DOI: 10.53469/jrve.2025.7(07).05

From Surface Implementation to Deep Integration: A Study on the Development Trajectory of Smart Classroom Construction and Application

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Abstract: ***The advancement of emerging information technologies has positioned smart classrooms as critical infrastructure for educational digitalization. However, empirical evidence indicates that smart classrooms frequently demonstrate limited integration with pedagogical practices, resulting in suboptimal educational outcomes despite substantial policy support and market expansion. This study examines the development trajectory, core characteristics, and functional models of smart classrooms. It identifies three core challenges hindering their effective implementation: (1) the misalignment between technology orientation and educational essence, (2) the mismatch between system complexity and governance capability, (3) the value conflicts between technology empowerment and educational equity. To address the aforementioned challenges, this study constructs the future development path of smart classrooms from four dimensions: educational orientation, systematic governance, equitable collaboration, and ecological innovation, aiming to provide an operable theoretical reference for subsequent research and practice.***

Keywords: Smart Classroom, Technology-Education Integration, Construction Challenges, Development Path, Educational Equity.

1. Introduction

With the rapid development of information technologies such as big data, cloud computing, and artificial intelligence, a technology revolution centered on intelligence is profoundly reshaping human society's production and lifestyle. In the field of education, these technologies are driving fundamental transformations in educational organizational and service models, leading human education toward the "smart education" stage [1]. In the process of systematic integration between technology and education systems, constructing a smart education ecosystem characterized by data-driven, personalized, and contextualized approaches has become a historical inevitability, and the transformation and upgrading of learning environments is also urgently needed [2].

Smart classrooms serve as critical infrastructure for smart education implementation. They facilitate the distribution of quality educational resources and promote educational equity. These functions align with the fundamental requirements of educational intelligence [3]. Compared to traditional classrooms, smart classrooms break through spatial and temporal limitations, and in the process of expanding learning activity scope and externalizing pedagogical wisdom thinking, provide strong support for teachers to deeply understand learning conditions, precisely adjust teaching strategies, and conduct personalized instruction [4]. At the policy level, the "14th Five-Year Plan for Digital Economy Development" issued by the State Council explicitly proposes deepening the advancement of smart education and orderly promoting intelligent infrastructure upgrades, creating a favorable environment for large-scale construction and deepened application of smart classrooms [5]. Market data shows that China's smart classroom market exhibits rapid growth. In 2022, the overall market size reached 3.891 billion yuan, with higher education dominating at 3.207 billion yuan, while the K-12 and other educational stages market size was 684 million yuan. This development trend indicates that smart classroom construction has become a significant investment focus for educational informatization. According to the "China University Informatization Development Report" released by China's Ministry of Education in 2023, the proportion of smart classrooms relative to total classrooms in China has increased progressively since 2020, rising from 7.2% to 15.3% in 2022, with universities accelerating the pace of smart classroom construction [6].

However, while smart classrooms are expected to revolutionize teaching models, optimize learning experiences, and improve educational quality, their construction and application face substantial practical challenges. Currently, smart classrooms frequently demonstrate limited integration between technology and pedagogy, resulting in suboptimal educational outcomes—a phenomenon that urgently requires in-depth research and systematic solutions. The urgency of effective smart classroom implementation lies in achieving comprehensive integration and achieving deep integration with teaching concepts, teaching content, teaching methods, teaching evaluation, and teacher professional development, producing observable and evaluable actual teaching benefits, can they truly empower educational transformation, improve educational quality and equity, and promote the common growth of teachers and students.

Based on the above background, this research focuses on key issues in smart classroom development, aiming to systematically review the development trajectory of smart classrooms from concept proposal to practical exploration, deeply analyze the challenges in their construction and application processes, and explore effective pathways and strategies for achieving sustainable integration and deep integration with teaching practice.

2. Literature Review

2.1 Concepts and Development Evolution of Smart Classrooms

The smart classroom concept originated in 1988 when Ronald introduced the term “Smart-Classroom” in his work on educational technology implementation. Initial conceptualizations primarily encompassed traditional classrooms enhanced with technological equipment such as personal computers, interactive video disc programs, closed-circuit television, video recording systems, satellite links, local area networks, and telephone modems in traditional classrooms [7].

With the continuous development of educational technology and the deepening of pedagogical concepts, the academic understanding of smart classroom concepts has gradually become richer and more diversified. From different perspectives, researchers have formed multiple definition approaches:

From the perspective of teaching interaction, Huang Ronghuai et al. (2012) believe that smart classrooms are new types of classrooms that provide convenient, optimized, and intelligent management for the entire teaching process [8]. Nie Fenghua et al. (2013) further emphasized their systematic characteristics, viewing smart classrooms as an organic integration of conceptual features, system models, and construction cases [9].

From the perspective of technical composition, Zhang Yazhen et al. (2014) pointed out that smart classrooms are learning environments constructed by ubiquitous computing technology, Internet of Things technology, cloud computing technology, real-time sensing, and machine intelligence, which can significantly enhance the learning experience of students and teachers and create seamless communication environments [10].

From the perspective of human-computer interaction characteristics, Chen Weidong et al. (2011) believe that smart classrooms are enhanced classrooms characterized by human-computer interaction and implementing intelligent space technology [11]. Zhou Yi (2021) views smart classrooms as specific implementations of typical smart learning environments, representing the high-end evolutionary form of multimedia and network classrooms [12].

The academic community maintains disagreements and controversies about the concept of smart classrooms. He Wentao et al. (2018), starting from the essential attributes of educational terminology, believe that smart classrooms are essentially the same as traditional classrooms in nature, both belonging to the category of educational terminology, having extensional characteristics but lacking unified essential connotations [13]. Synthesizing relevant research both domestically and internationally, smart classrooms can be understood as smart learning spaces that promote students’ knowledge construction, built with ubiquitous computing technology, Internet of Things technology, cloud computing technology, and intelligent technology. They are the materialized expression of typical smart learning environments, representing the high-end development form of multimedia and network classrooms.

Regarding the development history of smart classroom, Liu Lichun et al. divided the development history of smart classrooms into three stages based on technological development levels and application characteristics. In the first stage (1980s-1990s), new technologies represented by computers began entering traditional classrooms, constructing new learning environments, mainly including forms such as multimedia classrooms, multimedia language laboratories, and one-machine-multiple-screen classrooms. Early smart classroom applications focused more on distance education, with the main characteristics of this period being single-machine mode operation, where teachers were limited by single-machine operation and keyboard-mouse interaction, unable to achieve free teaching as in ordinary classrooms, and information technology had not yet achieved deep integration with education and teaching. In the second stage (2001-2008), scholars began exploring the possibility of smart classrooms achieving “synchronous teaching” based on distance education, committed to providing teachers and students with the same learning experience as face-to-face teaching. With the introduction of modern educational technologies such as human-computer interaction technology, Internet technology, and streaming media, smart classrooms broke through single-machine limitations, teachers and students escaped keyboard constraints, and adopted natural, multi-dimensional interactive means to interact with teaching content, entering virtual teaching environments of human-computer interactive dialogue. IBM’s proposal of the “Smart Planet” concept in 2008 also marked smart classrooms entering the third stage. In this stage, understanding of smart classrooms no longer simply started from classroom information technology equipment, but more from the perspective of learning environments, focusing on how to better establish open smart learning environments. Based on existing technology, smart classrooms fully utilize mobile devices and centrally controllable distributed intelligent spaces, implementing various teaching model innovations through ubiquitous computing technology, mobile technology, virtual reality, classroom live recording and broadcasting, and other means. Based on this, the types and functions of smart classrooms have further achieved diversified development, with various forms such as context-aware smart classrooms and open smart classrooms emerging [14].

2.2 Core Characteristics and Functional Models of Smart Classrooms

Smart classrooms are distinguished from traditional classrooms by their technological capabilities. While consensus on a precise definition remains elusive, the literature identifies key characteristics including interactivity, systematic integration, and intelligent functionality [15]. With the support of modern information technology, sensing technology, and artificial intelligence technology, smart classroom environments exhibit significant features such as diversified content presentation, flexible environment management, convenient resource acquisition, real-time teaching interaction, and intelligent situational awareness.

In terms of constructing functional models for smart classrooms, scholars have proposed several representative theoretical frameworks. Huang Ronghuai et al., based on the technical characteristics of smart classrooms, proposed the “S.M.A.R.T.” model, which covers five dimensions: Showing, Manageable, Accessible, Real-time Interactive, and Testing, providing systematic theoretical guidance for the functional positioning of smart classrooms [16]. Building on this, Nie Fenghua further expanded the theoretical framework, constructing the iSMART model that includes six aspects: infrastructure, network perception, visual management, augmented reality, real-time recording, and ubiquitous technology, enriching the functional connotations of smart classrooms [17]. Wang Yulong et al. constructed a demand-oriented smart classroom system model including seven modules, reflecting the transformation from theory to practice [18]. From the perspective of functional structure, Liu Xuan et al. proposed that the structural model of smart classrooms should include five major elements: physical/virtual environment, content and resources, teaching interaction, testing and evaluation, and data governance, emphasizing that smart classrooms should support functional needs in five aspects: teaching, learning, evaluation, management, and research [19].

At the practical level, smart classroom construction in domestic universities shows diversified development trends. Based on construction cases from domestic universities, He Kun classified smart classrooms into five types from four dimensions: spatial layout, resource acquisition, content presentation, and interaction methods: high perception, strong interaction type; strong interaction, low perception type; strong experience, low perception type; strong convenience, high clarity type; high clarity, strong convenience type [20]. This classification system reflects the differentiated choices and characteristic development of different universities in smart classroom construction.

In terms of specific construction practices, Wen Can et al., using Central South University as an example, studied integrated teaching support platforms based on smart classrooms [21]; Sun Feipeng et al., using Beijing Language and Culture University as an example, discussed the construction and evaluation of university smart classrooms [22]; Wu Nanzhong et al., using Chongqing Radio and Television University as an example, designed a smart classroom cockpit based on big data [23]; Cui Yaqiang et al., using Sichuan University as an example, considered the construction and operation mechanisms of university smart teaching environments [24]. These case studies demonstrate diversified explorations in smart classroom construction, models, operation, and technology from different angles, providing valuable practical experience and theoretical reference for the promotion and application of smart classrooms.

Overall, the core functions and construction practices of smart classrooms present the following development trends: first, the functional system is becoming increasingly complete, transforming from simple technological equipment accumulation to comprehensive smart learning environments; second, construction models are becoming more diversified, forming corresponding smart classroom construction types based on different needs and conditions; third, the combination of theory and practice is becoming closer, with construction cases from various universities providing verification and improvement foundations for theoretical models; fourth, the degree of technological integration is continuously deepening, with emerging technologies such as VR/AR, big data, and artificial intelligence being widely applied in smart classrooms.

As an important carrier of educational informatization development, smart classrooms continue to improve and innovate their conceptual connotations and development models. However, due to the diversity of conceptual connotations and differentiated construction paths, standardized construction and large-scale application of smart classrooms still face challenges, requiring further improvement in future research and practice, with greater attention to the realization of educational value and evaluation of application effects in smart classrooms, promoting the transformation of smart classrooms from technology-oriented to education-oriented, and achieving deep integrated development of technology and education.

3. Construction Challenges

Although smart classrooms show broad application prospects under the multiple driving forces of technology, demand, and policy, at the practical level, their development faces significant obstacles. There exists a significant gap between technical facilities and actual teaching applications, failing to effectively serve actual teaching. This gap is not only reflected in technical immaturity but also deeply reflects complex problems in multiple dimensions such as educational concepts, management models, and social equity. Through systematic analysis, these challenges can be summarized into the following three core dimensions.

3.1 Challenges of Misalignment between Technology Orientation and Educational Essence

A primary challenge in smart classroom implementation is the disconnect between technological capabilities and pedagogical requirements. This disconnect manifests in prioritizing infrastructure development over practical application and the insufficient integration of essential educational components.

First, the deviation of smart classroom construction concepts is the root of this challenge. Many current smart classroom construction projects are often technology-indicator oriented, pursuing the advancement of equipment and completeness of functions while ignoring the actual needs of education and teaching. This tendency of “building for the sake of building” leads to a large amount of advanced equipment being idle after construction, unable to truly serve teaching practice.

Second, the imbalance of core educational elements further exacerbates this contradiction. Smart classroom construction should revolve around core educational elements such as teaching, learning, evaluation, management, and research, but in reality, there is often a mismatch between technical functions and educational functions. For example, in teaching, over-reliance on technical means while ignoring the humanistic nature of teacher-student interaction; in the learning process, emphasizing the use of digital tools while lacking grasp of the essential laws of learning; in evaluation systems, over-dependence on data analysis while ignoring the diversity and complexity of educational evaluation.

Third, the contradiction between personalized needs and standardized products is also becoming increasingly significant. Current smart classroom products exhibit serious homogenization, making it difficult to meet the personalized needs of different schools, different disciplines, and different teaching models. Experience from developed countries such as Denmark shows that the degree of educational equipment construction is not simply positively correlated with students' digital literacy development; the key lies in the degree of deep integration between technology and education [25].

3.2 Challenges of Matching System Complexity with Governance Capability

Smart classrooms represent complex technology-education systems requiring multi-level coordination. Current governance structures frequently lack the capacity to manage this complexity effectively.

First, insufficient technical governance capability is the core manifestation of this challenge. This is reflected in several aspects: (a) the interconnection of digital resources still faces technical barriers, with data silos between different manufacturers and platforms being prevalent, affecting effective resource integration and sharing; (b) data security and privacy protection issues are becoming increasingly prominent, with the collection, storage, and use of educational data lacking unified standards and effective regulatory mechanisms; (c) quality control mechanisms for human-computer interaction are imperfect, making it difficult to ensure the stability and reliability of smart classroom systems.

Second, lagging management governance levels further constrain the effective operation of smart classrooms. In specific management practices, problems such as student online behavior supervision, visitor object management, and multi-terminal access control emerge one after another, and traditional management models find it difficult to adapt to complex management needs in digital environments. The development level of teaching software is relatively low, lacking professional applications that deeply align with educational and teaching needs, affecting the full utilization of smart classroom functions.

Third, the absence of operation and maintenance systems also increases mismatching problems. After smart classroom construction is completed, continuous technical support, content updates, equipment maintenance, and other operational services are needed, but most schools currently lack professional operational teams and stable funding guarantees. The contradiction between high operational costs and limited educational funds makes it difficult for many smart classrooms to continue playing their role. At the same time, improving teachers' digital teaching capabilities requires systematic training and support, but existing teacher development systems often cannot meet this need [26].

3.3 Value Conflicts between Technology Empowerment and Educational Equity

Smart classroom construction should promote educational equity, but in the actual implementation process, it may create new inequity problems, forming value conflicts between technology empowerment and educational equity.

First, conflicts are directly manifested in the amplification effect of the digital divide. Due to the lack of unified construction standards and evaluation systems, there are huge differences in smart classroom construction levels among different regions and schools, further widening existing educational gaps. According to data from the "China University Informatization Development Report (2020)," among universities included in the statistics, the smart classroom coverage rate for first-class university construction institutions is 17%, for first-class discipline construction institutions is 12%, for other ordinary universities is 7%, and for vocational colleges is only 6%. The differences in smart classroom penetration rates among different universities also reflect educational inequity for schools with different resource levels and economic conditions.

Second, conflicts between algorithmic governance and subject agency are becoming increasingly prominent. Smart classrooms extensively use artificial intelligence algorithms for teaching analysis and evaluation, but the "black box" characteristics of algorithms make the evaluation process lack transparency, potentially affecting the fairness of educational evaluation. Over-reliance on data-driven decisions may ignore the humanistic nature and complexity of education, leading to the weakening of teachers' and students' subject positions. Particularly in teaching evaluation, purely relying on data analysis results may produce bias, affecting students' comprehensive development.

Finally, teachers' subject positions also tend toward marginalization in the application of digital technology. Under the influence of technology-supremacist construction concepts, teachers' subject roles may be weakened, with "misplacement" or even "displacement" phenomena occurring. Excessive intervention by technological tools may weaken emotional connections and humanistic interactions between teachers and students, affecting education's essential functions. This tendency not only affects educational quality but may also exacerbate teachers' professional anxiety and adaptation difficulties [27].

4. Future Paths

Based on in-depth analysis of current smart classroom construction challenges, it can be seen that the root causes stem from multiple factors. To achieve effective implementation of smart classrooms, it is necessary to construct a systematic and sustainable development path. This path should start from educational essence, aim for equitable development, and use systematic governance as guarantee, forming a multi-level, comprehensive development framework.

4.1 Constructing Education-Centered Technology Integration Paths

Sustainable smart classroom development requires prioritizing educational objectives and establishing integration mechanisms that align technological capabilities with pedagogical requirements.

4.1.1 Establish education-priority design concepts.

Smart classroom development should adopt an education-first approach, implementing iterative design processes that progress from needs assessment through technical implementation to outcome evaluation. Specifically, it is necessary to conduct in-depth educational needs research in the pre-construction phase, clarifying specific needs of different disciplines and learning groups, and formulating targeted technical solutions based on this. Simultaneously, education-effect-oriented evaluation systems should be established, treating the educational value of technology application as core evaluation indicators and avoiding purely measuring construction effectiveness with technical indicators.

4.1.2 Establish diversified technology adaptation mechanisms.

Addressing the contradiction between current product homogenization and demand personalization, modular and composable technical architectures should be constructed, supporting schools in flexible configuration based on their characteristics and needs. Through designing functional architectures at different levels, providing support for platform services, content resources, and application functions, with each level being relatively independent yet organically connected, forming expandable and customizable overall solutions. Simultaneously, user-driven continuous improvement mechanisms should be formed, supporting teachers, students, and other users to participate in technology application optimization through joint efforts of government and enterprises.

4.1.3 Improve deep integration mechanisms between technology and teaching.

Specific paths for technology empowerment should be constructed around core educational elements such as teaching, learning, evaluation, management, and research. In teaching, focus on developing intelligent tools supporting interactive teaching, collaborative learning, and personalized guidance; in learning processes, strengthen functions such as learning analytics, learning path recommendation, and learning resource adaptation; in evaluation systems, establish diversified, process-oriented, and developmental intelligent evaluation models; at management levels, achieve intelligent upgrades in teaching management, resource management, and quality management; in research activities, use data analysis to support teaching reflection and improvement.

4.2 Improving Systematic Governance Support Systems

Smart classrooms, as complex technology-education systems, require establishing governance systems that match their complexity, providing systematic guarantees from multiple dimensions including technical governance, management governance, and operational governance.

4.2.1 Improve the standard system for technical governance.

Unified technical standards for smart classroom construction should be formulated, covering technical elements such as equipment configuration, network architecture, data formats, and interface specifications, ensuring interconnection between different manufacturers and platforms. Establish regulatory frameworks for data security and privacy protection, clarifying security requirements and privacy protection measures for various stages of educational data collection, storage, use, and sharing. Improve quality assurance mechanisms for human-computer interaction, establishing evaluation standards and monitoring systems for system stability, reliability, and usability. Promote professional development of teaching software, formulating software development standards and quality evaluation systems oriented toward educational applications.

4.2.2 Construct intelligent management governance models.

Intelligent teaching management platforms should be developed to achieve intelligent supervision of student online behavior, precise identification of visitor objects, and unified control of multi-terminal access. Establish artificial intelligence-based abnormal behavior detection mechanisms to improve management efficiency and precision. Improve governance frameworks for educational data, establishing comprehensive management systems for data asset management, data quality control, and data value mining. Simultaneously, strengthen digital capability building for management personnel, improving their levels of adapting to and utilizing digital management tools.

4.2.3 Establish sustainable operational guarantee mechanisms.

Diversified input guarantee systems should be constructed, establishing stable funding sources through government investment, social participation, market operation, and other methods. Establish professional operational service systems, providing continuous technical support, content updates, equipment maintenance, and other services for schools through government procurement, commissioned operations, cooperative construction, and other models. Improve teacher digital capability development systems, establishing systematic training courses, practice platforms, and evaluation mechanisms to support teachers' continuous improvement of digital teaching capabilities.

4.3 Building Equity-Oriented Coordinated Development Mechanisms

Smart classroom development must serve the fundamental goal of educational equity, narrowing the digital divide and promoting balanced development through multiple mechanisms including institutional design, resource allocation, and capability building.

4.3.1 Establish institutional frameworks for balanced development.

National and regional standards for smart classroom construction should be formulated, clarifying basic configuration requirements for schools at different levels and types, ensuring all schools can achieve basic digital teaching conditions. Establish counterpart assistance and collaborative construction mechanisms, promoting resource sharing and balanced development through developed regions supporting underdeveloped regions and high-quality schools helping weak schools. Improve supervision and evaluation systems, incorporating smart classroom construction and application levels into educational quality evaluation systems, promoting strengthened construction and application in all regions and schools.

4.3.2 optimize structural mechanisms for resource allocation.

Input structures should be adjusted, and while ensuring necessary hardware facilities, increase investment proportions in software development, content construction, teacher training, operational maintenance, and other aspects. Establish resource sharing platforms, achieving widespread sharing and efficient utilization of high-quality educational resources through cloud computing, edge computing, and other technical means. Promote industry-university-research collaboration, encouraging multi-party participation from universities, research institutions, enterprises, and others in smart classroom research and development and operations, forming collaborative innovation development patterns.

4.3.3 strengthen transparency mechanisms for algorithmic governance.

Algorithmic review and regulatory systems should be established, requiring artificial intelligence algorithms used in smart classroom systems to have explainability and reviewability, preventing algorithmic bias and discrimination. Improve supervision mechanisms for data-driven decision-making, ensuring transparency and fairness in educational evaluation and decision-making processes. Establish protection mechanisms for teacher and student rights, guaranteeing basic rights such as the right to information, choice, and supervision for teachers and students in digital educational environments.

4.3.4 maintain support mechanisms for teachers' subject positions.

The auxiliary position of technological tools should be clarified, emphasizing teachers' leading roles in education and teaching, avoiding excessive technological intervention in teacher-student relationships. Establish teacher digital capability certification systems, supporting teachers in improving professional education and teaching levels while mastering technological tools. Improve incentive mechanisms for teacher development, encouraging teachers to actively participate in digital teaching innovation and providing corresponding professional development support and career development opportunities.

4.4 Forming Collaborative Innovation Development Ecosystems

The sustainable development of smart classrooms requires constructing innovation ecosystems with multi-subject participation, multi-element coordination, and multi-level linkage, forming development patterns jointly promoted by government, schools, enterprises, society, and other parties.

4.4.1 Establish multi-subject collaborative governance structures.

Collaborative governance mechanisms with government coordination, school subjects, enterprise participation, and social supervision should be established. At the government level, strengthen top-level design and policy guidance, formulating development plans, technical standards, evaluation systems, etc.; at the school level, play subject roles, promoting smart classroom construction and application based on their characteristics and needs; at the enterprise level, provide technical support and service guarantees, participating in standard formulation and product research and development; at the social level, strengthen supervision and evaluation, promoting continuous improvement of construction quality and application effects.

4.4.2 Construct open and shared innovation platforms.

National and regional smart classroom innovation platforms should be established, gathering resources from government, universities, enterprises, schools, and other parties to conduct collaborative innovation and technical research. Promote the establishment of smart classroom innovation alliances, promoting deep industry-university-research integration and accelerating the transformation and application of scientific and technological achievements. Establish open-source technical communities, encouraging technology sharing and collaborative development, reducing innovation thresholds and costs.

4.4.3 Improve continuous improvement feedback mechanisms.

User feedback collection and processing mechanisms should be established, timely understanding needs and problems of teachers and students during use, promoting continuous optimization of products and services. Establish effect monitoring and evaluation systems, regularly conducting assessments of smart classroom construction and application effects, providing basis for policy adjustment and improvement. Establish experience summarization and promotion mechanisms, timely summarizing successful experiences and effective practices, promoting and exchanging through various channels.

5. Conclusion

Against the macro backdrop of China's accelerated advancement of the "14th Five-Year Plan for Digital Economy Development" and the construction of an "educational powerhouse," the development and application of smart classrooms are undergoing a crucial transformation — moving from a phase of superficial, technology-enabled adoption towards a phase of deep integration and grounded implementation within the educational ecosystem.

This process fundamentally represents a transformation demanding the deep coupling of technological logic with educational principles. Current practices reveal core contradictions: the misalignment between technology-driven approaches and the essence of education, the mismatch between systemic complexity and governance capacity, and the value conflict between technological empowerment and educational equity. These contradictions highlight the limitations of solely upgrading hardware.

Resolving this predicament necessitates not only establishing the core position of "education-centricity" in principle, ensuring that technological design and application serve the fundamental needs of teaching, learning, and assessment, but also requires the practical enhancement of a systematic governance and support framework. This entails addressing the adaptation challenges between technology and management through unified technical standards, intelligent management, and sustainable operations. Simultaneously, the development of smart classrooms must be guided by the value benchmark of "equity-orientation." This involves ensuring technological empowerment benefits all teachers and students equitably, rather than exacerbating existing digital divides, through balanced development institutional frameworks and transparent algorithmic governance mechanisms. Ultimately, a successful smart classroom is not a mere accumulation of technological devices, but the outcome of a collaborative innovation ecosystem involving multiple stakeholders including government, schools, and enterprises.

Smart classrooms achieve their intended purpose when they demonstrate effective integration of technology and pedagogy, functioning as learning environments that enhance educational quality and promote equitable access. This transformation requires moving beyond technology-centered approaches to create learning spaces that support creativity, enable personalized learning, and facilitate resource distribution. Such integration represents the evolution from conceptual frameworks to practical educational tools. This offers a practical solution, blending technological rationality with humanistic care, for the digital transformation of education in China and globally.

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