and big data to improve the efficiency and quality of education and teac hing, fostering students' innovative abilities and lifelong learning skills.

The main research content focuses on: (1) Theoretical construction and teachin g models of smart classrooms: studying the foundational theories and the construc tion of teaching models for smart classrooms. (2) Practical application and case st udies of smart classrooms: discussing the application cases of smart classrooms in actual teaching. (3) Roles and interaction of teachers and students in smart classr ooms: researching the changes in roles and modes of interaction for teachers and students within the smart classroom environment. (4) Application of smart classro oms in specific fields: focusing on the application of smart classrooms in specific

educational areas (such as vocational education, adult education, etc.). (5) Applic ation of smart classrooms in specific subjects: concentrating on the application of smart classrooms in various disciplines (such as mathematics, language arts, etc.). For example, Yuan Xiujuan [2 discussed the concept construction and model anal ysis of smart classrooms. Chen Ke [3] conducted related research using the "Sma rt Classroom" project with electronic bags as an example. Liu Qingtang and other s [4] studied the design and implementation of classroom interaction tools support ed by learning analytics. Wu Xiaowei and others [5] explored the problems and c ountermeasures of blended teaching in higher vocational professional courses in t he post-pandemic era. Li Kehong[6] researched the talent cultivation model of ad ult higher education under the perspective of artificial intelligence. Duan Rongjua n and others[7] explored the construction of foreign language smart classrooms u nder an international context. Gao Song and others[8] investigated the design of pre-class autonomous learning task sheets for junior high school physics smart cla ssrooms.

b) Technological Application and Innovation in Teaching Models.

This direction focuses on "#4 Teaching Model," "#5 Instructional Design," and "#6 Artificial Intelligence," with cluster labels including teaching models, educatio nal technology, intelligent technology, instructional design, teaching evaluation, art ificial intelligence, the intelligent era, application design, etc. Researchers primaril y study new teaching models and design concepts, such as project-based learning, flipped classrooms, etc., and how to apply these models and concepts in actual t eaching.

The main research content focuses on: (1) The application of technology in sm art classrooms: exploring how various technologies (such as Rain Classroom, AI, big data, etc.) can be applied to smart classrooms. (2) Smart classrooms and educ ational informatization: studying how smart classrooms contribute to the develop ment of educational informatization. Digitalization and Educational Transformatio n: focusing on how digital technologies can drive transformation in the education sector. (3) The impact of smart classrooms on learning outcomes: assessing the ef fect of smart classrooms on student learning outcomes. For example, Fang Yi[9] pointed out the effective application of smart classroom software in Chinese lang uage teaching; Li Peipei and others[10] conducted in-depth research on the applic ation of holographic technology in smart education; Cai Baolai[11] explored the e ssence and concept of classroom revolution empowered by artificial intelligence; Li Qi and others[12], taking "University Computer Basics" as an example, researc hed the smart teaching design and application based on Rain Classroom; He Hon gxing[13] investigated the application of "Augmented Reality" technology in biolo gy smart classrooms; Zhong Yuan and others[14] studied the improved YOLOv5 smart classroom face detection algorithm; Wan Fei[15] explored the teaching mod el of junior high school physics smart classrooms in an informational environmen t; Liu Bangqi and others[16] researched the innovation and application of subject teaching models based on smart classrooms; Ye Yuping and others[17] explored t he new changes in teaching methods led by smart education; Liu Jun[18] investig

ated the construction of geography smart classroom models supported by informat ion technology; Bian Jinjin and others[19] explored the design and effects of lear ning models based on smart classrooms; Wang Yue and others[20], taking geogra phy as an example, explored the construction and effectiveness of junior high sch ool smart classrooms; Wen Tong[21] researched the quality evaluation system of smart classrooms based on learning-oriented assessment.

c) Core Competencies and Learning Architecture.

This direction focuses on "#2 Core Literacy" and "#8 Learning Architecture," with cluster labels including core competencies, smart classrooms, group collabora tion, full participation, learning architecture, deep learning, artificial intelligence e mpowerment, and key skill cultivation. Scholars discuss the definition of core co mpetencies, methods of cultivation, and how to support the cultivation of core co mpetencies through the design of learning architectures. The main research conten t focuses on: (1) Focusing on the construction of smart classroom environments a nd the initial exploration of personalized learning strategies. Researchers are begin ning to consider how to cultivate students' core competencies in smart learning en vironments, including autonomous learning, critical thinking, and innovative capab ilities. (2) Focusing on the relationship between deep learning, smart teaching mo dels, and students' core competencies. Research is beginning to explore how to us e the technological support of smart classrooms to promote deep learning in stude nts, while also focusing on the design of evaluation metrics to quantify the impac t of smart classrooms on students' core competencies. (3) How to design and imp lement teaching models in smart classrooms that promote deep understanding and deep learning in students. Scholars are increasingly focusing on multimodal learni ng, personalized learning systems, and the impact of technology on the learning e xperience, as well as how to more effectively cultivate students' core competencie s through smart classrooms. For instance, Zheng Yunxiang[22] investigated the te aching model for college students' personalized learning from the perspective of c onstructivism; Xi Haixu and others[23] explored the architecture design and imple mentation strategies of smart learning environments; Shan Youqing and others[24] examined how classroom improvements can facilitate deep learning; Wu Junqi a nd others [25]developed and applied an analysis model for collaborative learning engagement in smart classrooms from a multimodal perspective; Peng Hongchao and others [26]investigated the design of flexible deep learning scaffolds for smar t classrooms.

d) Smart Campus and Industry-Education Integration.

This direction focuses on "#3 Smart Campus," with cluster labels including sm art campus, intelligentization, series of activities, etc. Scholars research how to uti lize artificial intelligence technology to improve the campus environment, enhance the efficiency and quality of campus management, and how to apply artificial int elligence technology in teaching and research. The main research content focuses on: (1) The research priority is understanding the basic concept of smart campuse

s and constructing a preliminary digital campus architecture. (2) Exploring the sp ecific implementation paths and strategies of smart campuses in actual operation. (3) The research is more focused on the comprehensive development of smart ca mpuses, including the reconstruction of the educational ecosystem and the innovat ion of intelligent learning spaces. (4) Although there are not many direct referenc es to industry-education integration in the literature list, the development of smart campuses is closely related to industry-education integration. Smart campuses pro vide a technological platform and teaching strategies for industry-education integr ation, supporting school-enterprise cooperation, work-study integration, and practic al teaching to meet the educational needs and industrial development of the new era.For example, Hu Qintai and others [27]investigated the developmental transfor mation of educational informatization: from "digital campus" to "smart campus"; Peng Zhaobo [28]explored strategies and models for constructing smart campuses in vocational schools in Jiangsu; Xiao Hui[29] examined reshaping the school edu cational ecosystem: constructing a "human-centered" smart campus; Wang Yufei[3 0] investigated the practice dimensions of artificial intelligence empowering vocati onal education, including promoting the deep integration and innovation of industr y and education, optimizing the provision of vocational education services, constr ucting vocational education teaching knowledge based on vocational characteristic s, conducting innovative vocational education teaching practices around the studen t subject, and perfecting vocational education training objectives aimed at higher-order vocational skills.

4 Analysis of Research Trends in Smart Classrooms

4.1 Interdisciplinary Design and Practice in Smart Classrooms

This explores how smart classrooms can be applied to interdisciplinary education, integrating STEM (Science, Technology, Engineering, and Mathematics) with arts education, and the methods for achieving this interdisciplinary integration within smart classrooms. For instance, an interdisciplinary smart classroom project might combine STEM education with arts education. Using virtual reality technology, students could explore scientific concepts within an interactive virtual environment while also learning about artistic design and creative expression.

4.2 Mixed Reality Technology in Advanced Skill Training

This researches the application of Mixed Reality (MR) and Augmented Reality (AR) technologies in professional skill training. In fields like interior design, students could use these technologies to simulate real interior environments and practice aspects like spatial layout, color matching, and material selection. Through wearable devices and interactive software, students can perform design operations in a virtual environment and receive real-time feedback and guidance, enhancing their design skills and aesthetic understanding. The application of this technology helps students better understand and

master the principles and techniques of interior design, laying a solid foundation for their future careers.

4.3 Personalized Learning Experiences Based on Affective Analysis

Combining affective computing and machine learning, this research focuses on students' emotional responses in the smart classroom environment. This might include developing systems capable of recognizing students' emotional states and adjusting the teaching content and strategies based on this information to enhance the learning experience. For example, a research project could use facial recognition technology and physiological signal monitoring (like skin conductance) to analyze students' emotional states. When detecting anxiety or frustration, the smart classroom system could automatically adjust the content, provide additional guidance and support, or employ more interactive, gamified learning methods to improve students' mood and engagement.

4.4 Pay attention to the interaction between the intelligent classroom and the classroom of all staff

Smart classroom should not only pay attention to the sound smart classroom teaching of students, but also attach great importance to the problems of disabled students in the use of smart classroom, and actively promote the use of disabled students to better complete the learning tasks of smart classroom.[31] In addition, on the basis of understanding students 'interests and characteristics, intelligent classroom learning can be interactive gamified to help teachers monitor and encourage students' participation in the classroom.[32]

4.5 Smart Classrooms and Global Educational Connectivity

This explores how smart classrooms can facilitate the sharing and connectivity of global educational resources. For instance, through international cooperative projects, offering cross-cultural, multilingual learning experiences can enhance students' global awareness and competitiveness. In projects aimed at global educational connectivity, students can collaborate with peers worldwide through online platforms, engaging in cross-cultural exchanges and collaborative projects. For example, through international online collaborative projects, students can learn a foreign language in real contexts and understand different countries' perspectives and practices.

5 Conclusion

Through the analysis of papers on smart classrooms, the following conclusions have been drawn:

1)Research on smart classrooms is primarily concentrated in institutions such a s the School of Educational Information Technology at South China Normal Univ ersity, the School of Information Science and Technology at Northeast Normal U

niversity, and the School of Information and Software Engineering at Northeast N ormal University. Teams led by authors like Liu Bangqi, Xie Yueguang, Tang Ye wei, and Pang Jingwen are the main research groups for smart classrooms.

2)Research on smart classrooms is focused on "Theory and Practice of Smart Classrooms," "Technological Application and Teaching Model Innovation," "Core Literacy and Learning Architecture," and "Smart Campus and Industry-Education Integration."

3)Future research trends include "Personalized Learning Experiences Based on Affective Analysis," "Interdisciplinary Design and Practice in Smart Classrooms," and "Smart Classrooms and Global Educational Connectivity."

Finally, the analysis reveals that while significant progress has been made in th eoretical construction and technological application in smart classroom research, t here are certain shortcomings in empirical studies, teacher and student participatio n, and educational equity. Future research needs to delve deeper and more compr ehensively into these areas.

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