

Construction and Practice of a Digital Intelligence Physiology Course Integrating Knowledge Graphs and AI

Cuifan Li, Xiaoxiao Lin, Jingjing Bo, Ruihan Song, Yingdong Cao

School of Medicine, Sias University, Zhengzhou 451100, Henan, China

Abstract: *As a pivotal foundational medical course for nursing programs, physiology encompasses a complex knowledge system with numerous abstract concepts and close clinical relevance. Traditional teaching models face challenges including fragmented knowledge dissemination, inadequate support for personalized learning, and insufficient cultivation of clinical thinking skills. Taking the construction of the digital-intelligent physiology course based on knowledge graphs at the School of Medicine, Sias University, as a case study, this paper systematically presents the philosophy, implementation pathways, and practical outcomes of the tripartite integration model combining “knowledge graphs—AI—nursing practice.” The course design uses knowledge graphs as a framework to structure knowledge, leverages AI technology as an engine to empower the entire teaching process, and is driven by nursing practice to cultivate competencies. It has established a blended teaching model featuring “online preliminary self-study—offline intermediate flipped classroom—post-class advanced extension,” forging a new digital-intelligent educational ecosystem characterized by visualized knowledge presentation, personalized learning pathways, and precise instructional strategies. Practice has shown that this model effectively enhances students’ learning outcomes and clinical reasoning abilities, offering a replicable paradigm for the digital and intelligent transformation of basic medical courses.*

Keywords: Knowledge graph, Artificial intelligence, Physiology, Digital-intelligent curriculum, Medical education.

1. Introduction

With the deepening advancement of “New Medical Education” and the implementation of the “Outline for Building an Educational Power (2024–2035),” educational digitalization has become a core driving force in reshaping the education ecosystem and promoting teaching reform. Physiology, as a foundational medical course in nursing programs, primarily investigates the patterns and mechanisms of human life processes, serving as a bridge between basic medicine and clinical nursing. However, due to its abstract concepts, complex mechanisms, and strong interconnectivity, students commonly face the dilemma of “understanding the lectures but failing to retain the knowledge, or retaining it but being unable to apply it.”

In recent years, the integration of knowledge graphs and artificial intelligence technologies in medical education has attracted growing attention. Studies have shown that knowledge graphs can integrate fragmented knowledge points into structured networks, helping students rapidly build systematic knowledge frameworks [1] [2] [7]. Generative AI technologies, represented by ChatGPT, offer new possibilities for personalized learning, intelligent tutoring, and learning analytics. Randomized controlled trials have demonstrated that a blended teaching model combining generative AI-powered digital mentors with knowledge graphs significantly improves nursing students’ academic performance, knowledge retention, and clinical reasoning abilities [3]. Against this backdrop, how to deeply integrate the structural merits of knowledge graphs with the intelligent capabilities of artificial intelligence to address long-standing challenges in physiology education has emerged as an urgent research priority.

The Physiology course team at the School of Medicine, Sias University, has launched a teaching reform initiative

integrating knowledge graphs, AI, and nursing practice [4] [5] [6], supported by a university-level digital intelligence curriculum project. After one full cycle of development and pilot implementation, the course has achieved phased results in restructuring its knowledge system, innovating teaching models, and integrating AI technologies. This article systematically summarizes the course’s development philosophy, implementation approach, and practical outcomes, aiming to provide a reference for the digital and intelligent transformation of foundational medical courses.

2. Realistic Challenges in Physiology Course Teaching

Physiology is a required course for first-year nursing students, covering 12 core chapters including cellular functions, blood, circulation, respiration, digestion, urine formation, neural regulation, and endocrine systems. The subject involves a large volume of knowledge, deep logical layers, and high levels of abstraction. Through long-term teaching practice, the course team has identified three major core challenges.

First, the contradiction between fragmented and systematic knowledge. The chapters in physiology are closely interconnected through causal and progressive relationships — for example, cellular bioelectricity forms the basis of neural transmission, and blood circulation is a prerequisite for understanding cardiovascular regulation. However, traditional teaching progresses chapter by chapter, often leaving students trapped in a “seeing the trees but not the forest” dilemma, making it difficult for them to grasp the overarching framework of “cellular function—organ physiology—system coordination—overall homeostasis.” The fragmentation of knowledge across courses and the scattered, isolated nature of teaching resources are particularly pronounced. Knowledge graph technology offers an effective technical solution by establishing semantic connections among knowledge points

[1] [2] [7].

Second, there is an inherent tension between standardized instruction and individualized learning needs. Physiology courses are designed for first-year students, who exhibit considerable disparities in foundational knowledge, learning capacities, and cognitive styles. Traditional classrooms follow a uniform pace and content for all students, leaving those with weaker foundations unable to keep up, while more capable students feel underserved. This “one-size-fits-all” approach fails to meet diverse learning needs, causing some students to develop anxiety due to prolonged struggles. AI-driven personalized learning path recommendations provide a pivotal direction for addressing this challenge [8].

Third, there is a gap between knowledge retention and clinical application. The learning objectives of physiology extend beyond mastering knowledge to applying physiological principles in explaining clinical phenomena and guiding nursing practice. However, traditional teaching emphasizes theoretical instruction and lacks effective bridges connecting physiological mechanisms with clinical problems, leaving students often unable to quickly activate and retrieve relevant knowledge when facing clinical situations. As relevant research points out, basic medical courses commonly exhibit a tendency to “emphasize knowledge transmission over skill development,” resulting in weak knowledge transfer abilities among students [9].

The root of these challenges lies in the static presentation of teaching resources, where the internal logic among knowledge elements is not fully articulated; learning pathways lack personalized adaptation, forcing students to passively follow a uniform pace; and there is a lack of effective connection mechanisms between theory and practice. Overcoming these issues requires simultaneous efforts at three levels: knowledge organization, learning pathways, and teaching interaction.

3. Pathways for Building Digital-Intelligent Courses through the Integration of Knowledge Graphs and AI

To address the aforementioned challenges, the course team established a development philosophy centered on “knowledge graphs as the framework, AI technology as the engine, and nursing practice as the orientation,” systematically advancing course development through three dimensions: restructuring the knowledge system, innovating teaching models, and deeply integrating AI.

3.1 Knowledge Graph Construction: From Dispersed Knowledge Points to a Structured Knowledge Network

The core task in constructing a knowledge graph is to integrate fragmented knowledge points into a structured knowledge network. Leveraging the Chaoxing Fanya platform, the course team systematically organized and reconstructed the knowledge points across 12 chapters of physiology [4] [5] [6].

Knowledge point extraction and categorization. The team first extracted 132 core knowledge points from each chapter based on the curriculum guidelines and nursing talent development requirements, then classified them into conceptual, principle-

based, mechanism-based, application-oriented, and integrative types. These different types of knowledge serve distinct instructional purposes: conceptual points emphasize memorization and comprehension, mechanism-based points focus on analysis and reasoning, while application-oriented points stress knowledge transfer and practical application.

Knowledge relationship construction. Based on knowledge point extraction, the team further clarified the logical relationships among knowledge points, including hierarchical relationships (e.g., “circulation” encompasses subtopics such as “cardiac pumping function,” “vascular physiology,” and “cardiovascular regulation”), prerequisite relationships (e.g., “cellular bioelectricity” as a prerequisite for “neural transmission”), parallel relationships (e.g., “pulmonary ventilation” and “gas exchange”), and progressive relationships (e.g., from “glomerular filtration” to “urine concentration and dilution”). A total of 468 knowledge relationship edges were established, forming a comprehensive knowledge network covering the entire textbook [1] [2] [7].

A three-layer knowledge graph architecture. The course constructs a visual knowledge graph with an integrated “knowledge–competence–problem” framework. The knowledge layer focuses on understanding concepts and mechanisms, the competence layer emphasizes the transformation of knowledge into clinical reasoning skills, and the problem layer activates relevant knowledge nodes through typical clinical cases. These three layers are interconnected, enabling students to explore application scenarios starting from specific knowledge points or trace underlying physiological mechanisms by starting with clinical problems.

Precise resource linking. After the knowledge graph was established, the team accurately linked 89 teaching videos, 472 practice questions, and 12 clinical cases to respective knowledge nodes [1] [4]. Resources are aggregated around knowledge points, enabling students to access corresponding instructional videos, case analyses, and exercises by simply clicking on any knowledge node—shifting from “people searching for resources” to “resources finding people.”

3.2 Innovation in Blended Teaching Models: From a Uniform Approach to Personalized Adaptation

Knowledge graphs provide a structural foundation for personalized learning, but to truly achieve individualized instruction, corresponding innovations in teaching models are also needed. Based on years of blended teaching practice, the course team has developed a three-stage blended teaching model: “online preliminary self-study—offline intermediate flipped classroom—post-class advanced extension” [3] [8].

Pre-class: Online self-study and intelligent assessment. Teachers post pre-class task lists and clinical cases via the FanYa platform, guiding students to independently watch instructional videos and complete self-assessment quizzes. The AI system automatically generates learning analytics reports based on students’ pre-class data, accurately identifying knowledge gaps at both class and individual levels, thus providing a precise starting point for in-person instruction. The core value of this phase lies in “enabling teachers to enter the classroom with students’ real questions.”

In-class: Offline intermediate flipped classroom with deep interaction. The in-person class no longer focuses on re-teaching foundational knowledge, but instead employs interactive teaching methods such as PBL (problem-based learning), CBL (case-based learning), group discussions, and thematic debates to emphasize the deep internalization and clinical application of knowledge. For example, in the “Circulatory System” chapter, instructors introduce a case study on “heart failure and artificial hearts” to implement a flipped classroom model, guiding students to explain the pathophysiology of heart failure by applying the principle of blood pumping, and discussing key nursing considerations for artificial hearts. AI-powered quizzes are embedded within the lesson, displaying real-time accuracy rates and enabling teachers to adjust their instructional strategies promptly.

After class: Advanced extension and personalized reinforcement. Based on students’ in-class performance and assessment data, the AI system delivers customized homework and supplementary resources to each student. Those with weaker foundations receive targeted instructional videos and intensive practice exercises, while more capable students are provided with cutting-edge developments and complex clinical cases. This “one-on-one” after-class reinforcement mechanism effectively addresses the coexisting problem that uniform assignments are either too difficult for some or not challenging enough for others [8].

The three interconnected stages form a complete teaching cycle of “diagnosis—intervention—consolidation.” During the 2024–2025 academic year, the course delivered a total of 294 classroom activities with 9,074 participations; assessments and assignments were administered 1,120 times involving 367 students. The high-frequency interaction and timely feedback mechanisms significantly boosted student engagement and improved learning outcomes.

3.3 Deep Integration of AI Technology: From Tool Assistance to Teaching Reconstruction

The application of AI technology in education has evolved from “tool-based assistance” to “process integration” and further to “instructional restructuring,” now forming a comprehensive AI-powered system covering the entire teaching chain.

AI-assisted lesson planning and resource generation. Teachers have widely used AI tools such as DeepSeek on a regular basis for courseware creation and enhancement, instructional case generation, and exercise design and organization. For instance, in the lesson design on “cardiac pumping function,” teachers utilized tools such as DeepSeek, html2web, and Feixiang Teacher to develop interactive visual teaching resources, including a “cardiac pumping process simulator” and a “virtual blood type identification experiment.” These tools transform abstract physiological mechanisms into operable, observable dynamic simulations, significantly reducing students’ cognitive load [4] [8].

AI-powered visual interactive teaching. Complex mechanisms in physiology have long been considered challenging for students. The course team leverages AI tools to transform abstract mechanisms into visual interactive

experiences. For example, in the topic of “cardiac pumping function,” students can drag sliders for “ventricular contractility” and “peripheral resistance” to observe real-time changes in aortic pressure waveforms and stroke volume. In the case of “spinal shock,” students can apply electrical stimulation at different intensities or simulate spinal cord transection to observe changes in lower limb contraction responses. Through hands-on interaction, students gain a deeper understanding of the relationships between preload, afterload, and cardiac function, with notably increased classroom engagement; 90% of students reported that the interactive simulations were “very helpful.”

AI practice library and intelligent learning analytics. The course team has established an AI practice library on the XueTong platform using tools such as DeepSeek, featuring practical tasks [9] [10] including “Blood Type Determination and Blood Transfusion Principle Application Scenario Simulation” and “Respiratory System Health and Physiological Mechanism Consultation.” The AI system evaluates students’ responses across multiple dimensions—such as patient history taking and knowledge relevance, accuracy of key concepts, and communication and standardization—and generates detailed learning analytics reports, providing teachers with precise recommendations for lesson planning adjustments. For instance, when the system identifies that students generally perform weakly in the “communication and standardization” dimension, it recommends incorporating standardized communication templates into nursing scenario training.

AI teaching assistants and personalized Q&A. The AI assistant deployed on the FanYa platform provides students with 24/7 instant question-answering services, enabling them to ask questions anytime and receive immediate responses. More importantly, based on students’ learning profiles, the AI assistant proactively recommends targeted instructional videos or practice exercises. This intelligent tutoring model—offering “instant answers upon inquiry” and “proactive content delivery”—liberates teachers from repetitive Q&A tasks, enabling them to focus more on guidance for higher-order thinking and emotional support [3] [10].

4. Practical Outcomes and Reflections

After a full cycle of development and pilot implementation, the course has achieved phased success across multiple dimensions. Significant results have been achieved in resource development. The course has established a knowledge graph comprising 132 knowledge points and 468 relational edges, uploaded 89 teaching videos (totaling over 900 minutes), and created a test question bank with 472 items. The course website has accumulated over 4.86 million visits, reflecting high-frequency usage and broad influence of the resources.

Students’ learning outcomes have improved. In the “Cardiac

Pump Function” teaching unit, the classroom assessment accuracy rate exceeded 90% after implementing the AI simulator; in the “Blood Types and Transfusion Principles” unit, the accuracy rate for ABO typing questions reached 92% after the application of the AI blood type simulator. Keywords such as “pride,” “responsibility,” and “dedication” featured

prominently in students' reflection logs, demonstrating that the emotional learning objectives have been strongly achieved. Questionnaire findings revealed that 90% of students rated AI interactive simulations as "very helpful" for their learning.

Teachers' capabilities have developed in tandem. In the course of developing digital and intelligent curricula, the teaching team has significantly advanced their digital literacy and instructional capabilities. Team members have repeatedly won the university-level honor of "Outstanding Teacher in Comprehensive Teaching Quality Evaluation" and have published a number of papers on AI-enabled teaching.

In practice, we have also gained several important insights. First, technology serves as a means rather than an end. The value of AI simulators and knowledge graphs lies in assisting students in comprehending abstract physiological mechanisms, rather than replacing teachers' pedagogical judgment. Teachers remain the primary designers of instruction, with technology serving to support the achievement of educational goals. Second, personalization requires appropriate guidance. Some students experience difficulty when confronted with personalized learning paths, requiring teachers to provide moderate guidance on learning pathways and strategies. Third, the appropriateness of visualization tools. The design of AI simulators must closely align with teaching objectives, avoiding the tendency toward technology for its own sake, and ensuring that technological complexity matches the actual needs of classroom contexts.

5. Conclusion

The practice of building the physiology digital-intelligent course demonstrates that integrating knowledge graphs with AI technology offers a viable pathway for reforming medical foundational education. Knowledge graphs address the issue of fragmented knowledge, enabling students to "see" the intrinsic connections among concepts; AI technologies address the challenge of personalized learning, enabling teaching to respond to each student's unique needs; and blended teaching models resolve the disconnect between theory and practice, enabling knowledge to be activated and applied within clinical contexts.

Of course, digital and intelligent transformation is an ongoing iterative process. In the future, the course team will further explore multimodal scenario generation (integrating VR/AR technologies) to enhance immersion and realism in learning; refine the AI-based learning behavior analysis system to create more accurate learning profiles for each student; and build a knowledge graph resource system covering the entire curriculum of medical humanities education, promoting the dissemination and sharing of digital teaching achievements. Only by upholding the fundamental goal of education through technological application can we continuously improve teaching quality within the new ecosystem of human-machine coexistence.

Fund Project

This work was supported by the 2025 Institutional Digital Intelligence Course Development Fund of Sias University (University Education [2025] No. 38).

References

- [1] Zhu Chongxian, Wu Hongxia, Rong Lina, et al. Research on the Path of Digital Reform for Medical Basic Course Groups in Higher Vocational Education Empowered by Knowledge Graphs [J]. Journal of Qiqihar Medical University, 2026, 47(7).
- [2] Research on the Construction and Application of Medical Biochemistry Knowledge Graph under the Perspective of Large-Scale Individualized Teaching [J]. Times Youth, 2025(5).
- [3] Effectiveness of a generative AI-powered digital tutor integrated with a knowledge graph in anatomy education for nursing students: a randomized controlled trial [J]. BMC Medical Education, 2026, 26(1):1026.
- [4] Digital Intelligence Empowers Innovation and Practice in Teaching of Organism Defense and Immunity [J]. Chinese Journal of Immunology, 2025, 41(6).
- [5] Digital Intelligence Empowers Reform and Practice in Basic Medical Education Courses [J]. Zhongguancun, 2026(1).
- [6] Digital Intelligence Course Development Workshop Empowers Teaching Innovation [EB/OL]. School of Medical Devices, Shanghai University of Medicine and Health Sciences, 2025-12-20.
- [7] An Exploration of the Application of Knowledge Graphs in Blended Teaching of Human Anatomy Courses [J]. Journal of Luohe Vocational and Technical College, 2025(2).
- [8] Exploration and Construction of an "AI + Knowledge Graph" Visual Teaching Model for the Biopharmaceutics and Pharmacokinetics Course Based on Outcome-Based Education [J]. Guizhou Medicine, 2026, 50(2):323-328.
- [9] Design Research on a Digital and Intelligent Teaching Platform for the Course "Advanced Nursing Practice in Emergency and Critical Care" Based on Knowledge Graphs [J]. Journal of Nurse Training, 2025(1).
- [10] An Initial Exploration of the Design and Construction of a Pharmacology Course Knowledge Graph [J]. Health Vocational Education, 2024(18).