Construction and Practice of the Digital-Intelligent Integrated Teaching Paradigm in Medical Education

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ABSTRACT Based on the demand for the digital–intelligent transformation of medical education, this study selects "Triadic Reciprocal Determinism (TRD)" as the theoretical basis, and builds a digital–intelligence integrated teaching paradigm to solve the problems of cross-platform interactive data fragmentation, difficulty of teaching staff and students adapting digital literacy, and the incompleteness of evaluation systems. The paradigm builds up the teaching philosophy of "TRD, Digital–intelligent Empowerment, and Wisdom Generation", forms a systematic top-level architecture of "three carriers, three channels, three stages, and four-dimensional evaluation", and constructs an operable Wisdom Generation teaching path, which extends from pre-class intelligent guided learning, in-class virtual–real integration, to post-class personalized consolidation. Based on teaching practice, the paradigm can effectively realize the educational goal of cultivating nursing professional talents who are "proficient in skills", "adept at critical thinking", "integrating with digital intelligence" and "endowed with humanistic sentiment", and it has provided a theoretical framework and practical solution for the digital–intelligent reform of medical education that can be replicated and scaled.

INDEX TERMS TRD; Digital–intelligence integration; Medical education; Teaching paradigm; Wisdom Generation

Educational digitalization is driving and transforming the world of education. In 2025, the Outline of the Plan for the Construction of China into an Education Powerhouse (2024–2035) was released by the Central Committee of the Communist Party of China and the State Council, which clearly stated that it mandates the promotion of Artificial Intelligence (AI) to drive educational transformation and opening up new development tracks and new development advantages through education digitalization. The building of "New Medical Education Initiative" also faces dual challenges in the cultivation of medical talents: deep interdisciplinary integration and AI-driven education. The conventional "teacher–student" teaching model has been unable to meet the need for medical talents in the digital–intelligent era. The study shows that in the intelligent era, the objects of education and teaching are changing from "binary interaction" to "triadic co-creation" [1]. In the same way, Wu Fati et al. introduced a "teacher–student–intelligence" triadic classroom model [2], and Zhao Xinran claimed that AI should be introduced in the classroom, creating a "teacher–student–intelligence" tetradic classroom model [3] , Qi Shunbin et al. also emphasized the need to develop a "teacher–student–machine" collaborative classroom [4]. However, there is still a lack of explanation of the internal mechanism of TRD and the rationale for its use in medical field in the existing research [1]. Currently, there exist data silos that prevents the sharing of information between teaching platforms, virtual environments, and intelligent agent systems, and the digital literacy of teachers and students is not yet fully aligned, nor are evaluation systems fully integrated with important aspects like human–machine collaboration. Therefore, it is necessary to build a teaching paradigm that is integrated with the characteristics of the medical field and has a TRD effect between digital teaching and intelligence teaching. Based on this nature, this study focuses on the teaching platform, virtual system, and intelligent agent as interactive carriers, and systematically studies the construction process and practice strategies of the digital–intelligence integrated teaching paradigm.

I. THEORETICAL FOUNDATION AND CONNOTATION OF THE TRD-BASED TRIPARTITE INTERACTION MECHANISM

A. PARADIGM EVOLUTION OF TEACHING INTERACTION THEORY: FROM BINARY INTERACTION TO TRIADIC SYMBIOSIS

There are three paradigms of teaching interaction theory. The "stimulus–response" model of the mid-twentieth century, which was dominated by behaviorists, saw teaching as the transmission of knowledge. During the 1980s, cog-

nitivism, which centers on learners' internal knowledge construction and interaction, overcomes the limitations of merely relying on external stimuli. Constructivism has come to define interaction in the twenty-first century as a process by which meaning is actively created by the learner in a social context, with a focus on collaboration and situated cognition.

Bandura's TRD is the theoretical basis for multi-subject interaction in teaching systems, which states that there is a dynamic relationship between individual, behavior, and environment. Based on this theory, Liu Shaoting proposed a three-dimensional theory of "individual–behaviour–environment" and created a digital–intelligent teaching reform solving mechanism based on this theory [5]. Xuan Cuixian et al. also built an analytical model covering three aspects: "multi-level internal and external environments", "individuals' composite knowledge" and "talent cultivation behavior", and ultimately verified the applicability of the theory in talent cultivation of vocational education [6].

With the advancement of AI technology, this theory has gained fresh dimensions for interpretation. Zhao Xinran pointed out that the traditional "teacher–student" model is transforming into a "teacher–AI–student" model with four interaction points between teachers, AI, media, and students. [3]. Wu Fati et al. put forward the triadic-subject classroom structure model of "teacher–student–intelligence" [2]. Li Yanyan et al. pointed out the transition from "binary interaction" to "triadic co-creation" in teaching subjects [1]. This is a basic shift in the logic of interaction, wherein intelligent agents become interactive subjects and fully engage in the processes of teaching decision-making, resource matching and feedback loop construction.

B. CONNOTATION AND APPLICATION LOGIC OF THE TRD-BASED TRIPARTITE INTERACTION MECHANISM IN MEDICAL EDUCATION

This study builds the medical teaching system on the basis of Bandura's TRD and introduces the concepts of intersubjectivity and cognitive symbiosis theory [7] into the teaching process, and explicitly defines the teaching subjects as teachers, students, and intelligent agents, and constructs teaching platforms, virtual platforms, and intelligent agent systems as carriers of the medical teaching system. Its connotation and application logic are expounded in three aspects.

Teacher–machine collaboration. Intelligent agents are used by teachers to diagnose learning conditions, accurately push resources, and predict teaching outcomes. Intelligent agents, in turn, are able to efficiently monitor learning trajectories, gather data, and return learning conditions, freeing up the time of the teacher to focus more on value guidance for students. According to Wu Fati et al., this is a structure conducive to converting teachers to "collaborative facilitators" [2].

Student–machine interaction. Intelligent agents provide students with personalized resources and instant feedback. Chai Xingzhu put forward a closed-loop model of "data perception → dynamic construction → feedback optimization" for the analysis of student-machine interaction [8].

Teacher–student interaction. The teacher–student interaction is shifting from experience-driven to data-enhanced mode with the help of intelligent-agent big data. Li Yanyan et al. described this change as a step forward from the "data-driven" teaching to the "digital-intelligence synergy and integration" [1].

Individualized demand is one of the great challenges in medical education; the knowledge system in medical disciplines is complex, and nursing skill operations are strict. Intelligent knowledge graph can be used for the diagnosis of weak points, resources can be pushed accurately according to it, virtual simulation platforms can provide zero-risk repeated training platforms, and intelligent agents can generate situational tasks based on the actual case for students to practice clinical decision making skills. Huang Yihan et al. proposed a triadic symbiotic coupling mechanism—"AI–human–scenario", as a reference to understand the ecological operation of this system [7].

II. CONSTRUCTION OF THE DIGITAL–INTELLIGENCE INTEGRATED TEACHING PARADIGM DRIVEN BY TRD

A. CORE PHILOSOPHY AND ARCHITECTURE DESIGN

This study builds the framework of a digital–intelligence integrated teaching paradigm, based on the teaching philosophy of "TRD", digital–intelligence empowerment, and wisdom generation. "TRD" is a deep interaction between teachers, students, and intelligent agents that constitutes a collective driving engine for the continuous operation of the system. "Digital–intelligent empowerment" is the technical aid provided by the full-process, multi-dimensional big data and AI to make the entire teaching process accurate, personalized, and intelligent. The idea of "wisdom generation" is to break the barrier of cognition, continuously interact with, change knowledge transmission to knowledge co-construction, and then generate deep clinical thinking literacy. This idea is similar to the classroom construction based on "cognitive symbiosis" proposed by Li Yanyan et al., which integrates multiple resources into a classroom and progresses from "static and closed" to "collaborative co-construction" [1].

The paradigm at the highest level outlines a systematic structure of "three carriers, three channels, three stages, and four-dimensional evaluation. The architecture is based on the three carriers: teaching platforms, virtual platforms, and intelligent agent systems. The paradigm realizes "intelligent teaching", "personalized learning", and "humanistic education" through the three channels: the "teacher–machine" collaborative decision-making channel, the "student–machine" virtual–real interaction channel, and the "teacher–student" multi-dimensional interaction channel. A continuous iteration of "learning–reflection–advancement" is created in the three phases of pre-class intelligent guided learning, in-class virtual–real integration, and post-class personalized consoli-

dation. The entire process of the teaching system is regulated and optimized by a four-dimensional evaluation system that covers teacher decision-making, student performance, intelligent agent response, and system ecology (Figure 1). The design is very similar to the triadic collaboration model of "teacher–AI–student" built on the "human-in-the-loop (HITL)" theory by Ke Yuding [9]. The three-dimensional structure of GenAI educational intelligent agents built by Chai Xingzhu: "data perception" → "dynamic construction" → "feedback optimization" is an implementable technical reference to the present framework [8].

B. FUNCTIONAL POSITIONING AND ROLE TRANSFORMATION OF THE TEACHING SUBJECTS

The seamless operation of the TRD ecosystem depends on the correct positioning of the functions of each of the subjects and the proactive role transformation.

The shift of teachers' roles and functions from knowledge transmitter to intelligent teaching facilitator. Teachers use big data of learning conditions to tailor intervention strategies, and critically modify intelligent agents' decisions. Wu Fati et al. pointed out that teachers have become more of a "collaborative facilitator" [2]. Mao Ting pointed out that the "subjectivity dissolution" problem should be avoided and that the position of the three subjects should be clarified [10].

Student role and functions: Passive recipients to active explorers in human-machine collaboration. Students independently design learning trajectories, combine learning resources, and continuously reflect on their learning in virtual-physical tasks. Yin Furong pointed out that to achieve digital–intelligent transformation, university students must have profound comprehension, the ability to integrate disciplines, and adaptability to technological iteration [11].

Intelligent agent functions and role: transforming an auxiliary tool to interactive subject with teaching functions. Intelligent agents facilitate accurate allocation of resources, adaptive control of learning processes, and on-line evaluation of operations proficiency. In terms of the "teacher—student—machine" collaborative model, Qi Shunbin et al. said that the role of the teacher is to design teaching and instruction, guide students to give value guidance, students actively construct their own knowledge systems, and the role of the intelligent agent is to do auxiliary work [4].

C. DESIGN OF A WISDOM GENERATION TEACHING PATH CONNECTING THE WHOLE PROCESS

Based on the basic philosophy and architecture of the paradigm, this study constructs a path of generating wisdom in pre-class, in-class, and post-class (Figure 2). The four-dimensional assessment system gives immediate feedback on the learning environment during the process, thereby pushing forward the continuous improvement of each step.

Pre-class stage. The intelligent agent combines platform information to create individually tailored preview resource sets. Once students finish the assignments, the system analyzes the effectiveness of students, accurately points out the weak points of students' knowledge, and pushes the learning analytics report to the teachers. During this stage the intelligent agent works as an intelligent teaching assistant to the teachers and an intelligent learning companion to the students. At this stage, the theory of closed-loop optimization of "data perception → dynamic construction → feedback optimization" is provided by Chai Xingzhu [8].

In-class stage. Teachers flexibly adjust the pace of teaching according to the real-time monitoring data and dynamically adjust the key teaching points and difficult points. Using the virtual platform, students complete simulated training and clinical decision-making scenarios created by the intelligent agent. The intelligent agent monitors students' paths in real-time and produces assessment reports, which are sent to the teacher terminal. The strategy of "pre-class intelligent diagnosis, in-class human–machine collaboration, and post-class personalized expansion" used by Ke Yuding is quite similar to the current study [9].

Post-class stage. The intelligent agent assimilates the information of the classroom interaction and establishes digital profiles that help teachers analyze learning conditions and create independent training modules to support students' simulated skill training. All the learning data are fed back automatically and creates a continuous improvement loop. Qi Shunbin et al. noted that to realize personalized learning and precise teaching, the three dimensions of technical architecture, teaching processes, and evaluation systems of triadic collaboration should be coordinated [4].

III. PRACTICAL EXPLORATION OF THE WISDOM GENERATION PATH

A. CROSS-PLATFORM DATA COLLABORATION AND RESOURCE INTEGRATION

One of the core bottlenecks toward implementing TRD is the inability to break down the data silos among teaching platforms, virtual platforms, and intelligent agent systems. Based on the Chaoxing Fanya platform and the Shandong Provincial Online Course Alliance platform, this research builds a four-dimensional intelligent knowledge graph of "knowledge–problem–competency–curriculum ideology and politics" (Figure 3), and combines the DeepSeek and Huiya Large Language Models (LLMs). This graph connects the three types of platforms organically with dynamic resource annotation, construction of clinical problems and resource chains, mapping of competencies and ideological-political integration.

In the Nursing Nutrition course, for instance, the intelligent agent gathers assignment and test information from the teaching platform, evaluates students' knowledge acquisition, and delivers tailored learning materials. A spiral learning loop of "questioning–argumentation–construction" is created between knowledge learning and clinical practice by forming three kinds of virtual scenarios: the Nutrition Community (case discussion and knowledge co-construction), the Nutrition Scenario Workshop (dietary

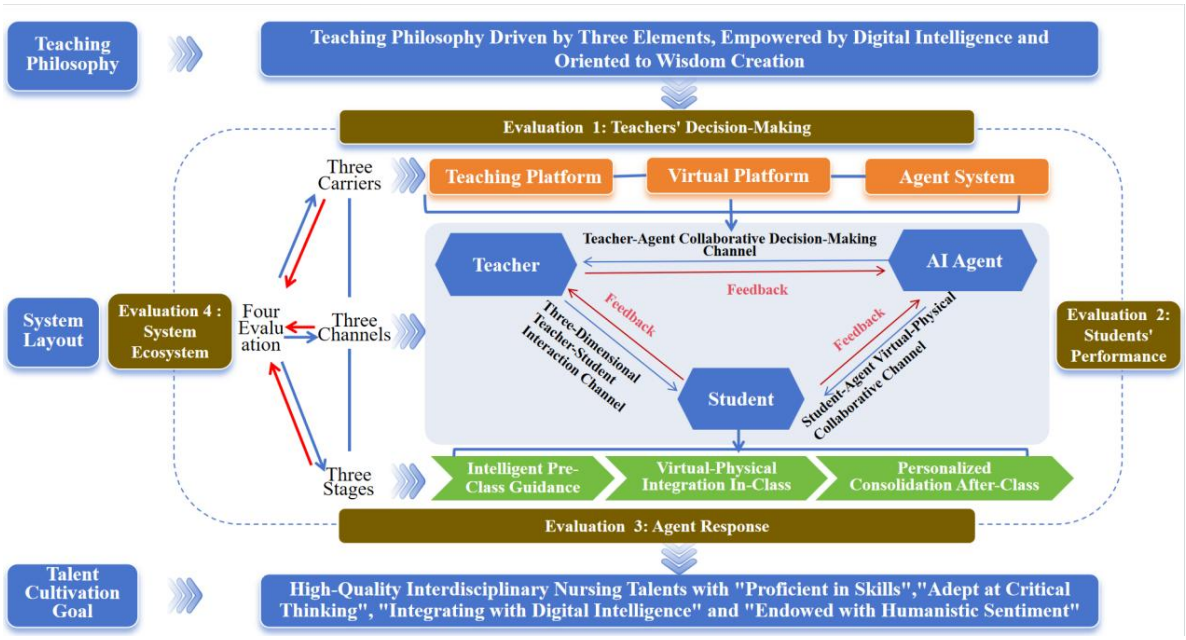

FIGURE 1. Digital–intelligence integrated teaching paradigm driven by TRD.

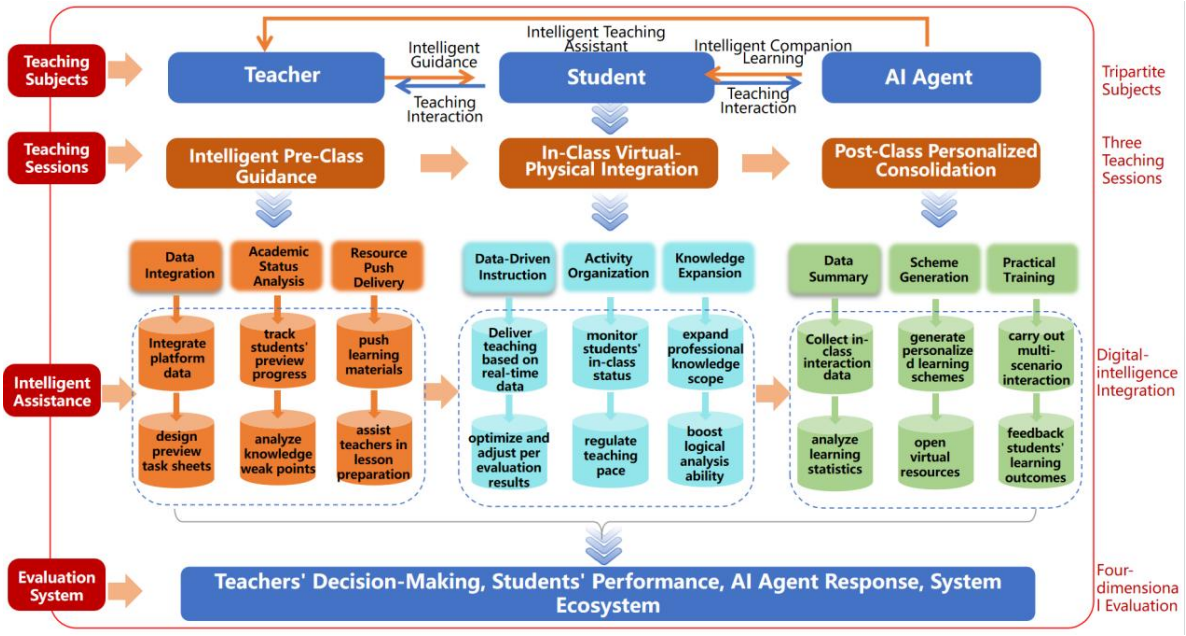

FIGURE 2. Wisdom Generation teaching path connecting the whole process.

plan design and argumentation), and the Virtual Clinic (immersive inquiry and decision support). The intelligent knowledge graph is woven between learning trajectories on all platforms, forming accurate digital profiles; data collaboration and resource integration between platforms realize the entire closed loop of "data collection – intelligent analysis – precise intervention – effect feedback". It is a theoretical confirmation and reinforcement of the loop of "data perception-dynamic construction-optimization by feedback" presented by Chai Xingzhu [8].

Ideology & Politics

B. HIERARCHICAL AND PROGRESSIVE CULTIVATION OF TEACHERS' AND STUDENTS' DIGITAL COMPETENCIES

The efficient functioning of the TRD relies on the digital literacy of teachers and students.

The three-step progressive training model of "basic application–digital–intelligence integration–wisdom generation" is carried out by theoretical lectures, hands-on practice

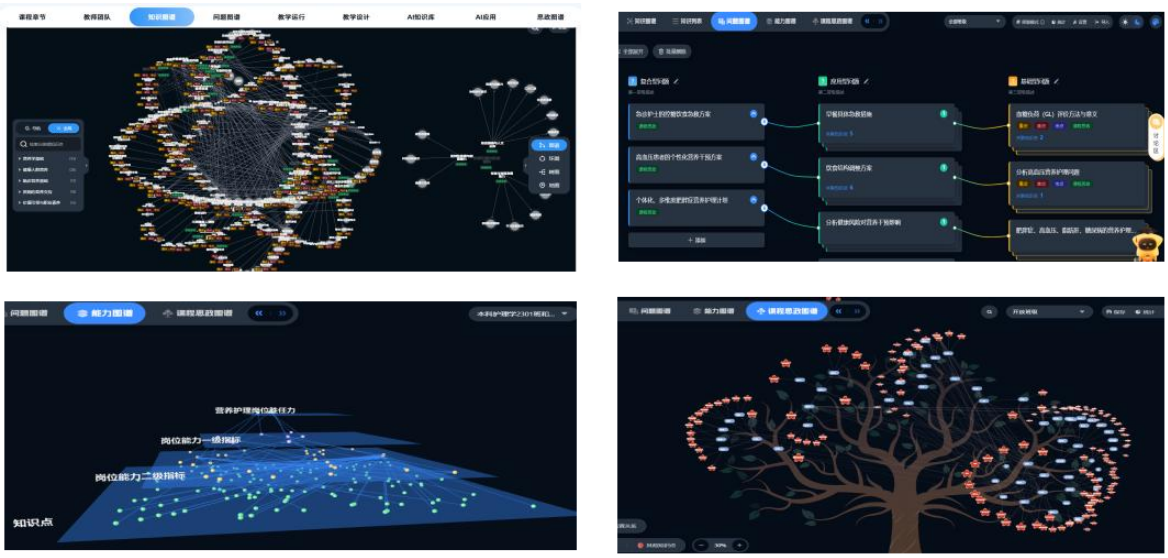

FIGURE 3. Four-Dimensional Linkage Diagram of Knowledge, Problems, Competencies and Curriculum Ideology & Politics.

with cases, and group discussions for teachers. The first focuses on engaging activities with intelligent tools, the second on learning to design instruction using digital–intelligent tools, and the third on developing resources across disciplines. This is similar to the digital-intelligence competency model for teachers that Fan Jianli put forward [12]. Mao Ting stressed the importance of strengthening teachers' and students' literacy together, as the risks of "cognitive inertia and cognitive overload" will otherwise arise [10].

In the teaching process, the teaching model of "Basic operation-Specialized training-Comprehensive application" is adopted. Basic platform skills and information literacy training are carried out at the early stage. During the middle phase, differentiated training modules for medical skills are set up. During the later stage, complex clinical medical practice simulation modules are used. The learning-companion role of the intelligent agent offers intelligent navigation support to novices and clinical decision-making support to experts. The digital-intelligent era is calling for university students to have a deep knowledge internalization, be capable of integrating disciplines, and be adaptable to the changes of technology, which is something that traditional learning paradigms can no longer achieve [11].

C. TYPICAL APPLICATION CASE: TEACHING PRACTICE OF THE NURSING NUTRITION COURSE

The case of a patient with diabetes is used as an illustrative example for the teaching task "formulating dietary intervention plans for patients with diabetes".

The intelligent agent collects the students' learning data on the knowledge points to be learned, and accurately calculates the students' grasp of the prerequisite knowledge, such as "glycemic index", sends targeted preview resources to students before the class, and generates a report on the students' learning condition, which is pushed to the teacher terminal for diagnosis. In class, the Virtual Nutrition Scenario Workshop, and under the direction of problem chains, e.g., "an emergency blood-glucose-control dietary plan for emergency nurses," students take the "route" of "symptom recognition–nutritional analysis–plan optimization. The intelligent agent helps students to solve clinical problems, and to review and consolidate knowledge, while the collaborative AI platform allows teachers and students to collaboratively create and create a teaching resource package that can be iteratively updated. Using the whole-class behavior data, teachers analyze and provide in-class tutoring, and vividly realize the paradigm of "in-class human–machine collaboration" proposed by Ke Yuding [9]. The intelligent agent will push the learning-condition report after class, and teachers will consolidate and reinforce students' nutritional nursing abilities according to the analysis of the weaknesses. For instance, teachers are able to assign simulated inquiry tasks via the Virtual Clinic, where students can act as clinical dietitians and have a dialogue with the virtual patient; the system gives feedback and evaluation in real time, which enhances the communication ability and nutrition plan designing capability of students (Figure 4). Qi Shunbin et al. pointed out that this model can successfully realize the personalized learning and teaching goal with high efficiency [4].

Preliminary practical results demonstrated that the model can significantly improve the clinical decision-making ability and ability of knowledge transfer for students.

IV. BUILDING THE FOUR-DIMENSIONAL EVALUATION SYSTEM

In order to fully measure the effect of the triadic-interaction intelligent teaching paradigm, this study sets up a four-dimensional teaching evaluation system.

FIGURE 4. Simulated inquiry.

Student dimension. The dimension emphasizes the clinical thinking ability, virtual operation ability, and human–machine collaborative efficiency of students, including the standardization of nutritional nursing procedures, the ability of students to interact with the machine as a team, and interdisciplinary integration. This dimension is based on the theoretical references provided by the "human–machine–event–object–field" model of Yu Liang et al. [13] and the multi-dimensional comprehensive "matrix" concept of Zhou Jin'ao et al. [14].

Teacher dimension. This dimension highlights the quality of the design of the teaching plan and the effectiveness of the teaching plan design in relation to the learning-condition report, that is, the matching degree between the learning-condition report and the teaching plan, the conversion efficiency of intelligent data, and the accuracy of the personalized guidance.

Intelligent agent dimension. The dimension focuses on the accuracy of resource recommendation, the credibility of learning-condition analysis, and the responsiveness of interactive feedback, and includes the content match between recommended content and learning needs, the gap between learning-condition analysis and the current state, and the lateness of feedback.

System dimension. This dimension is related to the fullness of the platform data collection, the stability of virtual environments, and the ease of data moving between platforms.

Each dimension is populated with indicators that are dynamically weighted based on the course characteristics, and data are gathered at the start, mid, and end of the semester to create a pluralistic system of evaluation, which combines longitudinal tracking with horizontal comparison. Yu Liang et al. have built a 5-layer empowerment system from the physical layer to the interaction layer, which has been used as a concrete operational paradigm for this framework [13].

V. CONCLUSIONS AND PROSPECTS

In the context of the demand for digital–intelligent transformation of medical education, this study is based on the foundation of TRD theory and the means of digital–intelligent empowerment to build a digital–intelligence integrated teaching paradigm for the medical education. First, the teaching philosophy of "TRD, digital–intelligent empowerment, and wisdom generation" is set, and the subjectivity of teachers, students, and intelligent agents as driving forces, and the technical process of digital–intelligence integration, and the trend of knowledge co-creation are revealed. Second, the paradigm builds a systematic top-level teaching layout of "three carriers, three channels, three stages and four-dimensional evaluation": according to the teaching characteristics, it constructs the "teacher–machine" collaborative decision-making channel, "student–machine" virtual–real integration channel, and "teacher–student" multi-dimensional interaction channel, and builds the teaching platform, virtual platform, and intelligent agent platform; it establishes pre-class intelligent guided learning, in-class virtual–real integration, and post-class personalized consolidation teaching stages; and runs the four-dimensional evaluation system throughout the teaching process. Thirdly, an operable wisdom generation teaching pathway that links the whole process is created, which is an ascending spiral learning loop. Theoretically, the paradigm has the ability to transcend the traditional linear teaching model, as shown in practice. The paradigm offers a systematic solution to the current medical education data silos, unclear role positioning, and slow evaluation feedback issues, as well as the difficulties of the cross-platform integration and linkage of data, through the triadic cyclic interaction model.

The conclusions of this study are preliminary. The teaching paradigm is limited by the scope of the samples and the duration of the project implementation, so the universality and effectiveness of the teaching paradigm need to be validated based on a larger-scale empirical study. Future work will focus on further expanding the scope of the practical courses, continuously improving the adaptive learning algorithms of intelligent agents, and continuously optimizing the quantitative indicators of the four-dimensional evaluation indicators, so as to make the triadic-interaction teaching paradigm gradually move from the stage of conceptual construction to the stage of ecological co-creation.

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