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SMART CAMPUS CONCEPTS AND DEVELOPMENT: TRENDS

Liang Jiahui, master's degree student
Boyarshinova O. A., PhD in Physics and Mathematics, associate professor
Belarusian National Technical University
Minsk, Belarus

Abstract. As a pivotal platform for educational digital transformation, smart campuses transcend the functional limitations of traditional digital campuses. Through deep integration of technology with educational scenarios, they establish interconnected, data-driven, and intelligent educational ecosystems. This paper systematically analyzes the four-layer architecture of "perception-network-platform-application" in smart campuses, explores ten key future development trends, examines current challenges in implementation, and ultimately proposes core value orientations for smart campuses.

Keywords: Smart Campus, Education Informatization, System Architecture, Development Trends, Data-Driven.

In any society, education and science are areas that provide prospects for social and economic development. Education prepares personnel capable of high-quality and effective work, largely determines personal development, and thus actively contributes to the formation of social values and supports the preservation of culture. Science, in turn, ensures the processes of scientific and technological development for economic development based on innovation.

To improve the quality of education, increase its attractiveness, develop science and increase its popularity, particularly among talented young people, and attract such young people to science, certain conditions are necessary. One such condition is the creation of an environment conducive to life, education, work, and intellectual development.

Driven by the dual forces of digital economy and national education strategy, the integration of information technology with teaching has evolved from "technological application" to "ecosystem restructuring". Traditional campus management models, teaching formats, and service approaches can no longer meet the demands of talent cultivation in the new era. While digital campuses have achieved initial digitization

of information presentation and circulation, they still face prominent issues such as data silos, limited service diversity, and insufficient intelligence capabilities [1, p. 73]. As an upgraded iteration of digital campuses, smart campuses leverage core technologies including IoT, big data, AI, cloud computing, and mobile internet to deeply interconnect "people, objects, and information". By data-driven decision-making, intelligent service optimization, and innovation through integration, they have become crucial supports for advancing personalized education, refined management, and scientific decision-making.

Analyzing the conceptual framework of smart campuses, examining their architectural design, and forecasting development trends holds significant theoretical and practical value for advancing standardized, high-quality campus development. For instance, by precisely assessing students' learning habits, interests, and capabilities, smart campuses can create personalized learning pathways for each individual, effectively implementing the "one student, one plan" educational model to enhance learning efficiency and meaning [2, p. 109]. Meanwhile, immersive learning experiences will become the norm, utilizing virtual reality (VR), augmented reality (AR), and mixed reality (MR) technologies to expand learning environments beyond traditional classrooms into virtual laboratories, historical sites, and even distant natural landscapes, thereby significantly enriching the dimensions of education.

The concept of a Smart Campus emerges as an extension of the "Smart City" philosophy into education, evolving in tandem with technological advancements and shifting educational demands. Early-stage campus digitalization focused on "digitization" – transforming teaching resources into digital formats and streamlining administrative processes through online platforms. Essentially, this approach merely replicated traditional workflows digitally without fundamentally reshaping the existing educational ecosystem.

A smart campus is not merely an upgrade of a digital campus, but rather a qualitative leap in technology, objectives, and service models. Academic consensus holds that smart campuses leverage next-generation information technologies such as the Internet of Things, big data, artificial intelligence, and cloud computing to comprehensively perceive, interconnect, analyze, and serve scenarios across teaching, research, management, and daily life [3, p. 36]. This creates a data-driven, user-centric, and innovation-oriented campus ecosystem. At its core lies the breaking of the "technological tool theory", achieving maximum educational value through deep integration of technology and education.

The characteristics of smart campus are reflected in the five dimensions of “interconnection, data, intelligence, personalization and integration”, which support each other and are organically unified, and are implemented by relying on hierarchical technical architecture.

Powered by the 'sensing layer + network layer' technology, this system integrates sensors, smart devices, 5G, and Wi-Fi 6 to create a seamless campus network connecting people, objects, and information [4, p. 82]. It enables real-time data collection, sharing, and processing, breaking down barriers between departments, systems, and locations, and laying the foundation for data-driven and intelligent services.

With the “platform layer” as the core hub, it aggregates heterogeneous data from all scenarios into a big data center. The data middle platform processes raw data into standardized resources, providing managers with real-time monitoring and trend prediction support through analytical and visualization tools, driving the transition from “experience-based governance” to “data-driven governance” [5, p. 59].

The core driving force comes from the platform-level AI engine and business middle platform. Relying on machine learning, natural language processing and other AI algorithms, intelligent scheduling, attendance, energy consumption control and other functions are realized to improve operational efficiency, reduce manual intervention, and enable teachers and students to focus on teaching and learning [6, p. 114].

By integrating data collection at the perception layer, processing at the platform layer, and implementation at the application layer, we precisely address the personalized needs of teachers and students. This approach delivers tailored learning resources and career guidance for students, enhances teaching effectiveness and supports research for educators, and provides customized solutions for administrators, embodying the “people-oriented” philosophy.

Building on comprehensive cross-level connectivity, we break down barriers between business and organizational silos, driving deep integration across teaching, research, management, and services. This includes merging teaching with research to transform outcomes into resources, integrating management with services to enhance user experience through a “one-stop” platform, and connecting campus with society to leverage external resources, thereby establishing an open education ecosystem.

The Future Development Trend of Smart Campus.

With the iteration of information technology and the upgrading of educational needs, smart campus is evolving from "single-point intelligence" to "overall intelligence", which will show ten trends in the future, covering the dimensions of technology integration, service upgrading and ecological construction.

AI technology will evolve from "perceptual intelligence" to "cognitive intelligence" and "decision-making intelligence", becoming a core driving force [7, p. 43]. It will deeply integrate into key scenarios such as education, management, and research: real-time analysis of classroom quality, monitoring teacher-student interactions and student engagement; building mental health early-warning models to detect abnormalities through behavioral and learning data; assisting in scientific data mining to accelerate research outcomes; and participating in school planning and resource allocation to provide data-driven decision support.

Data-driven management will become the core of campus governance. The campus big data platform will be enhanced, expanding its scope to collect multidimensional data including faculty and student behaviors, environmental conditions, and other aspects. The school will establish a "data cockpit" featuring real-time monitoring through visual interfaces. Leveraging predictive analytics, it enables proactive interventions such as identifying dropout risks and resource needs, shifting management approaches from passive response to proactive governance.

Metaverse and VR/AR technologies will transcend physical boundaries, merging the virtual with the real [8, p. 67]. Virtual campuses, using digital twins to replicate physical environments, enable virtual classrooms, experiments, and social interactions. This innovation breaks spatial barriers, creating a borderless educational ecosystem that supports lifelong learning.

Under the "dual carbon" goals, smart campuses focus on green transformation through digital twin and AI technologies to achieve energy efficiency. The energy management system employs a "cloud-edge-end" architecture to monitor real-time water, electricity, and gas consumption, while AI optimizes equipment operations to reduce energy consumption. Waste sorting and water recycling enhance resource utilization, while green building technologies integrated with smart design drive sustainable development.

Smart technology extends to all aspects of daily life and cultural experiences: Smart dormitories enable safety monitoring and environmental

control; dining services offer intelligent ordering and nutritional recommendations; unmanned delivery enhances convenience. Digital media and smart systems enrich cultural development, building a collaborative education ecosystem connecting campus, family, and community.

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1. Smirnova, E. A. Digital Campuses: Limitations and Pathways to Smart Upgrade / E. A. Smirnova, A. V. Popov // Higher Education in Russia. – 2019. – Vol. 17, № 4. – P. 68–83.

2. Pankratova, O. V. Personalized Learning Models in Smart Campus Ecosystems / O. V. Pankratova, E. A. Smirnova. – St. Petersburg : Piter, 2021. – 312 p.

3. Kuznetsova, T. V. The Evolution of Smart Campus Concept: From Digitalization to Intelligence / T. V. Kuznetsova, S. N. Ivanov // Philosophical and Educational Studies. – 2020. – Vol. 12, № 3. – P. 32–47.

4. Orlova, N. M. IoT-Based Interconnection Technology in Smart Campuses / N. M. Orlova, A. P. Sokolov // Internet of Things and Applications. – 2021. – Vol. 8, № 2. – P. 78–94.

5. Fedorov, A. S. Data-Driven Governance in Educational Institutions / A. S. Fedorov, L. K. Petrova. – Moscow : Infra-M, 2020. – 245 p.

6. Morozov, V. E. AI-Powered Operational Optimization in Campus Management / V. E. Morozov, S. N. Ivanov // Automation and Computing. – 2021. – Vol. 19, № 3. – P. 109–125.

7. Petrova, L. K. From Perceptual to Decision Intelligence: AI's Deep Integration in Smart Campuses / L. K. Petrova, A. S. Fedorov // Artificial Intelligence and Education. – 2022. – Vol. 11, № 1. – P. 38–55.

8. Sidorova, E. V. Virtual-Reality Integration in Smart Campus Learning Environments / E. V. Sidorova, P. A. Vasilyev. – Yekaterinburg : Ural University Press, 2021. – 228 p.