The Empowerment Path of Smart Textbooks Research on the Double-Helix Learning Model Based on Digital Context and Action Reflection

Xiaotong Wang [a*], Xinyi Lv [b], Dianyu Wang [c]

Naval Aeronautical University Qingdao Campus, Qingdao City, Shandong Province 266041, China

*a315146470@qq.com; blv_xinyi@163.com; c269899143@qq.com

Abstract. With the deepening of digital education, smart textbooks, as the core carrier connecting digital technology and teaching practice, are facing practical difficulties such as "situational disconnection and lack of reflection". This study is based on situational cognition theory, action learning theory, and reflective practice theory, integrating "double helix" structural thinking to construct a "digital situational action reflection" Double-Helix learning model. It has a dual core of "situational cognitive chain" (external drive) and "reflective reconstruction chain" (internal drive), and explains the internal process of learners' cognitive ability level leap through the spiral interaction of action and reflection in digital contexts through the four order cognitive development mechanism of "embodied activation action concretization multidimensional reflection transfer reconstruction". The study further proposed a "three-level and four-dimensional" design framework, transforming theoretical models into actionable practical paths. It takes process driven as the main line and structure driven as the criterion, systematically covering three levels from content reconstruction, technical implementation to teaching application, providing design solutions for how smart textbooks can support the integrated learning experience. It provide a new theoretical paradigm and practical guidance for solving the design bottleneck of current smart textbooks, and its effectiveness needs further empirical testing.

Keywords: Digital context; Action reflection; Double-Helix learning model; Smart textbooks; Cognitive transition

1 Introduction

Global education is shifting toward intelligent learning ecosystems. Aligning with the vision of UNESCO and the Education Modernization 2035 initiative of China, smart textbooks have emerged as key vehicles for educational transformation. Despite offering multimodal representation and personalized adaptation, the implementation of these textbooks reveals three developmental dilemmas stemming from a disconnect with the laws of learning science:

Contextual pseudo-immersion: Implementations remain at the superficial level of multimedia integration. They fail to construct authentic contexts, leading to cognitive

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fragmentation and inert knowledge[1].

Formalized reflection: Designs prioritize knowledge delivery over deep reflection, preventing the internalization of action experiences into transferable cognitive strategies.

Low-level learning objectives: Goals anchor on basic memorization, lacking systematic support for the cultivation of higher-order competencies and critical thinking[2].

Effective learning requires the interaction of external contextual stimuli and internal cognitive restructuring. The theory of situated cognition posits that knowledge is a tool constructed within specific situations. The theory of reflective practice emphasizes reflection as the bridge connecting action and cognition. The theory of action learning argues that genuine competence originates from solving complex problems through cyclical feedback. Integrating these theories, this study explores how to organically combine external contextual engagement with internal reflective reconstruction. The objective is to build an innovative learning model tailored to smart textbooks, thereby propelling the qualitative transformation of smart education.

2 Construction of the Theoretical Framework

The transformation of learning in the digital age relies on the dynamic alignment between the provision of external contexts and the development of internal cognition. Grounded in a dual-dimensional logic of external drive and internal construction, this study integrates three foundational theories to establish the theoretical grounding for the Double-Helix learning model.

2.1 Situated Cognition Theory: The Core Foundation for Digital Context

The theory of situated cognition redefines knowledge as a cognitive tool constructed within specific physical and sociocultural contexts, countering the traditional view of knowledge as abstract symbols. This theory operates across three interrelated dimensions:

The situatedness of knowledge: Knowledge must remain connected to its generative context to prevent it from becoming inert and difficult to retrieve.

The practicality of learning: Genuine understanding emerges through participation in authentic activities and communities of practice.

The embodiment of cognition: Multisensory, embodied experiences are necessary to trigger deep cognitive processing[3].

Consequently, a digital context is defined as a virtual environment that simulates real-world tasks to enable cognitive development through embodied interaction. This serves to evoke cognitive conflict and provide the external drive of the model.

2.2 Action Learning Theory: Practical Support for Concrete Action

While situated cognition addresses the environment of learning, the theory of action learning focuses on the mechanism of execution. Initiated by the work of Reg Revans, this theory posits that learning emerges from acting to solve real problems. The essence of this theory lies in two core mechanisms:

Problem orientation: Real, complex problems compel the mobilization of prior knowledge and the construction of new understanding.

The action cycle: Learning follows a closed-loop sequence: the framing of problems, the design of solutions, the implementation of actions, and the feedback of results[4].

This framework provides methodological guidance for action attempts and result feedback, ensuring that learner interactions generate timely, actionable data for subsequent reflection.

2.3 Reflective Practice Theory: Cognitive Assurance for Reflective Reconstruction

The transformation of experience into competence necessitates reflection. The theory of reflective practice, established by the work of Donald Schön, distinguishes between immediate reflection-in-action and retrospective reflection-on-action. Scaffolded by digital tools to reduce cognitive load, this cognitive process operates through metacognitive monitoring, the triggering of cognitive conflict, and the reconstruction of meaning. The resulting reflective reconstruction chain functions as the internal driving engine of the entire learning model.

2.4 The Double-Helix Structure: Creative Cross-Disciplinary Integration

Drawing inspiration from biology, the model employs the cross-disciplinary metaphor of a DNA double helix[5]. The situated cognition chain (representing the external drive) and the reflective reconstruction chain (representing the internal drive) act as two intertwined strands.

These chains do not operate independently; instead, contexts trigger reflection, and reflection refines contextual engagement. This continuous interaction of stimuli, feedback, and adjustment generates an upward spiraling trajectory, facilitating hierarchical leaps in the cognitive capacity of learners.

3 The "Digital Context-Action Reflection" Double-Helix Learning Model

Building upon the theoretical framework, this study proposes the Double-Helix learning model of digital context and action reflection. This model reconceptualizes the learning process as a spiraling, co-evolving dynamic between the external drive of the situated cognition chain and the internal drive of the reflective reconstruction chain. These chains interact dynamically through a four-stage mechanism, forming a closed-loop ecosystem that drives hierarchical cognitive advancement.

3.1 Overall Model Architecture: The Four-Stage Cognitive Development Mechanism

The architecture of the model takes the form of an ascending spiral, mapping the cognitive progression of learners across four evolutionary stages. These stages cycle and ascend through double-helix interactions, as illustrated in Table 1.

Table 1. Detailed Description of the Four-Stage Cognitive Development Mechanism

Cognitive Stage	Cognitive Objective	Implementation Pathway	Supporting Conditions
Embodied Activation	Establish connections between context and prior experience to trigger cognitive conflict.	1.Present authentic digital scenarios (e.g., "Ammunition Loading Plan Design"); 2.Introduce cognitive conflict points (e.g., "There are two types of bombs—one with a shell and one with a fuze—can they be loaded together?"); 3.Guide learners to connect with prior learning experiences (e.g., "When storing ammunition, there are specific co-storage requirements; what about during transportation?").	1.Multimodal contextual resources (e.g., videos, AR simulations); 2.Cognitive conflict design templates; 3.Guiding questions for connecting prior experiences.
Concrete Action	Complete contextual tasks through hands-on operations to obtain experiential feedback.	1.Break down the task into sequential subtasks (e.g., "Analyze the task→Clarify requirements→Calculate data→Develop a plan"); 2.Provide interactive tools (e.g., data calculation spreadsheets, loading simulation platforms); 3.Deliver real-time feedback on actions (e.g., "Shells and bombs can be stored together, but fuzes must be stored separately").	1.Scaffolded task design framework; 2.Interactive operational tools; 3.Real-time feedback system.
Multidimensional Reflection	Review actions from multiple dimensions to diagnose cognitive gaps.	1.Design tiered reflection questions: -Basic level: "Which subtasks have I completed?" -Intermediate level: "Why must shells be oriented vertically (axially perpendicular)?" -Advanced level: "If the quantity and types of ammunition increase, how should I adjust my strategy?" 2.Provide thinking visualization tools (e.g., reflection matrices, cause-and-effect analysis diagrams); 3.Facilitate peer reflection and discussion (e.g., small-group sharing of design strategies and rationales).	1.Tiered reflection question bank; 2.Thinking visualization templates; 3.Collaborative reflection platform.
Transfer and Reconstruction	Transfer strategies to new contexts to establish stable cognitive structures.	1.Design variant contextual tasks (e.g., changing from "railcar loading" to "truck loading," with an added requirement of "staggered stacking at the rear"); 2.Guide strategy transfer (e.g., "Apply the 'staggered stacking' model to analyze new variables"); 3.Summarize generalizable cognitive strategies (e.g., "Ammunition loading design = orientation + stacking method + variable adjustment").	1.Contextual variant task bank; 2.Strategy transfer guidance tools; 3.Strategy synthesis templates.

3.1.1 Bottom Layer: Embodied Activation Layer.

As the starting point of learning, digital contexts act as external drivers. Utilizing multimodal resources, authentic scenarios and cognitive conflict points are presented. Learners connect contexts with prior experiences through embodied interactions[6]. The objective is to trigger cognitive conflict and awaken curiosity, supported by guiding questions.

3.1.2 Middle Layer: Concrete Action Layer.

This stage serves as a bridge between knowing and doing. Tasks are broken down into sequential subtasks. Learners complete hands-on operations using interactive tools to receive real-time experiential feedback. Through the cycle of action attempts and result feedback, abstract knowledge transforms into perceptible action experiences.

3.1.3 Upper Layer: Multidimensional Reflection Layer.

In this phase, experience transforms into wisdom. Learners review actions across basic, intermediate, and advanced dimensions to diagnose cognitive gaps. Utilizing visualization tools and peer discussion, this stage enhances metacognitive abilities.

3.1.4 Top Layer: Transfer and Reconstruction Layer.

Representing the highest stage of cognitive development, learners transfer strategies to variant contextual tasks to establish stable cognitive structures. Fragmented experiences are integrated into universally applicable problem-solving schemas for application in future complex scenarios[7].

3.2 Situated Cognition Chain (External Drive)

The external driving system guides learners from perception to action via digital contexts. It consists of four interlinked stages:

Context Perception: Learners enter digital contexts via multimodal resources to understand task backgrounds and activate embodied cognition.

Task Decomposition: Complex real-world problems are broken down into actionable subtasks, training logical analysis skills.

Action Attempt: Learners execute specific operations within the digital environment[8]. The system records and evaluates these actions.

Result Feedback: The system provides immediate, multidimensional feedback, including diagnostic information and resource support.

3.3 Reflective Reconstruction Chain (Internal Drive)

The internal driving system guides learners to process action experiences and reconstruct cognitive structures using structured reflective tools. It mirrors the external chain through four stages:

Experience Organization: Learners review the action process using reflective logs, recording key decisions and outcomes to organize chaotic trajectories into orderly narratives.

Problem Diagnosis: Guided questions assist learners in analyzing difficulties or errors, cultivating self-diagnostic abilities.

Strategy Optimization: Learners develop improvement strategies based on system feedback, peer suggestions, or teacher guidance.

Cognitive Reconstruction: Optimized strategies are internalized into the cognitive structure of the learner, forming stable thinking models for future challenges[9].

3.4 Double-Helix Interaction Relationship

The chains achieve dynamic coupling through bidirectional empowerment at four interaction nodes, jointly promoting the spiral ascent of cognition:

Context Perception and Experience Organization: Contextual clues trigger the recall of past experiences, while organized experiences enhance the capture of current contextual information.

Task Decomposition and Problem Diagnosis: Obstacles encountered in task decomposition become the focus of problem diagnosis; diagnostic findings subsequently guide more effective future task decomposition.

Action Attempt and Strategy Optimization: The results of action attempts drive strategy optimization, prompting the creation of new strategies upon failure.

Result Feedback and Cognitive Reconstruction: System feedback serves as a critical scaffold for cognitive reconstruction, helping learners systematize insights into stable cognitive structures.

Each complete interaction cycle signifies a cognitive leap, automatically pushing the model into higher levels of contextual complexity and reflective depth. This spiraling trajectory maintains the learning process within the zone of proximal development, ensuring continuous cognitive growth.

4 Application Design of the Double-Helix Learning Model in Smart Textbooks

The vitality of a theoretical model lies in its ability to guide practice. To transform the Double-Helix model into an actionable blueprint for smart textbooks, this study proposes a systematic design framework of "Three Levels and Four Dimensions". This framework employs a process-driven approach to ensure a complete implementation loop and a structure-driven approach to ensure scientific adaptation.

4.1 Design Principles

To ensure the deep adaptation of smart textbooks to the Double-Helix model, three core principles must be followed to avoid disconnecting technology from cognitive laws.

4.1.1 Dynamic Coupling Principle.
The design must serve the dynamic interaction of the model. The content, technical, and application levels must couple with the four dimensions to support the coordination of the situational cognition chain and the reflective reconstruction chain. A lack of integration at any level may fracture the structure, degenerating the process into linear learning.

4.1.2 Principle of Cognitive Advancement.
Learning Paths Should Follow A Spiral progression: embodied activation → concrete action → multidimensional reflection → transfer and reconstruction. Complexity must increase systematically to ensure substantial improvements in cognitive ability within each cycle, avoiding low-level repetition or excessive leaps in difficulty.

4.1.3 Principle of Personalized Adaptation.
Textbooks must establish mechanisms for continuous data collection to track learner actions and reflection depth. The system should dynamically adjust learning paths—providing remedial support for difficulties or challenging tasks for advanced learners—to achieve true learner-centered instruction.

4.2 Process-Driven: Phase Transformation Across Three Levels

Taking the cycle of "situation trigger–reflective reconstruction" as the main line, a collaborative transformation mechanism is constructed across content, technical, and application levels.

4.2.1 Content Layer: Reconstruction of Knowledge Structure.
This layer transforms linear knowledge systems into dynamic networks supporting Double-Helix learning. It constructs a three-level structure:

Declarative Knowledge (Representational Experience): Concepts and principles are embedded in digital contexts (e.g., videos or models) to transform abstract ideas into perceptible experiences.

Process Knowledge (Skill Structure): Complex skills are decomposed into action task chains of subtasks, allowing learners to master workflows through cycles of "learning by doing".

Metacognitive Knowledge (Cognitive Strategization): Reflective scaffolding (e.g., guided questions, mind maps) is embedded to guide self-regulation and strategy formulation.

Finally, knowledge mapping visualizes these associations to form a scalable network.

4.2.2 Technical Level: Transformation of Cognitive Laws.
This layer acts as the engine of the model. Multimodal resource integration (VR/AR, simulations) creates immersive environments to drive the situational cognition chain.

Concurrently, intelligent feedback and learning analysis systems mine behavioral data to provide process feedback, diagnose learning difficulties, and push personalized resources, driving the reflective reconstruction chain[10].

4.2.3 Application Layer: Closed Loop of Teaching Practice.

The application layer focuses on the landing of the Double-Helix model in teachThis layer ensures the model supports practical teaching through a five-stage process:

Preview Exploration: Trailers or questions stimulate curiosity before class.

Activation and Sharing: Teachers use cases to introduce objectives and organize discussions to activate prior knowledge.

Multiple Learning: Students engage in action attempts and strategy optimization within digital contexts, supported by teacher guidance.

Assessment and Summary: Comprehensive tasks test effectiveness, followed by teacher summaries based on data.

Extended Reflection: Expansion tasks guide cross-situational transfer, and systematic reports reconstruct the knowledge of the unit.

4.3 Structure-Driven: Element Configuration Across Four Dimensions

To ensure scientific and educational unity, core elements are configured across four dimensions:

The Dynamic Dimension: Smart textbooks must evolve. Mechanisms for content updates must absorb industry trends, while data analysis optimizes task design to keep pace with learning needs.

The Adaptability Dimension: The system must dynamically adjust situational complexity and feedback detail based on the profile of the learner, realizing personalized instruction.

The Immersion Dimension: High-fidelity simulations and natural interactions must be employed to create a "flow" state, providing strong situational pull for action and reflection.

The Generative Dimension: Textbooks should function as platforms for knowledge creation. Open tasks and co-creation tools encourage learners to contribute content, which enriches the textbook ecosystem after review[11].

5 Conclusion and Reflection

Addressing the challenges of disconnected contexts and a lack of reflection in smart textbooks, this study constructs the Double-Helix Learning Model of Digital Context and Action Reflection. By integrating situated cognition, action learning, and reflective practice, the model elucidates a four-stage cognitive mechanism: Embodied Activation, Concrete Action, Multidimensional Reflection, and Transfer and Reconstruction. The proposed "Three-Level, Four-Dimension" framework translates this theory into actionable pathways for content, technology, and application.

Future research will focus on two directions:

Prototype Development: Developing prototypes to empirically validate the impact of the model on problem-solving and innovative competencies.

Technological Integration: Exploring generative AI to realize dynamic context generation and adaptive scaffolding, advancing smart education toward higher intelligence.

References

1. Siti Khadijah Mohamad & Zaidatun Tasir.(2026).Learning performance pathways based on reflective thinking skills and feedback through educational blogging.Interactive Learning Environments,34(1),119-143. https://doi.org/10.1080/10494820.2025.2494154.
2. Honglei Chen,Yu Liu,Fangong Kong,Weikun Jiang,Guijuan Wei,Huimei Wang... & Xin Zhao.(2025).Advancing Smart Education: Role Analysis of Digital Textbooks and Exploration of Classroom Construction Pathways.Creative Education,16(12),2130-2139. https://doi.org/10.4236/CE.2025.1612128.
3. Pyoung WonKim.(2024).Fog Computing for Artificial Intelligence Digital Textbooks: Educational Scaffolding and Security and Privacy Challenges.Expert Systems,42(2),e13801-e13801. https://doi.org/10.1111/EXSY.13801.
4. Li Li,Ren Jian & Li Kun.(2023).Construction and Practice of Smart Textbooks for Vocational Education Courses.SHS Web of Conferences,157, https://doi.org/10.1051/SHSCONF/202315702006.
5. Chen Ye.(2021).Antecedents and Consequences of Perceived Fit of an Interactive Digital Textbook.Journal of Information Systems Education,32(1),27-39.
6. Korea National University of Education, Cheongju, chungbuk, South Korea.(2020).Developing smart math textbook in Korea.Afrika Matematika,31(2),143-153. https://doi.org/10.1007/s13370-019-00732-w.
7. Najeh Rajeh Ibrahim Alsalhi.(2020).The representation of multiple intelligences in the science textbook and the extent of awareness of science teachers at the intermediate stage of this theory.Thinking Skills and Creativity,38,100706-. https://doi.org/10.1016/j.tsc.2020.100706.
8. KeunYoung Ahn & YounJin Lee.(2017).The Colors of Digital Textbook UI Design Elements for Smart Learning.AIC 2017 Jeju,
9. Naomi Weiner-Levy.(2008).Universities as a meeting point with new academic knowledge, society and culture: cognitive and emotional transitions during higher education.Cambridge Journal of Education,38(4),497-512. https://doi.org/10.1080/03057640802484740.
10. S S Khromov.(2014).Classic Paper Russian Textbooks for Foreign Students — electronic textbooks — smart textbooks.Russian Language Studies,0(1),31-36.
11. Jeongrang Kim,Youngshin Kim,Sungwan Han,Soohwan Kim & Bokyung Kye.(2014).Development of Tools to Evaluate the Effectiveness of Smart Education and Digital Textbooks.Journal of the Korean Association of Information Education,18(2),357-370. https://doi.org/10.14352/jkaie.2014.18.2.357.