

An Exploration of the Essence of Digital and Intelligent Education Transformation and Prospects for Future Research

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Abstract: Education is undergoing a paradigm shift from informatization and digitization to digital-intelligence integration. The study sorts out the three-stage evolution of digital-intelligence education. We argue that it represents not merely the simple application of technological tools, but a systemic transformation that reconfigures educational relationships, returns to the fundamental mission of education, and builds a sustainable educational ecosystem. Next, we analyzes the core applications of digital intelligence technology in personalized learning, intelligent learning guidance, and teacher transformation. It also points out current challenges such as context-dependent effectiveness, ethical and privacy concerns, and discrepancy teacher competency. Last, we proposes future research prospects from six key dimensions: human-centered development, scenario-based validation, and ecosystem development.

Keywords: Artificial Intelligence; Digital Intelligent Education Transformation; Educational Ecosystem; Human-centered Development

1. Evolutionary Stage: from Informatization to Digital Intelligence

Amid the profound integration of digital technology and artificial intelligence (AI), the education sector is going through a fundamental paradigm shift, giving rise to "Digital Intelligence Education." we can roughly divide it into three stages from "informatization" to "digital-intelligization", each with clear core goals and unique technical characteristics.

1.1 The Information Technology in Education Phase (Infrastructure and Resource Development)

This stage started from the end of the last century. Its core mission was to build "digital campuses", and two key goals were to realize the

digitization of teaching resources and the networking of management processes. In this period, computer, multimedia, and fundamental network communication technologies were widely applied. The main value of these technologies was to break down information silos, and enhance educational efficiency. The priorities of research focused on hardware deployment, the development of digital resource banks, and basic knowledge and skills training for teachers. However, the application of technology at this stage basically limited to the tool level, with integration into the teaching process being relatively shallow.

1.2 The Digital Education Phase (Data-Driven and Process Reengineering)

With the maturation of cloud computing and big data technologies, education began to enter a period of digital transformation, and the focus of development also shift from "using technology" to "data-driven optimization." Educational big data is now utilized for student performance analysis, instructional management, and precise evaluation. For instance, Learning Management Systems (LMS) and online learning platforms can automatically collect vast amounts of learning behavior data, which provides a reliable data basis for educational decision-making. In this stage, these data were regarded as as a critical production factor, driving the reengineering of educational processes and innovation in models, such as blended learning and online collaborative learning .

1.3 The Digital Intelligent Education Phase: Intelligent Integration and Ecosystem Reconstruction

This represents the profound transformation currently is on the way. Cutting-edge technologies including artificial intelligence (particularly generative AI), knowledge graphs, educational robots, and extended reality (XR) are deeply and organically embedded into educational scenarios, nurturing an intelligent

education ecosystem characterized by human-machine collaboration. The core of digital intelligence education lies in its "intelligence". It means that the system can accurately capture learners' needs, automatically generate personalized content, give adaptive feedback, and ultimately help learners improve the higher-order thinking and innovation capacities. This ecosystem is usually composed of three layers: the infrastructure layer (cloud-edge-device synergy), the core element layer (dynamic knowledge graphs, interdisciplinary curricula), and the application scenario layer (personalized learning pathways, blended teaching models). These three layers interact with each other and work together to reshape the educational ecosystem.

2. The Development of Digital Intelligent Education: from Empowering Tools to Ecosystem Transformation.

The core driving force behind this transition is in the comprehensive integration and deepened application of artificial intelligence technologies across the educational sector.

2.1 Implementation of Personalized Learning

The core premise of personalized learning lies in leveraging AI and data analytics to model and analyze learners' behaviors, backgrounds, preferences, and knowledge levels, so as to accurately identify individual differences between learners. Research has used genetic algorithms to generate customized learning paths for adaptive e-learning systems on students' profiles (Hsin & Erritali, 2019), while using artificial neural networks (ANN) and weighted sum models (WSM) to recommend collaborative activities on account of students' needs and preferences (Troussas et al., 2020).

2.2 Adoption of Intelligent Learning Guidance Systems and Educational Robots

Intelligent learning guidance and educational robots have gradually become important supports for teaching. AI-powered virtual tutors or physical social robots are increasingly applied in classrooms, particularly in early childhood education and language learning. These intelligent products can achieve natural conversational interaction, answer questions, provide emotional support, and serve as teacher assistants or learning companions. Chen et al. (2022) found that AI-driven virtual tutors and

social robots deliver immediate feedback and continuous emotional support, and have shown significant effectiveness in early education and language acquisition.

2.3 Restructuring Teachers' Roles and Professional Competencies

In the digital intelligence era, teachers have gradually transformed into designers and facilitators of learning processes, coordinators of human-machine collaborative teaching, and cultivators of students' digital literacy, rather than mere transmitters of knowledge. Among all the new requirements, teachers' digital competence has been critical. This competence encompasses technical application skills, digital teaching methodologies, data literacy, and ethical awareness. At present, however, disparities in digital competency development is still prominent across regions, urban-rural areas, and educational stages. In addition, there are also practical issues, such as technological over-reliance and insufficient innovation drive.

3. The Essence of Digital and Intelligent Education

"Digital Intelligence Education" is the reconstruction that penetrates to the core of the education system, and is far more than simple tech and tool application.

3.1 Transcending One-Way Empowerment: Teacher-Student Collaboration and Value Co-creation

For a long time, technology has been seen as an external "tool" or "entity", serving to boost teaching efficiency or diversify instructional approaches. But the rise of the digital-intelligent era requires us to shift this one-dimensional "empowerment" into a "relational" perspective. The essence of digital-intelligent education is that it reshapes the relationships among elements of the educational system. Technology becomes a structural force within the educational ecosystem, through deep interactions with educational subjects (teachers and students), instructional intermediaries (content and methods), and the social environment (policies and culture), rather than an external object that stays detached from the teaching process. At the heart of this relational approach is the way digital-intelligent technologies change interaction mode between teachers and students, and among students

themselves, through data flow, intelligent feedback, and personalized learning pathways. Teachers are no longer the sole authoritative providers of knowledge, but gradually evolve into learning designers, activity facilitators and collaborative researchers. Correspondingly, students turn from passive receivers into active learning participants and self-directed learners.

Gros & Lopez (2016) noted that when teachers and students are in co-creating learning activities, students not only enables students to be conscious their greater autonomy in selecting learning tools and resources, but also need to take on more responsibility. For teachers, it encourages them to reflect on their teaching practices, and make them aware that while they possess knowledge advantages, they still have shortcomings in technology application. These findings implies that the essence of digital-intelligent education lies not in one-way "empowerment" of education through technology, but rather in a new relationship where teachers and students work together to redefine the purpose and practice of education.

3.2 Reconstructing Educational Values: from Technology Application to Human Growth

Education always comes to life through what humans actually do. In this age of digital intelligence, this practical nature is prominently presented in the back-and-forth between technology and education, where they are mutual intermediaries and mutually shape each other. For one thing, technology deeply seeps into the entire process of teaching, learning, assessment, and management, reshaping what educational practice actually looks like. For example, AI-driven intelligent assessment systems provide instant and precise feedback, and revolutionize evaluation methods; while large language models and multi-agent systems let us build entire virtual teaching worlds, and provide immersive decision-making training environments.

For another, digital intelligent pushes us to ask about the basic question: why do we educate people in the first place, and what really matters most for young people to grow in this world? Education should focus more on areas that technology cannot replace, such as critical thinking, collaborative skills, socio-emotional learning, and the ability to navigate uncertainty when technology can handle with huge volumes

of information and skills training. In this time, the goal of education has transformed from imparting unchanging knowledge. Instead, it's about helping people build the skills for learning and adapting in turbulent environments.

Educational activities themselves continuously shape and define the boundaries and ethical norms of technological use in education. Particular needs, value tensions, such as the trade-off between equity and efficiency, privacy versus personalization, and ethical concerns in turn push technological adaptation and evolution. This two-way co-construction makes clear that the essence of digital intelligent education is not a one-dimensional expansion of technological logic, but rather an ongoing dynamic process where humans and technology collaboratively create value and grow together through the educational practice. In this process, teachers' subjectivity is far from diminished; rather, it is takes on new meaning: teachers no longer act solely as transmitters of knowledge, but transition to designers of learning experiences and coordinators of human-machine collaboration.

3.3 Innovating Sustainable Education: the Characteristics of the New Ecosystem

The ultimate goal of digital intelligent education is to build a harmonious, sustainable, human-centered educational ecosystem. Within this system, human stakeholders including teachers, students and school administrators interact closely with technology (such as artificial intelligence, big data and the Internet of Things) and the broader environment (policy, culture and infrastructure), enabling dynamic collaboration between all elements. Its core characteristics can be summarized as follows:

In personalized adaptive learning, data-driven strategies serve as the core mechanism that allows digitally intelligent education to deliver sustained learning outcomes. AI-enabled intelligent tutoring systems profile learners' behavioural patterns, mastery of knowledge and emotional engagement, then push out customized learning content, individualized learning paths and real-time feedback (Lin et al., 2023). Beyond boosting learning efficiency, this tailored approach most importantly fosters learners' metacognitive ability and self-regulated learning skills-core competencies that underpin lifelong, sustainable learning.

As for digital and AI literacy, AI proficiency has

become an essential skill for citizens in the digital age. Learners need not only to master the skills of using digital tools, but also to develop critical awareness of how algorithms operate, how embedded data biases arise, and what social impacts AI may bring. Incorporating AI ethics, algorithmic fairness and data privacy into the curriculum is an indispensable part of digitally intelligent education, and this step ensures that technological development can truly promote human well-being and social equity.

4. Core Issues: Focusing on Effectiveness, Ethics, and Teacher Development

As educational technology becomes more widely applied in practice, the focus of research has gradually shifted away from technical feasibility, toward in-depth exploration of core educational and social issues.

4.1 Application Effects and Empirical Research

Current studies extensively employ empirical methods, including experiments, case studies and systematic reviews, to examine how specific technological interventions affect students' academic performance, cognitive load, learning engagement and emotional attitude. However, Bauer et al. (2025) found through a field experiment that in structured statistical learning tasks, AI-generated adaptive feedback did not yield better skill acquisition than static feedback, and was even weaker than static feedback in improving learning interest. This conclusion is inconsistent with the previous findings in laboratory settings that adaptive feedback performs well in complex tasks, which reflects that the effect of AI education tools is dependent on specific application contexts.

4.2 Ethics, Equity, and Privacy Challenges

This is still one of the most controversial topics today. Studies have conducted in-depth discussions on issues such as algorithmic bias, data privacy, the digital divide, academic integrity, and the "black-box" nature of AI decision-making. Schiff (2021) argues that algorithms may replicate and amplify inherent cultural and socioeconomic biases in training data, bringing disproportionate harm to marginalized student groups. Therefore, carrying out critical reflection on technological application and adhering to value-oriented guidance to safeguard the fundamental goal of

education, in other words, promoting all-round human development and maintaining social equity and justice, has become a broad public consensus.

4.3 the Teacher Role and Professional Development

Current research agreed that AI will not replace teachers, but redefine their roles. Teachers need to evolve from pure knowledge transmitters into learning designers, learning guides, and emotional supporters. Consequently, it is crucial to build the teaching competencies for educators and provide digital literacy training in the era of intelligent education. Biagini (2025) emphasized that AI literacy should not be limited in pure technical proficiency, but should take ethical issues and social impact at its core. Accordingly, ethical education should be prioritized in cultivating teachers' professional competence in AI.

5. Future Research Prospects

Future research on the digital and intelligent transformation of education should focus on the following areas:

First, we need to deepen the development of "Empowerment Theory" and refocus on the fundamental goal of human development. Future research should transcend "technocentrism" and uphold the value proposition that "technology should empower people". This means shifting its attention from "what technology can do" to "how technology better support the all-round development of individual learners". In particular, we should prioritize exploring how technology can cultivate learners' higher-order thinking, nurture their socio-emotional competencies, and restore the subjective initiative of learners.

Second, we should strengthen scenario-driven empirical research. Research needs transform from general technological applications to specific, demand-oriented educational scenarios. For instance, we can explore how extended reality (XR) can be effectively applied to skill training in high-risk situations in vocational education. Going forward, more work should pay more attention to conducting rigorous quasi-experimental or design-based research in real-world settings, so that we can generate more convincing evidence.

Third, we require to pay attention to the ecological and systemic nature of transformation.

Nguyen et al. (2026) contend that digital and intelligent transformation calls for coordination across three layers: national policies at the macro-level, organizational capabilities at the meso-level, and classroom practice at the micro-level. In future research, more attention should be paid to meso-and macro-level topics, including school leadership, organizational culture, policy coordination, and infrastructure construction. Specifically, we need to explore more the transformation pathways and supporting strategies for underdeveloped regions and disadvantaged schools.

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