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Advancing Smart Education: Role Analysis of Digital Textbooks and Exploration of Classroom Construction Pathways

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Abstract

With the deep integration of information technology and education, digital textbooks and digital classrooms have become core drivers in promoting a paradigm shift in teaching. This paper aims to thoroughly analyze the core role of digital textbooks in content presentation, instructional support, and evaluation feedback, moving beyond their superficial perception as mere "digitized versions of printed textbooks." On this basis, the study proposes a student-centered, data-driven model for constructing digital classrooms. This model encompasses four key dimensions: the resource layer, activity layer, data layer, and community layer. Furthermore, the paper explores the main challenges encountered during the construction process and corresponding strategies, aiming to provide educators with theoretical references and a practical framework for systematically advancing the digital transformation of classroom teaching.

Keywords

Digital Textbooks, Digital Classrooms, Smart Education, Personalized Learning, Instructional

1. Introduction

Within the traditional "teacher-textbook-student" triad, the textbook serves as the core carrier of knowledge, and the classroom functions as the primary site for knowledge transmission. However, in an era where "digital natives" constitute the main student body, static, linear printed textbooks and the model of one-way

knowledge transmission in classrooms are increasingly inadequate for cultivating students' core competencies and innovative abilities (Castillo et al., 2025). The development of digital textbooks and digital classrooms signifies far more than the simple introduction of technological tools or a shift in media; it represents a systematic reconstruction concerning educational philosophy, teaching models, and evaluation systems. Its aim is to build a new, open, interactive, precise, and personalized learning ecosystem. Therefore, clearly understanding the profound role of digital textbooks and systematically planning the construction path for digital classrooms represent a pressing issue requiring in-depth research in current educational reform.

2. Analysis of the Core Role of Digital Textbooks

Three-Dimensional Value Beyond "E-books". Digital textbooks should not be simply regarded as PDF files loaded with multimedia resources. Their core value is reflected in the following three dimensions:

2.1. The "Hypermedia" Nature and Structuring of Content Presentation

Digital textbooks break the linear narrative structure of printed textbooks (Hermita et al., 2023). By integrating diverse media such as text, images, audio, video, 3D models, interactive simulations (e.g., PhET), and virtual reality (VR), they construct a non-linear, explorable "knowledge hypermedia" network. Students can deeply interact with knowledge through clicks, drags, zooms, and other operations based on their own interests and cognitive paths, visualizing abstract concepts and macroscopicizing microscopic phenomena, thereby deepening understanding. Simultaneously, knowledge is granularized and tagged, packaged by knowledge point, forming internal logical connections, which lays the foundation for generating personalized learning paths.

2.2. The "Scaffolding" Role and Interactivity of the Teaching Process

Digital textbooks are "intelligent cognitive tools" embedded in the teaching process (Reinhold et al., 2024). Their built-in functions like notes, highlighting, bookmarks, dictionaries, and knowledge graph generation provide students with personalized learning scaffolds. More importantly, they can integrate formative assessment, such as pop-up quizzes, instant polling, and discussion areas, enabling the "learning-testing-evaluation" loop to be completed instantly. Students receive immediate feedback, and teachers can grasp learning conditions in real-time, thus dynamically adjusting the teaching pace and realizing the shift from "teaching-centered" to "learning-centered."

2.3. The "Datafication" and Personalization of Learning Evaluation

This is the most revolutionary role of digital textbooks (Benerdal & Larsson,

2024). All student learning behaviors within the digital textbook such as time spent on a page, exercise accuracy, error types, resource click preferences, note content, etc. can be anonymously recorded and analyzed. Through these learning analytics technologies, teachers can accurately depict students' knowledge mastery, learning habits, and cognitive difficulties at both group and individual levels. This makes genuine personalized learning possible: the system can recommend specific learning resources, push targeted exercises, or issue learning alerts based on data, thus realizing the millennia-old educational ideal of "teaching students according to their aptitude."

3. Digital Textbooks: A New Engine for Teaching, beyond "E-Books"

Digital textbooks are far more than simply digitized versions of printed content. They are comprehensive learning platforms that integrate text, images, audio, video, animations, interactive exercises, and expansive hyperlinks. For both teachers and students, leveraging these features effectively is key to unlocking their immense potential.

For teachers, digital textbooks are innovators in instructional design and classroom management:

Building Contextualized and Personalized Classrooms: In traditional classrooms, explaining abstract concepts can be time-consuming and laborious. Digital textbooks, however, allow teachers to call up high-definition satellite images for geography, play historical footage to recreate the past, or use 3D models to dissect human organs. This vastly enriches the dimensions of teaching, making knowledge tangible and accessible. Furthermore, teachers can use the built-in tiered exercises and resource libraries of digital textbooks to create differentiated lesson plans based on the overall level of the class, catering to the diverse learning needs of all students.

Enabling Precision Teaching and Assessment: The learning management systems that accompany digital textbooks can record real-time data on student reading duration, quiz performance, knowledge gaps, and more. By analyzing this data, teachers can quickly identify common class-wide issues and individual weaknesses, allowing for targeted feedback and tutoring. These shifts teaching from being "experience-driven" to "data-driven," achieving a new level of precision.

Fostering Collaborative Inquiry and the Flipped Classroom: Teachers can use the digital textbook platform to assign group research tasks. Students, focusing on a specific topic, can use linked resources both within and beyond the textbook to gather information, organize it, and collaborate on projects, thereby cultivating critical thinking and digital literacy. Additionally, digital textbooks are ideal tools for implementing the "flipped classroom" model. Students acquire foundational knowledge before class by watching videos and completing basic exercises, freeing up class time for in-depth discussion, project-based exploration, and personalized guidance, truly realizing a "student-centered" approach.

For students, digital textbooks are boosters for self-directed learning and skill development:

Creating Personalized Learning Pathways: Students are no longer passive recipients of uniform information. They can selectively delve into supplementary materials based on their own interests and comprehension, re-watch videos explaining difficult concepts, or skip content they have already mastered. This partially returns the initiative for learning to the students, fostering self-directed learning abilities.

Using Interactive Features to Deepen Understanding: Instantly submitted exercises, drag-and-drop chemical molecular models, simulatable physics experiments... these interactive features provide immediate feedback, enabling students to "learn by doing," consolidate knowledge through trial and error, and transform abstract theory into concrete experience.

Constructing an Interconnected Web of Knowledge: Through hyperlinks and prompts for related knowledge points within digital textbooks, students can easily connect old and new knowledge, as well as concepts from different disciplines. For example, while studying a classical Chinese text, they can access links about the author's life, relevant historical context, and later literary critiques, thereby building a multidimensional, interconnected knowledge system rather than just accumulating isolated facts.

4. The Construction Path for Digital Classrooms: A Four-Layer Integration Model

Based on the aforementioned characteristics of digital textbooks, the construction of digital classrooms is a systematic project. We propose a four-layer integration model. It is crucial to note that the successful implementation of this model hinges on two fundamental preconditions at the institutional level. First, strong and sustained institutional support is required for top-level design, including the development of a clear digital strategy, investment in interoperable technological infrastructure, and the establishment of data governance policies that protect student privacy. Second, a robust, ongoing teacher training program is indispensable. This program must extend beyond mere tool operation to encompass the pedagogical redesign of lessons, data interpretation skills, and strategies for fostering the classroom community layer outlined below.

4.1. Resource Layer: Building a Multi-Dimensional Content Ecology with "Textbooks as the Core, Resources as the Domain"

Core: High-quality, officially approved foundational digital textbooks form the core, ensuring the scientificity and systematicity of the knowledge structure.

Expansion: Build an expanded resource bank seamlessly linked to the core textbooks, including but not limited to: micro-lecture videos, cutting-edge academic articles, real-world case libraries, links to digital museums, discipline-specific software tools.

Organization: All resources should be semantically linked via a knowledge graph, forming an open and expandable "learning resource domain" with core concepts as nodes, rather than a pile of isolated resources (Nayak et al., 2023).

4.2. Identify the Headings

Activity Layer: Designing Blended Learning Flows that "Fuse Online and Offline".

The essence of digital classrooms lies in the innovation of teaching activity design (Henning, 2020). The old model of "teachers demonstrating digital textbooks" should be abandoned in favor of a blended learning model that integrates online and offline activities.

Pre-class (Online): Students use digital textbooks for self-directed learning of foundational knowledge and complete simple self-assessment questions and open-ended problems, bringing the generated "data" and "questions" into the classroom.

In-class (Offline/Online Synchronous): Classroom time is primarily used for higher-order cognitive activities. Based on pre-class learning data, teachers organize group collaborative inquiry, project-based learning, debates, etc. Digital textbooks and classroom interaction tools (e.g., smart classroom systems) become the "workbench" supporting inquiry and collaboration.

Post-class (Online): Students complete tiered and flexible assignments via the digital textbook platform, participate in thematic discussions, or use built-in creation tools (e.g., writing code, creating digital stories) for knowledge creation and transfer.

4.3. Data Layer: Creating an Intelligent Closed Loop for "Data-Driven Teaching Decisions"

Build a data platform connecting digital textbooks, interactive tools, and the learning management system.

Data Collection: Comprehensively and unobtrusively collect procedural data from the teaching and learning process.

Analysis & Visualization: Utilize learning analytics dashboards to present teachers with class-wide knowledge maps, individual student learning profiles, and early warning information; present students with their personal learning progress and competency radar charts. For teachers, the most actionable metrics to monitor on these dashboards typically include real-time concept mastery rates, the distribution of common error patterns across the class, and indicators of student engagement such as time-on-task and resource interaction.

Decision & Intervention: Teachers implement targeted group guidance, individualized instruction, or adjust teaching strategies based on data insights; the system automatically pushes personalized learning resources and paths.

4.4. Community Layer: Fostering a Learning Culture of "Teacher-Student, Student-Student, Human-Machine" Multi-Dimensional Collaboration

Technology builds the "skeleton" of the classroom, while culture gives it its "soul." (Backfisch et al., 2021)

Teacher-Student Relationship: Teachers transition from "knowledge authorities" to "designers, facilitators, and collaborators" of learning.

Student-Student Relationship: Build positively interdependent learning communities through digital platform-supported group tasks, peer assessment, etc.

Human-Machine Collaboration: Guide teachers and students to correctly view technology, regarding digital textbooks and AI as "partners" that empower teaching and learning, not replacements, and cultivate their digital literacy and critical thinking.

Example: A Collaborative Inquiry on WWI Causality

Machine's Role (Data Provision & Task Automation): The digital textbook presents an interactive knowledge graph of the key factors (militarism, alliances, imperialism, nationalism). It then automatically divides students into small groups and assigns each group a primary factor to investigate deeply. It provides each group with a curated set of primary sources, historical maps, and short expert videos from its resource library.

Students' Role (Critical Analysis & Synthesis): Student groups collaborate (online or offline) to analyze their assigned materials. They discuss the credibility of sources, identify biases, and summarize their factor's role. They use the digital textbook's built-in collaborative tool (e.g., a shared whiteboard) to mind-map their findings and prepare a brief presentation.

Teacher's Role (Facilitation & Deepening Inquiry): The teacher circulates among groups, asking probing questions prompted by the real-time activity dashboard (e.g., "I see your group is focusing heavily on the alliance treaties. How might you reconcile the different perspectives presented in the German and British documents?"). The teacher helps students navigate complex historical interpretations that the AI cannot.

Synthesis and Human-Machine Interaction: Finally, the teacher facilitates a whole-class discussion where groups present their findings. Using an interactive whiteboard, the class collaboratively reassembles the factors from the digital textbook's knowledge graph, debating and drawing connections based on their human understanding. Here, the machine provided the structured data and organizational scaffold, while the humans (teacher and students) provided the critical thinking, synthesis, and nuanced interpretation.

This example illustrates a true partnership: the digital textbook handles information retrieval, basic organization, and group management, freeing up the teacher and students to focus on higher-order cognitive and social tasks. This is the essence of human-machine collaboration in the digital classroom.

5. Challenges and Countermeasures

The construction of digital textbooks and classrooms is not without challenges, primarily facing four major hurdles:

Mindset and Capacity Challenges: Teachers may face "technophobia" and "insufficient design capability."

Countermeasures: Conduct sustained, tiered, case-led teacher training, and es-

tablish cross-disciplinary teacher communities of practice to encourage collaborative design and experience sharing.

Resource and Technical Challenges: Risks of "information silos" and the "digital divide" exist.

Countermeasures: Schools need to strengthen top-level design, promote the interoperability of platforms and data, pay attention to disadvantaged student groups, provide necessary equipment and network support, and ensure educational equity.

The Risk of Over-Datafication: The heavy reliance on learning analytics may lead to an overemphasis on quantifiable metrics at the expense of holistic education. This can raise significant student privacy concerns and potentially narrow the curriculum, as teachers might feel pressured to "teach to the metric"—focusing only on what is being measured (e.g., quiz scores) while neglecting harder-to-quantify skills like creativity, collaboration, and critical thinking.

Countermeasures: Establish strict data ethics and privacy protection guidelines, ensuring transparent data collection and usage policies with informed consent. Furthermore, professional development should guide teachers to interpret data as formative and diagnostic tools, not as definitive judgments of student worth. The evaluation system itself must be reformed to balance quantitative data with qualitative assessments, such as portfolio reviews and project-based evaluations, to present a complete picture of student growth.

Evaluation and Management Challenges: Traditional evaluation systems struggle to measure higher-order competencies and collaborative spirit in digital classrooms.

Countermeasures: Reform teaching evaluation standards, emphasize process data, and introduce diverse evaluation methods based on portfolios and performance tasks.

The Path to Integration: Digital as the Tool, Tradition as the Foundation

While embracing digital textbooks, we must clearly recognize that technology is always a tool, and the core of education is "cultivating people." The valuable heritage of traditional teaching—what we might call "traditional knowledge"—should not be discarded, but rather imbued with new vitality in the digital age (Chang & Chen, 2023).

Firstly, the capacity for deep reading and systematic thinking requires a return to "tradition."

The fragmented information and diverse presentation styles of digital textbooks can easily lead to scattered attention and superficial thinking among students. Here, teachers should consciously guide students toward "deep reading." (Arie et al., 2023) For instance, after using digital resources for background learning, require students to return to the pure text for annotation, excerpting, and reflective writing. A specific pedagogical strategy to facilitate this is "Guided Annotation," where the teacher provides students with a digital text embedded with prompts and a dedicated digital notebook. Students are instructed to not merely highlight text, but to use a consistent set of symbols or comment tags (e.g., (Arie et al., 2023)

for questions, (Gayoso-Cabada et al., 2019) for key insights, (Chang & Hwang, 2022) for connections to other knowledge) to mark the text. They are then required to elaborate on these annotations in their digital notebook—for example, explaining why a certain point is crucial, or formulating a specific question about a confusing passage. This structured process transforms passive reading into an active dialogue with the text, slowing down the cognitive process to foster critical analysis and retention. This process of deep engagement with the text is crucial for developing logical reasoning, critical thinking, and linguistic sensitivity—things no technology can replace.

Secondly, the value of writing by hand and engaging both mind and body is irreplaceable.

Writing Chinese characters is not just a skill; it is a form of cultural and cognitive training. In subjects like mathematics and physics, the process of manually working through calculations and derivations embodies the organization of thought and logical rigor (Lubis & Yudhi, 2021). Teachers should encourage students to use traditional note-taking to consolidate knowledge frameworks after learning with digital textbooks, and to use pen and paper for complex calculations and compositions. Neuroscience shows that handwriting activates broader regions of the brain, aiding memory consolidation and knowledge internalization.

Thirdly, teacher-student interaction and emotional connection are the soul of education.

No matter how intelligent a digital textbook is, it cannot replace a teacher's encouraging glance, a reassuring pat on the shoulder, nor can it replicate the spark of intellectual collision in group discussions or face-to-face debates. Teachers should use the class time saved by digital textbooks to organize more group activities, thematic debates, role-playing, and other activities requiring high levels of interpersonal interaction. Technology should serve to deepen the connections between people, not become a barrier.

Finally, the ancient wisdom that "practice yields genuine knowledge" is never obsolete.

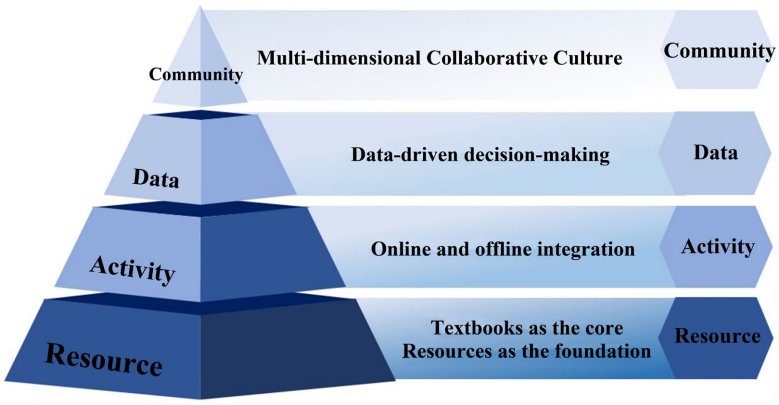

Figure 1. A schematic diagram illustrating the "Four-Layer Integration Model for Digital Classrooms," depicting the relationships between the resource, activity, data, and community layers.

No digital simulation, however, realistic, can fully replicate the awe of hands-on instrument calibration and observing chemical reactions in a lab; no virtual museum tour, however clear, can match the experience of standing before an artifact and feeling the weight of history. Digital textbooks should act as a bridge connecting the classroom to reality, inspiring students to go out, observe, practice, and create. As shown in Figure 1.

6. Conclusion and Outlook

Digital textbooks are the "intelligent engine" activating digital classrooms, while digital classrooms are the "practical field" for realizing the value of digital textbooks, shown in Table 1. The deep integration of the two is driving education

Table 1. A summary table titled "Core Value Dimensions of Digital Textbooks," which concisely contrasts the three dimensions with their key characteristics and practical implications.

Value dimension	Core features	Practical significance
Hypermedia and Content Structuring	Nonlinear, multi-modal, exploratory	Make abstract knowledge concrete and support individualized cognitive approaches
The role of scaffolding in the teaching process	Interactivity, embedded assessment, immediate feedback	Realize the transformation from "teacher-centered" to "student-centered"
Data-based learning evaluation	Learning behavioral analysis and personalized insights	Make "tailored teaching" possible and achieve precise education

from "standardized production" towards "personalized growth." The future educational landscape will be a smart learning environment where digital textbooks serve as a key hub, integrating physical space, social relationships, and digital information. Educators should proactively embrace this transformation, starting by building a solid resource foundation, using innovative teaching activity designs as the engine, navigating with data intelligence, and ultimately fostering a vibrant learning community, thereby laying a solid foundation for cultivating innovative talents adapted to future society.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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