From Computer Labs to BYOD: Evolution and Challenges of One-to-One Digital Learning Environments (Postprint)

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Abstract

Since its proposal in the early 21st century, the one-to-one digital learning environment has evolved through computer classrooms, tablet classrooms, e-schoolbags, and bring-your-own-device (BYOD) initiatives, during which both teachers' and students' cognitive paradigms and pedagogical paradigms have undergone tremendous shifts; this transformation has also brought numerous concerns and challenges to schools, teachers, and students. This paper introduces the evolution of one-to-one digital learning environments, analyzes the causes and effects of cognitive and teaching-learning changes resulting from environmental shifts, addresses the problems and challenges faced in current applications of one-to-one digital learning environments, and proposes corresponding solutions and strategies, aiming to lay a foundation for future research directions.

Full Text

Preamble

Title: From Computer Labs to Bring Your Own Device: The Evolution and Challenges of One-to-One Digital Learning Environments
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Abstract: Since the concept of one-to-one digital learning environments was proposed in the early 21st century, it has evolved through computer labs, tablet classrooms, digital schoolbags, and BYOD (Bring Your Own Device). This transformation has fundamentally shifted cognitive and pedagogical paradigms for both teachers and students, while also raising significant concerns and challenges for schools, educators, and learners. This paper examines the evolution

of one-to-one digital learning environments, analyzes the causes and effects of cognitive and instructional changes brought about by this environmental shift, identifies current problems and challenges in the application of these environments, and proposes strategies to address them, aiming to establish a foundation for future research directions.

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Since its introduction at the 2002 IEEE Wireless and Mobile Networking Conference, the one-to-one digital learning environment has undergone eighteen years of development. Numerous countries worldwide, including China, have conducted extensive practice and research on the construction and application of such environments. Under the guidance of the national "13th Five-Year Plan for Educational Informatization," infrastructure networks marked by the "Three Connections and Two Platforms" have matured, laying a solid foundation for China' s educational informatization development. With the advancement of artificial intelligence, big data, and virtual reality technologies, one-to-one digital learning environments have transitioned from fixed computer lab instruction to ubiquitous learning with devices brought into and out of classrooms. However, this evolution has also introduced concerns: the benefits of digital learning environments may be far outweighed by their potential to disrupt classroom dynamics; they may exacerbate urban-rural educational resource disparities; and the application of big data analytics and AI technologies may infringe upon student privacy, raising questions about the boundaries between information silos and privacy protection. These challenges hinder the development of one-to-one digital learning environments and compel us to carefully examine their evolution and implications while developing appropriate countermeasures.

1.1 Changes in Device Mobility

A one-to-one digital learning environment provides each student in a classroom with a digital device terminal, through which learning tools, platforms, and resources are accessed to complete learning and teaching activities with the assistance of teachers or artificial intelligence. Under this concept, computer labs, tablet classrooms, digital schoolbags, and BYOD all fall within the scope of one-to-one digital learning environments (see Table 1). As technology has advanced, terminals have evolved from expensive and bulky desktop computers to lightweight laptops and now to affordable tablets and smartphones. This shift in device mobility has extended and expanded the boundaries of the classroom, al-

lowing students to continue learning activities and interactions at home through their devices' strong connectivity and interactivity, thereby creating possibilities for more flexible classroom content. The service scope of one-to-one digital environments has consequently expanded beyond information technology classes to encompass regular curriculum instruction, with digital terminals bridging offline classroom interactions to after-class activities and enabling the integration of information technology with traditional teaching.

The transformation from computer labs to BYOD has also changed classroom teaching theory from behaviorist, teacher-controlled instruction to constructivist, activity-based learning focused on collaborative knowledge construction. Both teachers and students have experienced a gradual shift toward greater freedom and precision in their teaching and learning processes. The strong interactive nature of one-to-one digital environments has made blended learning and flipped classroom models feasible, while the digital, paperless environment—enhanced by big data analytics and AI—has inevitably driven pedagogical paradigm shifts. These changes in teachers' and students' underlying cognitive logic and patterns occur progressively alongside the characteristics of one-to-one digital learning environments, ultimately generating substantial transformations in teaching paradigms.

1.2.2 Changes in Teaching Paradigm

The cognitive paradigm characteristics of one-to-one digital learning environments—hypertext discreteness, interactivity, immersion, and shareability—determine that teaching differs significantly from traditional classrooms. In conventional settings, teaching resources are largely monopolized by teachers, who serve as primary knowledge transmitters and central figures in the classroom, resulting in centralized knowledge dissemination. To help beginners understand abstract concepts, teachers must identify classic application scenarios during instructional design and spend considerable class time describing these scenarios. Furthermore, traditional classrooms require all students to maintain identical learning paces, forcing teachers to ignore the needs of both struggling and advanced learners due to instructional schedule pressures and resource monopolization. Consequently, teachers have neither the conditions nor the incentive to shift from teacher-centered paradigms, and many instructional reforms have merely produced "performance lessons" or "showcase lessons" that fail to genuinely transform pedagogy. Students, lacking cognitive tools and resources, cannot assume classroom ownership, as evidenced by flipped classroom research where limited class time and conventional resources restrict preliminary understanding of abstract knowledge to outside class hours.

One-to-one digital learning environments break teachers' monopoly on instructional resources. Through digital textbooks and networks, students gain classroom ownership and can select resources matching their learning styles. Digital terminals contain numerous cognitive tools and rich instructional resources to support students at various levels. Big data analytics and AI can construct

learner profiles based on students' learning trajectories and styles, precisely identifying weaknesses and providing personalized reinforcement. With abundant, hierarchically distributed educational resources, teachers are liberated from their role as primary knowledge transmitters and gain greater freedom in curriculum design, shifting their focus from content design to overall framework, activity flow, and layered knowledge and assessment design. In this environment, truly student-centered instruction becomes possible, enabling teachers to focus on students' knowledge construction and overall comprehension, transforming their role from instructional implementers to knowledge designers.

1.2.3 Changes in Learning Paradigm

The evolution of one-to-one digital learning environments has transformed learning paradigms. Students have moved from centralized learning to ubiquitous learning, as digital terminals extend learning across space and time. The strong interactivity and connectivity of terminals enable ubiquitous learning, allowing students to learn anytime, anywhere, and engage in discussions and knowledge sharing with peers at will. One-to-one digital environments bring offline classroom interactions online while effectively integrating formal and informal learning. Students assume agency in their learning process, utilizing resources and networks to select materials matching their learning styles and ensuring every student can access rich learning resources. Additionally, knowledge construction becomes more diverse, as students can use digital tools and networks for independent inquiry or employ online collaboration tools for cooperative exploration and group learning, allowing student-centered constructivist theory to flourish in teaching and learning.

2. Concerns and Challenges of One-to-One Digital Learning Environments

While environmental changes have brought many positive transformations to education and teaching, they have also introduced new concerns and challenges, primarily in the following areas:

2.1 Teaching Philosophy and Model Issues

In one-to-one digital learning environments, the relationship between teachers and students is no longer simply one of transmission and reception. With electronic terminals as mediators, both teaching and learning models have changed, and the entire teaching process has become decentralized. Teachers' primary task should be to serve as knowledge designers who help students construct understanding while acting as classroom instructors. However, many digital schoolbag developers and teachers currently view these environments merely as mobile versions of computer labs. Developers continue to focus on classroom management and teacher assessment tools rather than cognitive and activity

tools, while teachers maintain traditional lecture-based philosophies in their instructional design, simply converting paper textbooks to digital formats. This prevents one-to-one digital learning environments from effectively helping students construct knowledge. Worse still, due to digital terminal stability issues and the characteristics of digital textbooks, student learning outcomes may be poorer than in traditional classrooms.

2.2 Technical Complexity and Teaching Model Diversity

One-to-one digital learning environments represent modern products combining multiple educational concepts and advanced technologies, encompassing mobile or local networks, environmental construction, and teaching management and tool software development. These three technical components are tightly integrated and interdependent; any bottleneck or interaction problem can severely disrupt the teaching process. In practice, issues such as network congestion, software crashes, desynchronization between control software and terminal updates causing loss of control, and student terminals escaping classroom management frequently occur. These problems stem primarily from teachers and developers failing to understand and adapt to the connotations and concepts of mobile teaching environments, still perceiving digital schoolbags as extensions of computer labs. Technically, developers must address the contradiction between large-scale network data concurrency and limited local network bandwidth. To maintain teachers'traditional dominant and controlling position, they have struggled to develop centralized control consoles with mobile screen-locking capabilities, further exacerbating network congestion. Additionally, teachers' information technology teaching competencies and philosophies vary significantly, and since teaching philosophy determines instructional design and implementation, different teachers employ vastly different teaching methods in one-to-one digital learning environments. Existing environments cannot accommodate teachers with varying skill levels and needs. Consequently, teachers must not only address mismatches between teaching models but also resolve complex and fragile technical issues, often spending more time learning and maintaining equipment than on effective instruction, creating structural imbalances among teachers, students, and devices in the classroom.

2.3 Educational Input-Output and Potential Urban-Rural Dual Imbalance

Implementing one-to-one digital learning environments in regular classrooms requires investment in three areas: environmental construction, teacher training, and ongoing equipment maintenance. According to the 2018 Guangdong Provincial Department of Education's "Guidelines for the Construction of Smart Classrooms in Primary and Secondary Schools (Trial)," constructing such environments requires basic teacher environment construction, network facilities, multimedia design, teaching terminals, recording and broadcasting systems, application control systems, and digital resources. These investments are substan-

tial yet can only equip a single classroom, making it unrealistic to implement one-to-one digital learning environments in every classroom across primary and secondary schools. Due to resource scarcity, centralized smart classrooms can only serve as experimental sites for a minority of teachers and schools to conduct instructional research and demonstration lessons. Additionally, new one-to-one learning environments require long-term, continuous investment in targeted teacher training. Finally, digital equipment follows regular maintenance and replacement cycles, and subsequent equipment maintenance and obsolescence will become a significant burden for schools. Currently, China' s urban-rural educational disparities remain substantial, and addressing these input-output issues while balancing urban-rural educational equity presents a major challenge.

2.4 Information Silos and Student Information Privacy Boundaries

Many teachers and parents remain skeptical about digital devices and information technology entering classrooms, expressing opposition to their use. Their concerns exist at two levels: First, digital devices may increase students' cognitive load and distract their attention. Due to insufficient self-control, students may not leverage the advantages of digital devices but instead become immersed in devices and virtual networks. The rich yet poorly targeted multimedia content in digital learning increases cognitive load and attention dispersion, making it more difficult for students to truly understand knowledge. Second, there is a contradictory tension between digital islands and student information privacy boundaries. China is currently promoting the elimination of information silos across industries to enable big data and AI technologies to break traditional sector barriers and drive innovation through "Internet Plus" initiatives. However, "Internet Plus Education" faces several major issues: (1) Do big data analytics and AI technologies infringe upon student information privacy? (2) Do these technologies exacerbate educational inequality? (3) Do they violate the fundamental purpose of education? Currently, regional imbalances in educational resources create hierarchical and selective functions in learning evaluation. Privacy concerns are less prominent when student data does not affect real-world academic evaluation, but as information silos break down and students' digital learning performance influences evaluation, advancement, and even employment opportunities, tensions between digital privacy boundaries and information silos intensify. As process-oriented evaluation gains prominence, AI and big data technologies risk further aggravating urban-rural educational disparities and violating educational principles. How to protect student information privacy, navigate the boundaries between digital silos and privacy, and design reliable AI and big data technologies to better serve students requires careful consideration.

3. Countermeasures and Implications for One-to-One Digital Learning Environments

After analyzing the evolution and challenges of one-to-one digital learning environments, how can we leverage their advantages while addressing the concerns they raise? We must first analyze their primary strengths: strong interactivity, precise collection of student learning data, and rich, diverse resources and teaching assistance tools. Strategies should therefore maximize these characteristics.

3.1 Bringing Classroom Interaction to Mixed-Environment Teaching Interaction

The 2020 pandemic disrupted normal school operations, prompting education departments to rapidly implement online courses. Teachers and students immediately utilized existing tablet classrooms, digital schoolbags, and BYOD devices, applying the competencies they had developed through previous one-to-one digital learning environment practices. The high interactivity of electronic terminals addressed common online teaching issues such as student distraction and monotonous instructional methods, enabling relatively smooth implementation of online education. As offline teaching resumes, we should vigorously promote blended learning based on BYOD or digital schoolbags to help students develop good ubiquitous learning habits and digital literacy.

3.2 Developing One-to-One Digital Learning Environments in Special Education Schools to Gradually Implement Inclusive Education

For most people, one-to-one digital learning environments offer enhanced learning opportunities, but for students with disabilities, they can be lifelines. Existing terminal devices' assistive functions can effectively help deaf, blind, and cognitively impaired students learn alongside their peers. Investing in one-to-one digital learning environments in these schools offers greater cost-effectiveness than in regular primary and secondary schools. Such environments can help disadvantaged groups better integrate into society and improve their lives through their own efforts. As these environments advance in special education schools, they will enable universal inclusive education where everyone can access learning opportunities.

3.3 Developing Synchronous Urban-Rural Classrooms Through One-to-One Digital Learning Environments

Urban-rural educational resource disparities remain significant, and implementing one-to-one digital learning environments in every classroom is not realistic. How then can we better utilize existing environments? In recent years, many regions have conducted research on synchronous urban-rural classrooms using

smart classrooms and one-to-one digital learning environments. They have mobilized schools with concentrated educational advantages to use these environments' high interactivity and real-time capabilities, enabling renowned teachers to conduct simultaneous lessons across different locations. This allows students in remote areas to interact with distinguished teachers in real time and share excellent educational resources with urban peers, expanding access to quality instruction. Additionally, many companies are developing diversified products tailored to urban and rural needs, enabling one-to-one digital learning environments to bridge educational gaps.

3.4 Transforming Digital Environment Teaching Philosophy and Improving Teachers' Digital Literacy

Many problems in one-to-one digital learning environments stem from teachers and product developers' failure to transform their teaching philosophies. Educators should therefore begin with teacher training to help teachers and developers understand that students should be the protagonists in these environments, while teachers should serve as guides and facilitators rather than managers and controllers. However, philosophical transformation is a lengthy process, so teacher education programs must address digital literacy requirements for digital learning environments to prepare future educators. Meanwhile, governments, universities, and enterprises should conduct research at a higher level on how digital environments can better bridge urban-rural educational divides and promote effective development.

3.5 Designing Reasonable and Transparent Big Data Analytics and AI Algorithms While Establishing Student Information Privacy Firewalls

To address concerns about big data analytics and AI infringing on student privacy and the tension between breaking information silos and protecting privacy, we should prioritize transparency in algorithms. All aspects—from data collection and profile building to big data analysis, evaluation scale generation, AI recommendations, and learning evaluation scope and content—should be subject to transparent discussion and analysis. This enables users and administrators to understand whether data analysis and intelligent recommendations truly serve students, promote fairness, and support personalized development. Additionally, we must establish student information privacy firewalls that prohibit forcing students or guardians to disclose evaluation data for student selection when they do not consent, thereby affecting students' future educational opportunities. Information technology should serve every student rather than create more unfair selection mechanisms.

The evolution and development of one-to-one digital learning environments have opened broader horizons for education while introducing multiple concerns and challenges. Whether a new technology can truly be applied in education de-

pends not on learning efficiency or technological advancement alone, but on whether it enables learners to access educational opportunities more equitably and obtain freer education. The future development of one-to-one digital learning environments should adhere to this principle.

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Note: Figure translations are in progress. See original paper for figures.