

# Development of AI-Based Personalized Textbooks: Theoretical Framework and Practical Strategies

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**Abstract:** Personalized learning has become a central issue in contemporary educational reform. As the fundamental carrier of teaching and learning, the intelligent transformation of textbooks has emerged as a key pathway for advancing the implementation of personalized education. This study focuses on the development of AI-based personalized textbooks. By defining their conceptual connotations and core components, identifies three essential characteristics: generative, adaptive and evolvable. Building upon this foundation, a three-dimensional theoretical framework—comprising the knowledge layer, cognitive layer, and technological layer—is constructed from the perspectives of epistemology, cognitive science, and technological synergy. Furthermore, four practical strategies are proposed: constructing a “human-machine co-creation” dynamic content ecosystem; implementing a “data-driven” precise adaptation scheme; creating an “integrated virtual-physical” intelligent interactive environment; upholding the ethical and safety boundary of “technology for good”.

**Keywords:** Artificial intelligence; Personalized textbooks; Knowledge graphs; Cognitive diagnosis; Human-machine collaboration

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## 1. Introduction

In today's society, artificial intelligence and digital transformation are reshaping the education field. These two forces, combined with modern learning science research and the traditional teaching concept of “teaching students in accordance with their aptitude”, jointly promote the transformation of personalized learning from theoretical assumptions to actual needs. Textbook is the carrier of curriculum and the foundation of teaching, which has far-reaching influence. It quietly affects teachers' teaching mode and students' learning process. However, the current standardized and immobilized textbooks have certain limitations on teaching, and it is difficult to meet the needs of individual learners. “Learning analytics and educational data mining”<sup>[1]</sup> enables artificial intelligence to

transform textbooks from static pages into responsive and intelligent interactive tools. This technological change provides practical expectations for resolving the long-standing personalized teaching problems. However, researchers need to pay attention to the fact that although scholars have systematically expounded the value, challenges and opportunities of artificial intelligence in the field of education<sup>[2]</sup>, textbooks are rarely explored as an independent theoretical category. Without this theoretical foundation, practice may fall into the dilemma of pure technical instrumentalism-tools leading teaching methods rather than teaching methods leading tools. Therefore, this study aims to construct a solid theoretical framework of AI-based personalized textbooks, and clarify its core elements and operation mechanism.

## **2. Connotation and characteristics of AI-based personalized textbooks**

### **2.1. Conceptual definition of AI-based personalized textbooks**

At the intersection of teaching and technology, it is AI-based personalized textbooks. It uses intelligent diagnosis algorithms to process multimodal student data, and then improves the learning experience through an adaptive learning model. These systems can dynamically generate teaching materials, reshape the knowledge structure, create personalized learning routes, and change assessment methods.

This study identified three important factors that are closely linked to achieve this function. First, intelligent technology infrastructure is the core driving force. Artificial intelligence integrates three key levels: the data layer collects information from learning management platforms and various devices; the algorithm layer uses knowledge tracking and reinforcement learning technology to follow up the learner's understanding progress; the interaction layer uses natural language processing and generative tools to achieve interactions such as "instant feedback" and "automatic content generation"<sup>[3]</sup>. As a result, the knowledge system has shifted from a linear development to a dynamic network. The framework supports unlimited combinations according to individual needs. Finally, knowledge adaptation evolves into continuous communication rather than one-time adjustment: the textbook runs the "perception-decision-feedback" cycle mechanism and updates student portraits in real time. This circulation mechanism ensures the common progress of textbooks and learners.

### **2.2. Key characteristics of AI-based personalized textbooks**

AI-based personalized textbooks fundamentally redefine the core element of education. They not only transform the teaching content into digital form, but also comprehensively transform the operation mode of the learning support mechanism. This change is determined by three closely linked key characteristics: generative, adaptive and evolvable.

First of all, generation technology has completely changed the mode of production of educational content. AI-based personalized textbooks regard knowledge as a modular component, that is, "knowledge units" that can be dynamically reorganized. Generative artificial intelligence combined with knowledge graph technology can generate teaching materials, exercises and explanatory feedback in real time, so that each learner can obtain content that accurately matches students' current needs and situations. Secondly, adaptability realizes the personalization of daily learning experience. Today, we are moving from "Teaching in accordance with aptitude" to "ability to teach in accordance with aptitude"<sup>[4]</sup>. AI-based personalized textbooks really have the ability to achieve this goal: these systems will create dynamic learner profiles and are continuously optimized in each learning interaction. Third, evolvability overcomes the problem that

traditional textbooks are difficult to synchronize the speed of knowledge update. Traditional textbooks need to go through a long revision cycle, while artificial intelligence enhanced edition can continue to learn and improve, and absorb subject development and practical experience in real time. These characteristics do not work alone: generation enhances adaptability, adaptability contributes to evolvability, and evolvability in turn strengthens generation. This is actually a profound reshaping of the question of how educational resources can help learners in the era of intelligent technology.

### **3. Theoretical framework for the development of AI-based personalized textbooks**

#### **3.1. Knowledge layer: Content organization dimension based on knowledge graphs**

The theoretical framework is based on the knowledge layer, and its main role is to solve the core problems. The knowledge graph technology has subverted the linear and fragmented logical structure of traditional textbooks and brought significant innovation. It can build a systematic and interrelated knowledge system, so as to realize the personalized customization function.

First, knowledge points no longer exist in isolation. This study decomposes the subject content into precise “knowledge units”, and thus builds a huge semantic network. These associations are naturally generated and are not limited by chapter division. Second, interdisciplinary connections have been fully expanded in practical applications. Context-personalization through Generative Artificial Intelligence (GAI) enables the real-time creation of diverse learning material and tasks tailored to each student’s unique interests, surpassing what educators can provide in practice.<sup>[5]</sup> Thirdly, the knowledge system needs to evolve with the development of disciplines. Traditional textbooks have lagged behind when entering the classroom. The framework is continuously updated with the help of artificial intelligence-assisted mechanisms, but technology alone is not enough to meet the needs.

This layer thoroughly reconstructs the flow, interaction and integration of knowledge in the learning process. Here, the process of adaptation occurs naturally, rather than imposed, marking a real paradigm shift from mechanical page-turning learning to focusing on thinking cultivation.

#### **3.2. Cognitive layer: Learning adaptation dimension based on cognitive diagnosis**

The key to personalized learning lies in a fundamental problem that needs to be solved from the cognitive layer. This idea is not to regard students as passive recipients of knowledge, but to base the compilation process of textbooks on the actual development and operation mechanism of human cognition.

This teaching mode is learner-centered. Multi-dimensional learner portraits are constructed by collecting multimodal data. These portraits combine cognitive ability, learning style, emotional state and knowledge structure, and are a description model that is dynamically updated with each interaction. The combination of cognitive diagnosis theory and machine learning technology has contributed to this evolving understanding mechanism. Cognitive load theory shows that efficient learning requires precise regulation: artificial intelligence-driven perception tools can judge whether learners are close to cognitive overload or face redundant information in real time, and textbooks will adjust content difficulty, information density and interaction form before frustration occurs, which reflects active teaching. When these elements are coordinated and unified, the learner’s portrait and cognitive load data will be input into the algorithm system to explore the knowledge graph. The system generates a personalized learning path based on this, fully considering the unique starting point of each student. Different learners may master the same concept with

the help of completely different learning order and auxiliary means.

This layer transforms textbooks from one-way teacher tools to interactive partners. It can adapt to the way learners process information, so as to provide adaptive cognitive support dynamically adjusted according to learners' needs. The final AI-based personalized textbooks can not only understand the knowledge that students need to master, but also grasp their most efficient way of learning.

### **3.3. Technological layer: Interaction and feedback dimension based on human-machine collaboration**

Educational technology often falls into a misunderstanding-prone choice: to pursue complete automation or to implement appropriate digital improvements. At the technical layer, the core idea is to use human-machine collaboration to create an efficient “new personalized learning system”<sup>[5]</sup>. This ideology recognizes that artificial intelligence has the most prominent value in improving learners' autonomous learning ability. It combines theoretical basis and practical application, and transforms abstract teaching concepts into specific learning feelings.

First of all, the intelligent tutoring system is no longer just a simple tool, but a partner in teaching. According to the scaffolding theory, these systems can give accurate quantitative help and flexibly adjust the cognitive scaffolding according to the learner's real-time situation. The point is that they maintain the core role of teachers by transforming complex learning data into practical understanding. When students encounter difficulties, the system will feedback the learning rules to teachers, so that teachers can take evidence-based intervention measures in time. This creates an atmosphere of collaboration: artificial intelligence is responsible for scale management and pattern recognition, while teachers focus on interpersonal communication and detailed guidance. Secondly, the multimodal interactive interface solves the basic practical problems of learning—some students use visual presentation to understand concepts, some students like oral explanation, and some students learn through interactive simulation. By integrating multiple sensory pathways, the system respects different cognitive processing methods and aims to optimize cognitive load through dual-channel processing. Third, the evaluation and feedback mechanism changes the evaluation method from accidental judgment to continuous dialogue and communication. Formative assessment and summative assessment are integrated into a unified diagnostic system. Real-time tests, interactive forms and problem-solving methods together constitute a continuous feedback loop. The accuracy of this diagnosis directly affects the cognitive and knowledge level, promotes the automatic updating of content, and clarifies the specific direction of intervention for teachers.

This layer has finally achieved far-reaching educational goals. The real innovation lies in how to coordinate the cooperation between human insight and machine intelligence.

## **4. Practical strategies for the development of AI-based personalized textbooks**

### **4.1. Constructing a “human-machine co-creation” dynamic content ecosystem**

Educational technology has never been able to replace human wisdom. The discussion of artificial intelligence in the field of education has built a vibrant ecosystem. In this system, machine intelligence and human expertise work together.

First of all, human professional knowledge, as the guide of ethics and teaching, must provide stability for any textbook system based on artificial intelligence. Although artificial intelligence has shown great potential in the field of education, it is not feasible to use it to replace human participation without prudence.<sup>[6]</sup> Experts in various fields should design a basic knowledge graph framework. This human-led top-level design

ensures that artificial intelligence serves teaching objectives rather than controlling educational principles. Secondly, as an extensible content creator, machine intelligence transforms this foundation into vivid learning resources. Large language models can provide multiple interpretations of complex concepts. The boundary of textbooks has been continuously expanded, beyond the scope of the ability of a single author team. Thirdly, the feedback loop, as a driving force for evolution, ultimately optimizes the entire ecosystem. Personalization increases the learning outcomes and engagement of students by providing appropriate challenges and timely feedback.<sup>[7]</sup> This information drives continuous improvement through prudent human decision-making. For content that may be more sensitive (such as historical records or scientific disputes), it is particularly important to adopt the process of “machine preliminary screening + manual review”. The algorithm will prompt potential problems according to the preset standards, but the final judgment on the cultural adaptability of the content and the teaching effect is still made by professionals.

This collaborative production model takes moral values and humanistic care as the core of technological development, making AI-based personalized textbooks more adaptive.

#### **4.2. Implementing a “data-driven” precise adaptation scheme**

Data often presents a paradox: although massive amounts of information are ubiquitous, deep insights are scarce. This part faces this practical problem, breaks through the limitation of surface indicators, and creates an intelligent adaptive system.

Firstly, the cognitive diagnosis model is used as the core analysis tool to transform the huge data into practical knowledge. The Item Response Theory (IRT) has evolved from a simple right and wrong score to a tool for assessing the possibility of knowledge mastery at different difficulty levels. The deep knowledge tracking model mines the potential links between concepts. This diagnostic accuracy makes the evaluation shift from summary conclusions to formative guidance. Secondly, the differentiated intervention strategy as a response mechanism further improves this closed-loop system. The key to precise adaptation is that different students with the same grades may need completely different support. For learners with a greater cognitive burden, the textbook can adopt the “scaffolding teaching mode”, disassemble the complex proof into easy-to-understand steps; for advanced learners, the system can introduce real-world problem situations.

This data-driven approach finally reinterprets the fairness of education. The unique advantage of the system is that it can show the implicit cognitive map of each learner and adjust the educational environment accordingly.

#### **4.3. Creating an “integrated virtual-physical” intelligent interactive environment**

Textbooks are changing from static pages to a vibrant learning ecosystem, which represents one of the most significant changes in the field of education. This change has prompted us to rethink beyond the mere digitization of existing content: when “real individuals” and “virtual digital agents”<sup>[8]</sup> are integrated, what forms of learning resources can be developed.

First of all, immersive embodiment, as a way of cognitive support, fundamentally redefines how abstract concepts are transformed into concrete cognition. Embodied cognition theory shows that our brain constructs meaning through physical interaction with the environment. This transformation from symbolic abstraction to embodied interaction bridged the gap between theoretical cognition and practical insight, making the hidden elements in learning immediately visible and operable. Secondly, intelligent agents become continuous learning partners in uncertain situations. Always online intelligent tutoring assistants will maintain a

continuous dialogue with knowledge, associate new problems with the evolving knowledge network of learners, and recommend related concepts that they may want to explore next. However, these intelligent agents do not replace educators, but extend the scope of teaching beyond classroom boundaries and school time, providing a mentor who is always accompanied and tracking each student's unique learning path.

This integrated teaching environment ultimately reshapes the inclusiveness of education. Learners with different learning preferences can understand the same basic concepts through their own preferred sensory pathways.

#### **4.4. Upholding the ethical and safety boundary of “technology for good”**

The deep integration of technology is bound to cause potential risks, and the AI-based personalized textbook must not turn a blind eye to them. “Technology for good” should be regarded as an insurmountable ethical bottom line.

First of all, data privacy is an important factor in the integrity of teaching, which makes technical protection an inevitable moral choice. The efficient operation of personalized textbooks is highly dependent on the continuous collection of learners' personal data, which makes them face severe privacy security risks. The scope of data collection should be standardized according to the “minimum necessary principle”, and a transparent data authorization and notification mechanism should be established to ensure the legal compliance of data use. Secondly, algorithmic fairness, as the core principle of cognitive fairness, challenges the apparent advantages of personalized teaching. Accurate matching may soon be transformed into predictive isolation, and the algorithm will trap students into self-fulfilling restrictive prophecies. In response to this problem, the AI-based personalized textbook needs to add fairness constraints to ensure the introduction of diverse and challenging knowledge modules to actively break information barriers and “narrow the education gap”<sup>[9]</sup>. Thirdly, human subjectivity, as an irreplaceable cognitive insight, defends the key areas of education to achieve real change. Although artificial intelligence has reshaped the way of teaching and learning to some extent<sup>[10]</sup>, it should not damage the dominant position of teachers in teaching and the autonomy of learners in the learning process.

The ultimate ethical concern of artificial intelligence textbooks lies in its humility. Those systems that can recognize their own limitations really highlight the essence of educational technology. “Technology for good” means not only to serve learners, but also actively to achieve their own upgrading by cultivating human abilities that machines cannot replicate.

## **5. Conclusion**

Driven by artificial intelligence, personalized textbooks have become a typical representative of revolutionary potential in the field of education. They fundamentally promote the transformation of traditional printed textbooks to dynamic and intelligent learning resources. Such emerging educational tools have three key characteristics: generative, adaptive and evolvable. The research shows that this change is achieved through three interrelated layers: the knowledge map promotes the networked structure of content and accurately reflects the true understanding of learners' concepts; cognitive diagnosis technology can accurately match according to individual needs; human-machine collaboration creates an interactive response system that provides effective feedback. These factors together provide theoretical support and a practical path for the Development of AI-Based Personalized Textbooks. In the future, with the further evolution of artificial intelligence technology and the continuous accumulation of educational data, AI-based personalized

textbooks will play a greater role in solving the uneven distribution of educational resources and realizing individualized teaching, and become an important engine to promote the modernization of education.

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