World Journal of Educational Studies
Print ISSN: 2959-9989
Online ISSN: 2959-9997
DOI: https://doi.org/10.61784/wjes3225

THE THREE-DIMENSIONAL GENERATION MECHANISM OF DIGITAL TEXTBOOKS FOR VOCATIONAL EDUCATION FROM THE PERSPECTIVE OF EMBODIED COGNITION

Min Wang[1*], ChunWei Ma[2]
[1]*Shanghai Technical Institute of Electronics & Information, Shanghai 201400, China.*
[2]*Shanghai University of Engineering Science, Shanghai 201600, China.*
[*]*Corresponding Author: Min Wang*

Abstract: The building of digital textbooks for vocational education focuses on the technical presentation currently, while limited attention is paid to bodily engagement in skill acquisition. Based on embodied cognition theory, this paper treats the digital textbooks as an environment that provides perception and interaction, and this paper proposes a three-dimensional generation mechanism: perceptual situation, cognitive transformation, and motivational regulation. Perceptual situation focuses on whether the environment can respond to the learner immediately and forms a cycle of exploration and feedback; cognitive transformation promotes situated ability through safe trial and error and self-reflection, while motivational regulation offers suggestions according to the learner's state and allows the learner to make decisions. The three-dimensional mechanisms interact with each other, forming the cycle of perception → cognition → motivation → perception. This paper also takes safety wiring as an example and demonstrates how the three-dimensional mechanism works, offering a theoretical basis for the transformation of digital textbooks into cognitive ecosystems.
Keywords: Embodied cognition; Vocational education; Digital textbooks; Three-dimensional generation mechanism; Skill acquisition

1 INTRODUCTION

In April 2025, the Ministry of Education published the Opinions on Accelerating the Digitalization of Education, which called for promoting intelligentization in an all-round way [1]. This showed that digitalization had entered a new stage, with the focus shifting from technology to how technology could change learning. Qi Zhanyong et al. pointed out that the transformation can drive systemic reform in education by reconfiguring the elements of education and optimizing resources [2]. However, current research focuses on how the education system changes, with far less attention paid to changes in learners' cognition.

The digital textbooks are highly interactive and are not limited by time and space. Therefore, they become an important tool for rebuilding knowledge broadcast and method of study [3]. Vocational education and industry development have higher requirements for digital textbooks, which require not only to transfer knowledge but also to let the body join in the process of skill study, forming the sense of a real situation. However, digital textbooks have the problem of paying more attention to technology with less sense of users. The important problem of technology first is that skill acquisition is simplified to symbol transfer and action simulation; embodiment and environment simulation are lower, the skill that students acquire is hard to transfer to real work situations, and the evaluation system is also hard to suit the process of vocational education. Researchers studied the problem. Wei Miao et al. point out that embodiment should be realized in the design, development and application of digital textbooks [4]. Qin Guofeng et al. point out that virtual simulation is taken as a teaching method and that the framework of teaching design is built under an embodied perspective [5]. Wei Yue et al. emphasized that digital textbooks should transfer from static knowledge to a dynamic knowledge platform [6]. Feng Chaojun et al. point out that the framework should be built from organization management and technology standards [7]. Chen Weidong et al. emphasized the rebuilding of intelligent technology [8].

Though the above studies offered different perspectives for the development of digital textbooks, most of them focus on the teaching method and process of development, lacking a systematic scheme of how the textbooks support the interaction between body and environment dynamically. Therefore, this paper takes the digital textbooks as the dynamic cognitive environment, which promotes the transfer from textbooks to a cognitive ecosystem by the environment creating, process supporting, and motivational regulation.

2 THEORY BUILDING OF DIGITAL TEXTBOOKS FOR VOCATIONAL EDUCATION UNDER EMBODIED COGNITION THEORY

2.1 The Development of Embodied Cognition Theory

Embodied cognition theory starts from Merleau-Ponty's phenomenology of perception. Different from Descartes's mind and body theory, its core is to confirm the main position of body in cognition: it takes cognition as the process of

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interaction between body and environment rather than the symbol calculation in the brain. Heidegger extends the phenomenology to the ontological level, pointing out that comprehension appears between the practice of body and environment. In the 1980s, cognitive psychology defined cognition as the process of body movement to form meaning, not the passive presentation of the outer world. Li Hengwei et al. point out that cognitive science is in the process of reform, emphasizing the constitutive role of body in cognition process [9]. Ye Haosheng further identifies the core characteristics of embodied cognition: embodiment, embeddedness, extension, and enaction [10]. With the development of VR, AR, embodied cognition theory passed three stages: concept advocacy, technology integration, and ecological development, forming the body-technology-environment cooperation embodied study ecosystem. This theory tells us that the design logic of digital textbooks should change from how to show knowledge to creating an environment in which multiple senses are engaged, supporting action exploration, and promoting the formation of cognition from the interaction of body and environment.

2.2 Why Vocational Education Needs an Embodied Turn

Vocational education has the character of taking practice as orientation, which sets high requirements for body engagement and situated experience in textbook development. The core of embodied cognition theory is to form cognition through the dynamic interaction between body and environment. The building of digital textbooks and embodied cognition match closely, so it is necessary to bring embodied cognition theory into the building process of digital textbooks. This is mainly reflected in the following three aspects:

First, skill acquisition has a bodily feature. Liu Ya et al. researched the teaching of vocational dance and found that dance cognition is an integrated experience formed through the direct participation of the body in space, time, and rhythm [11]. Zhao Chunyang et al. transform situated learning involving bodily participation into students' structured knowledge by letting students feel changes in the weight of a patient's drainage fluid [12]. This bodily feature of skill acquisition is consistent with the cognition obtained through the body's interaction with a situation in embodied cognition theory. Through this bodily feature, skills and professional competence are formed and developed.

Second, digital technology makes embodiment possible. Digital technology offers key support for the realization of embodied cognition. Pan Haisheng et al. reveal how digital technology empowers the teaching space of vocational education from the perspective of space production theory, pointing out that digital technology provides environmental support by reconfiguring the interactive relations among physical space, virtual space and social space [13]. But space reconfiguration is only an external condition; the embodiment of digital textbooks also needs an internal transformation of cognitive mechanisms. Wei Miao et al. examine online learning environments and point out that digital learning spaces are in a transitional stage from disembodied to embodied, where bodily participation and situational embeddedness play a key role in reshaping the learning experience [14]. Zhang Pengqian et al. point out that embodied intelligence technology can make cognition situated, and further reshape the underlying logic of education [15]. VR and AR can create highly realistic virtual training scenes; students achieve embodied interaction through wearable devices, gaining operating experience close to real settings and immediate feedback. Combined with AI to analyse students' operating behaviour, personalized guidance can be provided. Digital textbooks, empowered by digital technology, transfer abstract theory into bodily experience that is perceptible, operable and interactive.

Third, the shift from disembodied to embodied. Technology makes embodiment possible, but current digital textbooks are still limited by disembodied cognition. Traditional digital textbooks based on cognitive load theory are focused on the structured and modular presentation of information to reduce extraneous load. But this decontextualized content organization strips away the bodily engagement required by skill acquisition, which simplifies skill acquisition to symbol transfer and action simulation, hard to reach the core of how the body constructs cognition, so the skills learned in a virtual environment are hard to transfer to real work settings. Also, the evaluation system relies on outcomes, which makes the process-level performances that can reflect thinking, such as the steadiness of a hand and the reasonableness of an inspection sequence, easily overlooked. Individual differences between learners can be ignored. The move from disembodied to embodied would allow digital textbooks to be driven by cognition rather than by technology.

2.3 Three Fundamental Changes of Digital Textbooks

Traditional textbooks take knowledge transfer as the core and give little thought to bodily participation and situated experience. Learners are thus left in a state of passively receiving information, with the hand and the brain kept apart. Current digital textbooks transform the carrier of cognition from static text to dynamic situations; learners obtain professional competence through the real-time interaction between body and virtual environment. The digital textbook thus changes from a tool for transmitting knowledge into an environment for cognitive practice. This change shows in three aspects:

First, the subject of cognition changes from a disembodied mind to the body itself. Li Yanping et al. point out that vocational education in the digital-intelligent era should build the subject position of the body in skill acquisition [16]. At this point, the textbook is no longer merely to transfer symbolic knowledge, and the learner is no longer an abstract information processor. The design of digital textbooks focuses on how the body experiences it. Second, the interaction mechanism changes from one-way transmission to dynamic coupling. Traditional textbooks only output and learners receive; embodied textbooks emphasize the coupling process of action to feedback to perception to adjustment. The environment that the textbook creates can give real-time, multidimensional feedback to the learner's bodily actions, and

then the learner adjusts their actions to form cognition within this closed loop. For example, in the process of disassembling an aircraft engine, the learner adjusts the angle and force of a torque wrench with a force-feedback glove; the virtual situation feeds back resistance and part positions in real time, and the learner completes the embodied experience from abstract operating rules to body–tool–situation through the perception–action loop. Third, the value orientation changes from knowledge copying to practice generation. The value orientation of traditional textbooks is to copy existing knowledge efficiently, while that of the embodied textbook is to form situated, personalized practical wisdom through participation in practice. It concerns what the learner can do and how to judge and act in the complicated situation. The evaluation standard shifts from reproducing a standard answer to examining the ability to solve real-world problems.

The shifts above reveal the transition of digital textbooks from disembodied to embodied. The subject of cognition, the interaction mechanism, and the value orientation constitute the core of this transition, and technological empowerment offers the conditions that make it possible, turning digital textbooks from static tools for presenting content into constructors of a dynamic cognitive ecosystem.

3 RESEARCH METHODOLOGY AND DESIGN VALIDATION

Design-based research (DBR) methodology is a cycle of systematic design, implementation and reflection in real settings, integrating theory building with practice improvement and generating transferable knowledge through intervention design and iterative refinement. DBR includes four stages: the analysis and exploration stage identifies practical problems and builds a theoretical framework; the design and development stage constructs an initial solution; the implementation stage tests the solution in real settings and collects feedback; the reflection stage revises the design and develops the theory further. This study will construct the three-dimensional generation mechanism, develop a design scheme for safety wiring, and validate the reasonableness of the design through expert formative evaluation. Classroom implementation and validation of effects will be done in later research.

Formative evaluation aims to diagnose defects in a design and optimize the scheme. Two aviation maintenance experts, three vocational education teachers, and one senior technician were invited to collect expert feedback. According to the experts, the situation design of the three-dimensional mechanism was rated highly in recovering operating feel and embedding safety rules, but the technician suggested broadening the tolerance of the trial-and-error space so as to keep more room for exploration. The experts think that a self-confirmation stage should be added to the motivational regulation mechanism. Based on the expert feedback, this paper designed a layered tolerance mechanism and added learner decision-making, with the system giving suggestions only and not making decisions. Experimental work will be designed later to validate the real effects of measures such as skill transfer.

4 THREE-DIMENSIONAL GENERATION MECHANISM OF DIGITAL TEXTBOOK

Embodied cognition theory shows that skills are acquired in the process of interacting with the environment while the body is embedded in a situation, so the textbook should not be a static carrier of predefined content but a dynamic process that evolves together with the learner, continually generating new meanings and abilities in real-time interaction. The three fundamental shifts of the textbook need concrete operating mechanisms to take effect. This paper constructs a three-dimensional mechanism of perceptual situation, cognitive transformation and motivational regulation, sets out its form of organization and implementation, and offers a theoretical framework for the transition of digital textbooks from an electronic page to a cognitive ecosystem.

4.1 The Perceptual Situation Generation Mechanism

Perception and situation are not separated in the skill acquisition process; digital textbooks should connect the learner's exploratory actions with the situation's responsive feedback. The core of the perceptual situation generation mechanism is to create a responsive situation that the body can perceive. This situation should support the body's multi-sensory perception and should also return feedback in time to keep interaction smooth. To realize this mechanism, visual, auditory, tactile and force information should be dynamically combined according to the task; then the virtual objects should respond to the learner's actions in ways that obey physical laws; finally, action and feedback should be closely linked, so that the learner's exploratory actions can immediately trigger the situation's response, and the response can in turn adjust the learner's perception in real time. The key point is to grasp the tolerance range: rules involving the safety bottom line must be enforced strictly, and any violation should be blocked immediately with the consequences shown; for behaviour concerning skill optimization, attempts and adjustments within a certain range should be allowed, which avoids depriving learners of trial-and-error opportunities because of excessive error prevention, and also prevents wrong operating habits from forming because of too much tolerance.

4.2 The Cognitive Transformation Generation Mechanism

Skills are not prearranged operations; they are the practical ability that learners form in the process of safe trial and error, accurate feedback and self-reflection. The cognitive transformation generation mechanism is to create learning conditions that support knowledge generation, for example, offering a controllable trial space and marking key points, which makes skills transfer from procedural knowledge to situated ability. The trial space makes the learner obtain

understanding in safety. The feedback mechanism requires accuracy, offering hints at key points and reinforcing the body's memory of correct operations. Reflection supports process reflection and comparison; learners can check the records and adjust themselves. This mechanism makes knowledge transfer from passive reception to active personal experience and maintains the learner's subject position.

4.3 The Motivational Regulation Generation Mechanism

Skill acquisition is a continuous process, in which the attention, attitude and fatigue degree of learners change. The motivational regulation mechanism captures the learner's status and forms regulation suggestions, which makes the textbooks grow together with the learner. In this mechanism, action data and body signals should be captured to judge the learner's current skill level and cognitive load status. Also, the regulation suggestions should be offered based on the teacher's teaching experience and wisdom as well as the system's analysis; the suggestions are given to the learner in real time, but the final decision is made by the learner himself to balance the system and the learner. Attention should be paid to the fact that the core is regulation, not control, so technology should serve cognitive laws rather than replace the cognitive process.

The three-dimensional mechanism is an integrated whole of dynamic links, as shown in Figure 1. The perceptual situation mechanism obtains input from multi-modal data such as visual and auditory information, and offers an embodied basis for the cognitive transformation mechanism; the cognitive transformation mechanism generates ability-level signals such as error patterns in the trial–feedback–reflection process, offering a diagnostic basis for the motivational regulation mechanism; the motivational regulation mechanism outputs complexity parameters, such as situation difficulty and task load, and applies a reverse adjustment to the perceptual situation mechanism, forming a perception–cognition–motivation–perception cycle structure. This linkage spirals continuously, and the level of complexity increases after each cycle, promoting the learner to a higher level.

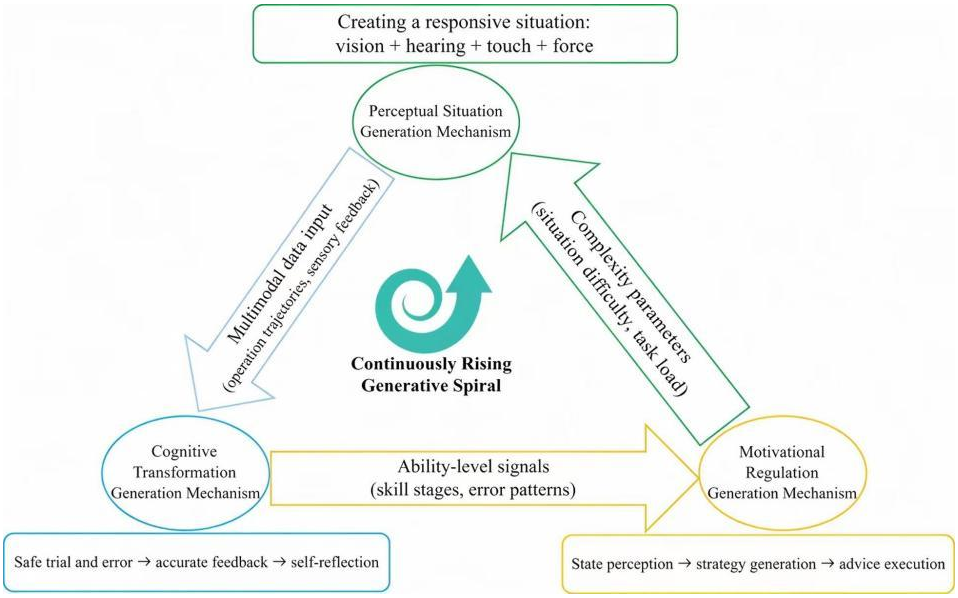


Figure 1 Three-Dimensional Mechanism of Vocational Education Digital Textbooks

5 APPLICATION STRATEGY AND IMPLEMENTATION PATH OF THE THREE-DIMENSIONAL GENERATION MECHANISM

The three-dimensional generation mechanism builds a complete framework from theory to operation for the development of digital textbooks, in the three aspects of situation design, process support and system assurance.

5.1 Application of the Perceptual Situation Mechanism: Creating an Embodied Learning Situation

The perceptual situation mechanism transforms abstract knowledge into perceptible and operable tasks, and learners obtain skills and experience in the real-time interaction between body and situation. Learners can perceive while doing by embedding conceptual knowledge into bodily operation. For example, in the gear transmission section, learners feel the torque changes under different design parameters through a device; resistance can be felt directly, and the relationship between transmission and torque can be understood. For complex operations, they can be divided into sub-tasks, and key points should be marked. In the aircraft safety wiring operation, the task starts in a simple plane; once learners are familiar with basic operations, it gradually moves to smaller spaces. When an operation violates the specification, a warning is triggered. Hand stability is improved through this embodied learning situation, and correct operations can be converted into bodily experience. In creating embodied learning, the situation should be realistic to support bodily perception and provide immediate and smooth feedback.

5.2 Application of the Cognitive Transformation Mechanism: Supporting the Process of Skill Generation

The cognitive transformation mechanism supports skill generation in the interaction by creating learning conditions of safe trial and error, accurate feedback and self-reflection. For example, in the operation of aircraft maintenance safety wiring, an angle difference within a certain range will trigger a hint, but a mistake will appear if the difference exceeds the threshold, so that the learner can explore within a controllable range. At key change points, the system will provide feedback through touch and vision, and the memory of correct perception is reinforced through safe trial and error and suitable feedback. Also, the learner can inspect himself at a higher level by checking the operation records, operation tracks and types of mistakes, which offer a reference for future learning.

5.3 Application of the Motivational Regulation Mechanism: Establishing System Safeguards

The application of the motivational regulation mechanism requires building specifications for data collection to ensure transparency in algorithm design and to safeguard the subject position of the decision-making mechanism, so that technology serves cognitive regulation. The principles of minimization and situational rules should be followed when collecting data. The data collected should be those essential to skill acquisition, such as operation tracks, completion time and types of mistakes; it is forbidden to collect data unrelated to learning, and the collection must be known to and permitted by the learner. In algorithm design, the logic and adjustment criteria are open to the learner, supporting the learner in understanding the system's judgment; questioning and choosing alternative schemes are allowed when necessary. Also, the learner can choose to accept, modify or ignore the suggestion and make the final decision.

5.4 Coordinated Implementation of the Three Mechanisms: The Safety Wiring Task

Aircraft have the features of high risk, high precision and strong bodily engagement, which makes traditional disembodied training modules face an embarrassment for new operators: not being allowed to operate and lacking real experience. Therefore, it became a typical context for examining the real use of embodied digital textbooks; the safety wiring operation is used to show the coordinated logic.

As shown in Figure 2, in this task, in terms of the perceptual situation, the virtual engine is a highly simulated model that can show the working area, tools and narrow spaces. The learner wears a glove with force-feedback capability and enters the virtual space; as his operating gestures change, different forces are felt, and the deformation of the wiring and the constraints of the space are shown, so that the learner can gain a sense of force and situation. In the initial stage, the situation offers visual guidance and assistance, while in the proficient stage, the situation reduces the degree of assistance and increases the intervening elements to prompt skill improvement. In cognitive terms, a tolerance range is set for the angle between the two hands; the learner tries different angles to obtain different force feedback and compares the results of different angles to find the optimal angle.

In terms of motivational regulation, the system continuously records operation tracks, etc.; when the system detects that the time taken for a correct operation has decreased, the complexity of the system is increased; when a fatigue signal is detected, information about resting, simplifying the task, etc. can be shown. Then the learner decides what to do in the next step, and the system will optimize its strategy based on the learner's decision. The inspection–analysis–suggestion–decision–learning process is formed. The learner obtains comprehensive professional competence through several cycles.

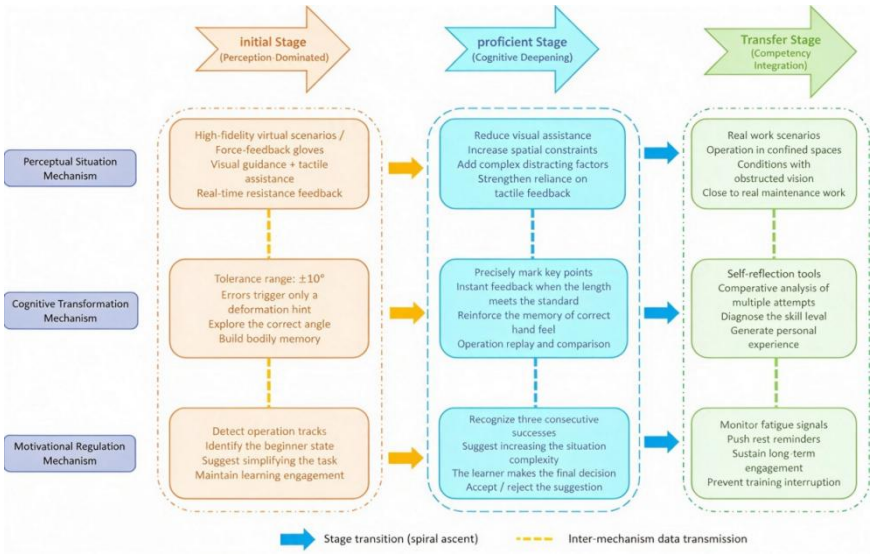


Figure 2 Three-Dimensional Mechanism Coordinated for the Safety Wiring Task

6 CHALLENGES AND RESPONSE

The digital textbooks for vocational education edited according to embodied cognition theory face some challenges in the usage process. So the cognitive laws should be obeyed to avoid technology dependence in the building process.
The perceptual situation mechanism replaces the real situation with a virtual one, but little research has been done on whether the bodily experience is consistent with that of the real situation and whether it can bring operational memory to the learner. Situation design should collect the operation data of experts and learners according to the need for bodily memory, and compare the perception and operation in virtual and real situations to validate the reality of the perceptual situation.
The cognitive transformation requires the support of a trial-and-error–feedback–reflection cycle. For the tactile feedback of key operations, high-precision devices are required, while simple devices and schemes are sufficient for some assisted stages, so that skill learning is in a position higher than device operation and technology serves cognition.
Motivational regulation requires the collection and recognition of the learner's actions, but this may lead to over-monitoring of operating habits, physiological signals and privacy issues. Furthermore, if the learner does not know why the system makes recommendations and adjustments, the learner's subject position is undermined. Therefore, the learner should know why the system gives such suggestions and make the final decision.

7 CONCLUSION

This paper proposes a three-dimensional generation mechanism of perceptual situation, cognitive transformation and motivational regulation, and also discusses its organizational form, implementation path and coordinated operation. It offers theoretical support for digital textbooks, but the mechanism needs to be validated further.

COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

FUNDING

The research received funding from the Shanghai Education Scientific Research Project (2026) under Grant No. C2026022.

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