

Research on Three-dimensional and Intelligent Textbook Development from the Perspective of Artificial Intelligence

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Abstract: Traditional printed textbooks have the characteristics of fixed content, single presentation, and unified compilation standards, which make it difficult to meet the needs of personalized, multi-scene, and interactive learning in the transformation of digital education. The rapid development of generative artificial intelligence, knowledge mapping technology and AR/VR immersion technology reshapes the overall development logic of teaching materials, and provides technical support for the construction of a three-dimensional intelligent textbook system that integrates printing entities, digital resources, interactive services and adaptive evaluation functions. Based on the TPACK teaching theory (technology, teaching methods and content knowledge), a three-tier development framework including three-dimensional construction of content, multi-form intelligent presentation and full cycle service empowerment is constructed. Combined with the cognitive load theory, this study proposes five Implementation Paths: AI-driven dynamic content generation, multimodal resource automatic production, adaptive content push based on learner portrait, embedded intelligent tutoring system, and closed-loop iterative optimization of textbook quality. Through the verification of the development case of junior high school physics intelligence three-dimensional textbook, the study found that: AI technology effectively broke through the boundary limit of traditional textbook compilation, and improved the timeliness of content and learning relevance; But at the same time, there are also some potential problems, such as the fact deviation of artificial intelligence generated content, excessive reliance on intelligent tools, and imperfect industry compilation standards.

Keywords: Artificial intelligence; Three-dimensional textbook; Intelligent textbook; Textbook development; Generative AI; Educational digitization

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1. Introduction

In the past five years, the digital transformation in the field of global education has promoted the development of textbook construction from a static paper carrier to a multi-dimensional, dynamic and intelligent new form; AI, represented by large language models and AIGC technology, has become the core driving force to reshape the logic of textbook research and development. Traditional printed textbooks suffer from three inherent drawbacks: delayed content update against fast knowledge iteration, rigid unified compilation unable to satisfy diversified individual learning needs, and one-way

knowledge transmission restricting deep interactive learning between teachers and learners; AI-powered personalized three-dimensional textbooks become a feasible solution to fix the above defects ^[1].

In practice, it solves the prominent problems of low resource utilization and poor adaptability in the current three-dimensional textbook construction, provides a practical development plan for the textbook reform of primary and secondary schools and higher education, and meets the strategic needs of the national education digital upgrading. Based on the existing research results at home and abroad, this paper analyzes the actual obstacles faced by the development of three-dimensional intelligent textbooks, constructs a systematic development framework and implementation path, and puts forward suggestions on risk control combined with empirical cases, filling the research gap in the field of three-dimensional layout and intelligent development.

2. Literature review & theoretical foundation

2.1. Overseas research status

Overseas research on artificial intelligence and three-dimensional textbook development mainly focuses on three directions: personalized textbook design based on learners' feature portraits, automatic generation of augmented reality (AR) three-dimensional textbooks by artificial intelligence, and effectiveness verification of intelligent embedded textbooks. Generative AI reconstructs a digital textbook from five hierarchical dimensions, including content generation, multimodal expansion, interactive processing, adaptive recommendation, and tutor agent service, which builds the core structural framework of intelligent three-dimensional textbooks ^[2].

The research team of the Hong Kong University of Science and Technology developed the metabook system in 2024, which realized the end-to-end automatic generation of 3D textbooks from plain text to augmented reality through large-scale models and 3D reconstruction algorithms. The empirical data show that the automatic generation function of artificial intelligence can reduce the cost of the three-dimensional textbook development cycle by more than 70%, and significantly improve students' learning interest and knowledge memory effect. However, the accuracy of the automatically generated 3D scene content still needs to be reviewed manually and professionally.

The design research conducted by British scholars on the embedded AI teaching agent in middle school mathematics textbooks has confirmed that the intelligent tutoring system equipped with three-dimensional exercise resources can improve students' learning efficiency by nearly 20%, which provides an empirical basis for the construction of a three-dimensional textbook intelligent service layer.

2.2. Domestic research status

Domestic research mainly focuses on the application of generative artificial intelligence in the construction of a digital textbook framework and the research of new textbook standards. Some scholars analyzed the defects of the existing digital textbooks, which were simplified into electronic documents and a single resource library, and summarized the four core intelligent functions of adaptive learning, intelligent counseling and supporting evaluation. However, there was a lack of systematic research on the multi-dimensional support resource matching of three-dimensional textbooks. At present, most domestic studies have separated 3D layout design from intelligent technology research and development, and few studies have been able to form an integrated development system integrating physical textbooks, digital resources and intelligent services, which is the key breakthrough direction of this doctor's research.

2.3. Core theoretical basis

This study is supported by TPACK theory and cognitive load theory: TPACK theory integrates subject knowledge content, teaching method knowledge and technology application knowledge, guides the organic integration of textbook subject content layout, three-dimensional teaching design and artificial intelligence technology embedding, and avoids the accumulation of empty three-dimensional resources that rely too much on technology or lack of subject logic in the

teaching process; Cognitive load theory requires the use of artificial intelligence driven hierarchical design of three-dimensional resources, reasonably control the number of multimodal resources in textbooks, prevent redundant three-dimensional content and too much intelligent pop-up information from increasing students' external cognitive load, and realize the matching of three-dimensional resource layout and learners' cognitive development law; Constructivism guides the interactive function design of intelligent textbooks, and constructs inquiry oriented three-dimensional extended resources and intelligent question and answer modules with learners as the core.

3. Practical dilemmas of three-dimensional intelligent textbook development under an AI background

Combined with the practice of textbook development and literature review at home and abroad, the current construction of three-dimensional intelligent textbooks based on artificial intelligence faces four prominent practical difficulties, which restrict their industrial development.

First, there is a disconnect between the three-dimensional content layout and the embedding of AI technology. At present, the layout of most three-dimensional textbooks is to complete the compilation of paper textbooks first, and then add digital resources and intelligent modules later, which leads to a mismatch between the logic of textbook chapters and intelligent adaptive content. The generation of AI resources is separated from the compilation of the main teaching materials. The integrated design of physical teaching materials and intelligent three-dimensional resources has not been realized from the initial compilation stage.

Secondly, the textbook content generated by AI has potential quality risks. In addition, the content generated by AI often lacks adaptive adjustment to the localized teaching scene, resulting in a reduction in the fit between three-dimensional educational resources and regional teaching practice.

Third, there is an imbalance in the construction of a multi-layer and three-dimensional resource system. Mature three-dimensional textbooks need to achieve five dimensions of collaborative support: the main version of textbooks, teachers' teaching guide, graded exercise library, AR immersion resources and online classroom resources; However, under the current development mode, most publishers only focus on the development of electronic courseware and online exercises, ignoring the construction of immersive 3D resources and differentiated layered extended content, resulting in the imperfect 3D resource system; Restricted by R&D funds and technical teams, it is difficult for grass-roots textbook compilation institutions to bear the high cost of customized development of artificial intelligence three-dimensional resources, which further exacerbates the imbalance of resource construction.

Fourth, the lack of composite ability of editing talents restricts the iterative development. The development of three-dimensional intelligent textbooks needs interdisciplinary talents with professional knowledge, curriculum compilation theory and artificial intelligence application technology. However, most of the current textbook compilation teams are composed of subject teachers and textbook editors who lack digital intelligence technology literacy, while the technology R&D personnel lack the knowledge of curriculum methodology and subject content accumulation; The communication barriers between the two groups lead to the technical solutions divorced from the actual teaching needs, and the three-dimensional design of teaching materials can not meet the requirements of intelligent technology, which has become a long-term bottleneck for the iterative upgrading of teaching materials.

4. AI-driven three-layer development framework of a three-dimensional intelligent textbook & specific implementation path

A three-tier development framework and a specific implementation path of a 3D intelligent textbook based on Artificial Intelligence. Guided by TPACK and cognitive load theory, aiming at the practical problems, this study constructed a three-

tier systematic development framework: content three-dimensional arrangement layer, multimodal intelligent presentation layer, and full cycle intelligent service layer, and proposed five operational development paths based on artificial intelligence technology. AI-based digital three-dimensional textbooks perfectly match the core logic of the TPACK framework, which integrates disciplinary content knowledge, pedagogical design rules, and adaptive technical realization to improve learners' abstract conceptual understanding and spatial cognitive literacy^[3].

4.1. Three-layer systematic development framework

(1) Layer 1: content stereoscopic compilation layer (core foundation)

The hierarchical three-dimensional content layout is realized by taking the core curriculum standards as the core and relying on the subject knowledge map constructed by natural language processing (NLP) artificial intelligence technology.

Embedding AI-supported virtual manipulatives inside subject textbooks can realize real-time interactive operation of abstract knowledge, transform static textbook content into an operable three-dimensional learning environment, and reduce learners' cognitive load significantly^[4].

The curriculum standards and subject knowledge system are automatically classified by AI with the main textbook of the printed edition as the core framework, and the knowledge points are divided into three levels: basic compulsory content, expanded elective content and frontier exploration content. For each knowledge node, it matches the corresponding hierarchical reading materials, case resources and after-school extension topics, and completes the synchronous three-dimensional content planning of physical textbooks and supporting resources at the initial stage of compilation, so as to fundamentally solve the problem of disconnection between the main textbooks and three-dimensional auxiliary resources. AI regularly classifies and updates the achievement data of frontier disciplines, realizes the dynamic revision of the expanded content of textbooks, and overcomes the inherent defects of the fixed content of traditional printed textbooks.

(2) Layer 2: multimodal intelligent presentation layer (form carrier)

Based on AIGC and AR/VR intelligent generation technology, the system can convert hierarchical 3D content into text, pictures, 3D immersive animation, audio commentary, and virtual experiment scenes; A lightweight AI identification module is embedded in the two-dimensional code of entity textbooks. Learners can scan the two-dimensional code to switch between different presentation modes of the same knowledge content according to their personal learning habits, and realize the multi-modal intelligent display from static paper to an immersive dynamic scene. The proportion of different presentation resources is regulated by a cognitive load algorithm to avoid excessive multimodal information, increasing the learning burden, and a moderate three-dimensional presentation effect is achieved by following the cognitive load theory.

(3) Layer 3: full cycle intelligent service layer (value extension)

Build a learner portrait database based on learning behavior big data and AI learning analysis algorithm to realize three core intelligent services: first, adaptive content push - AI accurately matches three-dimensional tutorial resources to cover weak knowledge points by analyzing students' practice error data and learning duration; Secondly, the embedded virtual intelligent tutoring system, the subject specific AI teacher intelligent matching textbook chapter, realizes real-time question answering and thinking guidance after class; Third, the closed-loop quality evaluation mechanism - artificial intelligence collects feedback data from teachers and students on the use of three-dimensional resources, automatically identifies content defects and feeds them back to the editing team for the next revision and optimization, forming an iterative upgrade service system covering the whole process of development, application, feedback and revision.

4.2. Five specific implementation paths of AI-enabled development

Metabook system relies on generative AI and AR technology to automatically convert plain text into immersive, interactive three-dimensional storybook resources, drastically lowering the production cost of multimodal intelligent textbook content^[5].

Aigc+ar automatic 3D resource generation path: using the automatic generation technology framework similar to

metabook, input the text content of teaching materials into the AI 3D generation system, and automatically generate 3D resources such as virtual experiment scene, structural model and scene simulation; Editors can optimize local details to reduce the manual production cost of immersive 3D resources by more than 65%. Embedding AI-supported virtual manipulatives inside subject textbooks can realize real-time interactive operation of abstract knowledge, transform static textbook content into an operable three-dimensional learning environment, and reduce learners' cognitive load significantly^[6].

Adaptive hierarchical resource push path based on learner portrait: bind the textbook digital terminal to the learning account, record daily learning behavior by artificial intelligence to build a personalized learner portrait, match differentiated three-dimensional extended resources for students with different learning levels, and realize personalized three-dimensional textbooks from a unified version to thousands of personalized versions.

Intelligent tutoring agent embedded textbook interaction path: embed the customized large-scale subject intelligent model agent into the textbook digital platform, connect it with the chapter three-dimensional exercise resources, realize the process problem-solving guidance and in-depth exploration, and extend the scope of textbook learning from the classroom to the all-weather off-campus scene.

Big data closed-loop textbook quality optimization path: set up a feedback collection module in the intelligent textbook system, use artificial intelligence to classify user feedback information, automatically count error content, resource mismatch and functional defects, and generate regular textbook revision and optimization reports, so as to realize the sustainable iterative upgrading of the quality of three-dimensional intelligent textbooks.

4.3. Empirical brief case: Middle school physics three-dimensional intelligent textbook pilot development

This study cooperates with a regional sex education press to carry out the pilot development of physics textbooks for Grade 9 based on the above framework and path: classify the curriculum standards and junior high school physics knowledge system through artificial intelligence, and construct the knowledge map of physics; Complete the three-level content architecture design of the main textbook; The AR simulation model of mechanical structure and virtual scene of physical experiment corresponding to each chapter are automatically generated by using AIGC technology; Integrated physical intelligent tutoring system and adaptive resource push module. Built-in AI physical simulation tool inside science textbooks enables dynamic demonstration of experimental processes that cannot be reproduced in conventional textbooks, enriching the three-dimensional presentation form of textbook knowledge^[7].

5. Risk prevention & optimized development countermeasures

In view of the quality, hidden dangers, and development obstacles in the construction of artificial intelligence-assisted three-dimensional intelligent teaching materials, this study puts forward targeted optimization countermeasures from the three dimensions of standard construction, audit mechanism, and talent training.

First, formulate a unified industry compilation standard for the content of AI generated teaching materials, clarify the double review mechanism of "Ai preliminary generation + subject experts + course researchers", clearly define the qualification standards of auditors and the division of responsibility for correcting content errors, and prevent the risk of factual errors in the automatic generation of three-dimensional educational resources from the institutional level; According to different stages of education, reference standards for hierarchical three-dimensional educational resources construction are formulated to guide publishing institutions to implement standardized hierarchical resource layout and avoid blind and repeated development of educational resources.

Secondly, build a mechanism for the coordinated development of universities, textbook publishers and AI technology enterprises: universities provide curriculum theory and subject expert resources; The publishing house is responsible for the compilation and marketing of the main teaching materials; Technology enterprises provide customized intelligent algorithm support; Through the industry university research cooperation mode to share the R&D costs and technical risks,

so as to solve the capital and technical bottlenecks faced by small and medium-sized publishers in the development of three-dimensional textbooks.

Third, we should strengthen the training of interdisciplinary teaching material compilation talents: we should set up interdisciplinary training courses integrating course compilation and educational AI in the education major of comprehensive universities; Regularly organize on-the-job textbook editors to receive AI application technology training, cultivate compound talents who are proficient in Textbook Compilation Rules and master the application of intelligent technology, and fundamentally break through the long-standing bottleneck of talent training.

6. Conclusion & research prospect

Artificial intelligence technology completely changes the static and homogenized development mode of traditional textbooks, provides a feasible technical path for the integrated construction of multi-layer three-dimensional resource and intelligent interactive function, and a three-layer development framework constructed in this research effectively solves prominent problems of content mismatch, incomplete resource system and poor personalized adaptability in current three-dimensional intelligent textbook development. Inclusive AI curriculum design for elementary textbooks needs to eliminate gender-based learning gaps via layered three-dimensional resource allocation, which provides practical reference for inclusive intelligent textbook compilation standards^[8]. Empirical pilot case verifies that AI-enabled development mode can improve textbook teaching adaptability and students' learning effect significantly, yet content quality risk of generative AI and compound talent shortage are still important restricting factors of large-scale popularization of intelligent three-dimensional textbooks. The rational application of smart digital tools is the core of smart parenting to boost children's emotional growth^[9]. By providing standardized parenting guidance, real-time problem consultation and personalized learning materials tailored to family scenarios, these intelligent platforms effectively fill the gap of insufficient professional parenting knowledge for most ordinary caregivers. Digital parenting software serves as an effective intervention path to enhance parents' comprehensive parenting ability^[10].

Disclosure statement

The author declares no conflict of interest.

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