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Mathematical Intelligence Blended Teaching Model Based on Knowledge Graph – A Case Study of Surgical Nursing

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Abstract. Digital intelligence refers to the integration of digital technologies and intelligent digitalization, which encompasses the development and application of data as a new productive force for societal benefit. Blended teaching has become essential in adapting to the educational advancements of the digital intelligence era. The deep integration of digital intelligence technology and classroom teaching has become the new norm of education and teaching reform. As the core technology of artificial intelligence (AI), a knowledge graph can express the knowledge system visually, integrate educational resources, collect learning process data to realize the monitoring and diagnosis of the learning process and meet the diversified needs of intelligent education applications. It is an effective tool for deeply integrating nursing education and AI. As healthcare technology continues to evolve and knowledge is rapidly updated, students need to continually learn and update their knowledge base so as to keep up with professional development. Therefore, this study explored the practical strategy of digital–intelligent blended teaching of Surgical Nursing by reshaping and integrating the course content, sorting out the course knowledge system, and constructing the course knowledge graph to enable students to systematically master the learning content and access high-quality learning resources. It provided a reference for the digital transformation of higher education, with a view to promoting the consolidation of students' mastery of basic knowledge, improving students' clinical thinking and comprehensive ability to implement holistic care for patients, and cultivating students' ability to acquire and use cutting-edge knowledge.

Keywords. Blended teaching, knowledge graph, mathematical intelligence, Surgical Nursing

1. Introduction

Courses are fundamental in achieving the goal of professional personnel training. Surgical Nursing is a core course in undergraduate nursing education and teaching, which helps nursing students meet the needs of job work, modern clinical nursing development, and health services [1]. This course is highly professional and practical, emphasizing scientific and standardized working procedures in teaching and application.

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In traditional teaching, teachers usually carry out routine teaching based on the theoretical framework of Surgical Nursing and nursing procedures. Teaching content, methods, and format are relatively fixed and monotonous. A large number of nursing students find it boring and difficult to understand. To address this issue, teachers should improve their teaching methods [2]. The Minister of Education, Mr. Huai Jinpeng, delivered a keynote speech on "Joining hands to promote the application, sharing, and innovation of digital education" at the 2024 World Conference on Digital Education. He proposed to widely gather wisdom, effectively build consensus, discuss and share, and join hands to build a new engine of digital education [3]. The digitalization of education is an inevitable outcome of the development of education in this new era. "Internet + education" has not only changed the way teachers teach and students learn but also begun to deeply affect the concept of education, educational culture, and educational ecology [4]. Digital intelligence is the integration of digital technology and intelligent digitalization, which refers to the cultivation and development of data, a new productive force, and the societal benefit of using digital intelligence technology [5]. Educational digitization, as one of the cutting-edge explorations to further advance digital education, aims to promote the digitization of education using the latest digital and smart technologies [6].

Blended teaching is an inevitable approach to adapt to the development of education in the age of digital intelligence. The deep integration of digital intelligence technology and classroom teaching has become the new norm of education and teaching reform, and its advantages have become increasingly prominent [7]. With the integration of "Internet + education" in recent years, platforms have gradually opened up, and various teaching resources have emerged. Examples include, such as catechism, national wisdom education public service platforms, and other online learning resources [8]. It makes students' access to learning resources diversified and convenient [9]. However, the current online education resources, such as Massive Open Online Courses (MOOC), can neither clarify the relationship between various knowledge points of "Medical Nursing" nor accurately locate the weak knowledge points of students. Therefore, automatically recommending learning content such as prior knowledge points and key knowledge points for students is not possible [10]. Moreover, students usually lack an in-depth understanding of the overall knowledge structure, and finding suitable high-quality learning resources in a short time is difficult [11-12]. Given the large and complex number of Internet learning resources, students need to spend a lot of time selecting learning resources, resulting in information overload and low satisfaction with online learning [13-14]. However, educators need to resolve some issues brought about by online education, such as fragmentation of knowledge and uneven quality of online learning resources [15]. Using information technology to help students systematically master course content and quickly and purposefully recommend high-quality learning resources is worth exploring. As the core technology of artificial intelligence (AI), a knowledge graph can visually express knowledge systems, integrate educational resources, collect learning process data to enable monitoring and diagnosis of the learning process, and meet the diversified needs of intelligent education applications. It is an effective carrier for the deep integration of nursing education and AI [16]. Currently, the knowledge graph has become one of the research hotspots in the field of AI and natural language processing [17-18]. It is mainly used in education and teaching to assist teaching, knowledge management, and personalized learning [19-21].

Our school's "Surgical Nursing" course is a provincial-level blended online and offline first-class course. Using modern information technology and the carrier of the

Super Star MOOC platform, this study maximized the use of all types of high-quality teaching resources and explored mixed online and offline teaching systems. It restructured and integrated the curriculum content, organized the curriculum knowledge system, and constructed a curriculum knowledge graph to enable students to systematically master the learning content and obtain high-quality learning resources. This approach helped students systematize the fragmented knowledge points in the learning process, allowed students to choose the learning content, arranged the learning progress and learning plan independently as the main learning body, built the overall knowledge network, and laid a solid foundation for learning. Through exploring a practical framework for digital–intelligent blended teaching in Surgical Nursing, we aimed to enhance students' understanding and retention of fundamental knowledge, refine their clinical reasoning and comprehensive capabilities in delivering holistic patient care, and foster their ability to acquire and apply cutting-edge information. This endeavor sought to provide valuable insights for the digital transformation of higher education.

2. Construction of Knowledge Graph for Surgical Nursing Course

2.1. Optimization of the curriculum system and enrichment of the curriculum resources

Based on the outcome-based education concept, which focuses on being "outcome-oriented and student-centered," we used a reverse-thinking approach to build the curriculum [22]. We changed the traditional lecture model with textbook chapters and then reshaped and integrated the course content using a "disease-oriented" approach. The content covered anesthesia, trauma, oncology, craniocerebral diseases, thoracic diseases, abdominal diseases, and so on. Teaching tasks were developed according to the teaching objectives, and the teaching tasks were organized into separate knowledge units. For this purpose, it was necessary to organize the entire course into modules according to the knowledge structure and refine these modules into hierarchical individual knowledge units based on the characteristics of the knowledge graph. The course system was restructured and integrated to incorporate the main content lines of typical clinical cases. It was based on teaching theoretical knowledge around the etiology and pathology of diseases, clinical manifestations, treatment, and nursing care, with reference to the latest research progress and clinical guidelines. The course team accurately constructed a high-quality teaching resource base based on knowledge points. The resources included 229 teaching videos, 365 nonvideo resources, and 746 other course materials. The types of resources included multimedia courseware, videos, cases of course ideology, mind graph, CiteSpace-based visualized knowledge graph, references of the latest research progress, quiz questions, and so on. They were prepared as materials for students to construct the knowledge framework.

2.2. Design of the overall framework of the knowledge graph

The curriculum team built a knowledge graph of the curriculum from the four levels of knowledge system, knowledge domain, knowledge unit, and knowledge point, from top to bottom level by level, and then formed a structured knowledge system. Guided by the curriculum objectives, we adopted the two routes of "chapter–section–knowledge point–

curriculum resources" and "knowledge area–knowledge unit–knowledge point–curriculum resources" to design the overall framework of the knowledge graph. We extracted key knowledge points and constructed a multi-level, net-like structured knowledge point system based on the structured data in the syllabus and textbooks, taking diseases of the urinary system as an example (Table 1).

Table 1. Design of the overall framework of the knowledge graph for Surgical Nursing

Knowledge area	Knowledge unit	Knowledge point	
		Level 1	Level 2
Nursing of patients with urinary system diseases	Nursing of patients with urinary calculi	Upper urinary tract stones	Etiology; Pathophysiology; Clinical manifestations; Auxiliary inspection; Handling principles; Nursing assessment; Nursing diagnosis; Nursing measures; Nursing evaluation
		Lower urinary tract stones	Etiology; Pathophysiology; Clinical manifestations; Auxiliary inspection; Handling principles; Nursing assessment; Nursing diagnosis; Nursing measures; Nursing evaluation
	Nursing of patients with urinary system injury	Kidney injury	Etiology; Pathophysiology; Clinical manifestations; Auxiliary inspection; Handling principles; Nursing assessment; Nursing diagnosis; Nursing measures; Nursing evaluation
		Bladder injury	Etiology; Pathophysiology; Clinical manifestations; Auxiliary inspection; Handling principles; Nursing assessment; Nursing diagnosis; Nursing measures; Nursing evaluation
		Urethral injury	Etiology; Pathophysiology; Clinical manifestations; Auxiliary inspection; Handling principles; Nursing assessment; Nursing diagnosis; Nursing measures; Nursing evaluation
	Nursing of patients with hyperplasia and tumors of the urinary and male reproductive system	Benign prostatic hyperplasia	Etiology; Pathophysiology; Clinical manifestations; Auxiliary inspection; Handling principles; Nursing assessment; Nursing diagnosis; Nursing measures; Nursing evaluation
		Carcinoma of the bladder	Etiology; Pathophysiology; Clinical manifestations; Auxiliary inspection; Handling principles; Nursing assessment; Nursing diagnosis; Nursing measures; Nursing evaluation

2.3. Association of the knowledge graph

Starting from the extracted knowledge points, the course team analyzed the connection between them and the logical relationship between various course resources (covering multiple subcategories such as textbooks, videos, exercises, etc.). Then, the sequential and containment relationships among them were clarified. We connected the knowledge points through the curriculum resources, analyzed the inclusion and sequential relationships according to the two lines of the design, used the knowledge points to support the curriculum objectives, and distinguished the relationship to which the knowledge points belonged (Fig. 1). The specific steps were described next.

The first step was to organize the knowledge points of the course according to the syllabus. Starting from the knowledge domain, the knowledge units (chapters and sections) were related, and the knowledge points at all levels (level 1 and level 2) were deconstructed to achieve "granularity" refinement.

The second step was to establish the relationship between knowledge points. The knowledge points were linked together based on different logical structural relationships, such as hierarchical relationships, antecedent relationships, correlation relationships, and so forth, to facilitate the formation of the knowledge system.

In the third step, course resources, such as multimedia courseware, videos, cases of course contemplation, mind maps, references to the latest research advances, quiz questions, and so on, were linked to knowledge points. This process focused on student development and was aligned with graduation and professional certification requirements. Then, tags were created for each knowledge point, such as key points, difficult points, test points, and course ideology and politics, to be associated and retrieved in the knowledge graph.

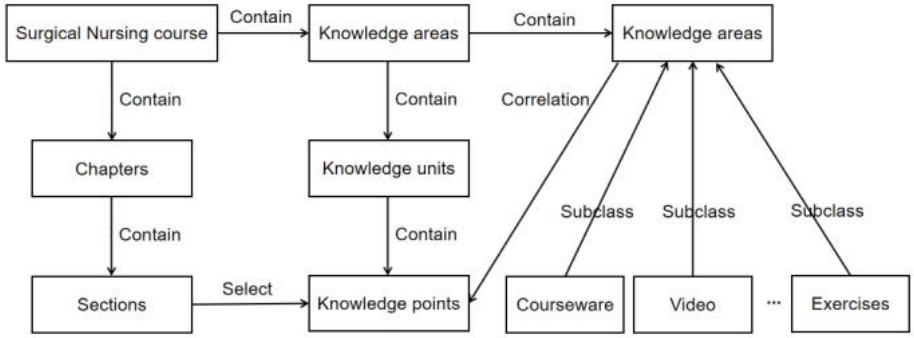

Figure 1. Relationship between the attributes of the Surgical Nursing course.

3.Knowledge Graph–based Mathematical Intelligence Blended Teaching

The course team constructed a knowledge graph-based digital–intelligent blended teaching model based on the knowledge graph from the three major elements of system, subject, and activity, using the Super Star Catechism platform as the carrier and making full use of the modern digital technology in the era of digital intelligence. System refers to the platform and tools supporting the development of smart classroom teaching. Subject refers to teachers and students. Activity refers to the three teaching segments of smart classroom teaching practice: before, in, and after class. We designed a flowchart of the knowledge graph–based mathematical intelligence blended teaching model (Fig. 2) to make the model more replicable and operable, with the smart teaching process as the main axis, starting from the dual roles of teachers and students.

The operation of the whole model included three links before, in, and after class, combining knowledge graphs with classroom teaching. It provided a positive cycle of support for smart teaching and constituted a process cycle of continuous improvement of education through the four steps of guiding–teaching–learning–assessing. The specific process of the model was discussed in the following sections.

3.1. Learning online (Guide)

Before class, the teachers assigned learning tasks online, guided students through relevant course chapters using the knowledge graph and showed students the chapter's knowledge points and their relevance. Students could initially master the lower-order

knowledge learning in Bloom's cognitive law through cases and independent learning tasks (with teaching content, teaching objectives, discussion topics, etc.) through micro-class learning and online discussion. Teachers checked students' mastery of knowledge online before class to provide a basis for offline classroom instruction.

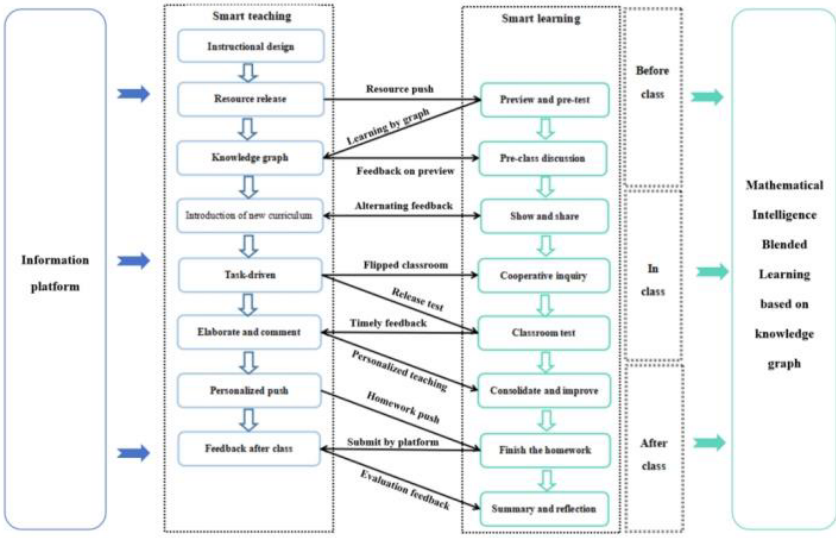

Figure 2. Flowchart of knowledge graph–based mathematical intelligence blended teaching model.

3.2. Raising competence offline (Teaching)

Offline, the teacher first showed the knowledge graph of each chapter, learning along the "map", and grasping the teaching objectives, key points, and difficulties of the course from a global perspective. Different forms were used for different teaching difficulties, such as etiology and pathophysiology, which could be taught by the heuristic teaching method to guide students in understanding the process of disease occurrence and development. Taking the chapter "Upper Urinary Tract Stones" in Surgical Nursing as an example, using a heuristic teaching method to explain the cause of disease and pathophysiology could guide students in understanding the disease occurrence and development process. The case teaching method was applied because the clinical manifestations were the key knowledge. This helped students independently refine the characteristics of the clinical manifestations of diseases from clinical examples, which enhanced their memory. Treatment methods were explained in detail using illustrations, which covered complex topics. Nursing measures belonged to operational knowledge. The content could be visualized more vividly by playing relevant operation videos and other online teaching resources. Nursing operations could be simulated and practiced by applying the scenario-based simulation teaching method and role-playing. After completing some content-intensive lectures, teachers conducted flipped classroom knots or Problem-Based Learning (PBL) pedagogy. Students were asked to follow pre-assigned groups for staged classroom in-group discussions to enhance their understanding and higher-order learning skills. In addition, teachers used the Super Star Learning Pass platform for classroom check-in, questioning, discussion, testing, voting,

and so forth to fully mobilize students' participation and enthusiasm in classroom learning.

3.3. Consolidation and internalization after class (Learning)

After the class, the teacher assigned online homework and pushed personalized learning resources based on the self-study portrait before the class and the effectiveness of teaching during the class. Teachers answered questions or communicated online. Students further consolidated and internalized their knowledge and skills through AI-teaching assistants and chapter quizzes.

3.4. Double-drive assessment using diagrams and numbers (Assessment)

Teachers could understand the students' mastery of each knowledge point through the feedback of the knowledge graph in the Super Star Catechism platform. Students could discover their knowledge weaknesses in this class through the "personalized chemistry diagnosis" of the knowledge graph. They also carried out personalized learning for some knowledge points that they had not mastered well through the personalized learning path and learning resources recommended by the knowledge graph. Taking "Nursing of transplant patients" as an example, the average completion rate of students was 93%, the average completion rate of watching the video of "3D animation demonstrating the process of kidney transplantation" was 91.86%, and the average completion rate of reading references in recommended resources was 93.02%. Students showed significant interest in expanding resources. However, the mastery rate of the chapter test was 100% at the highest level, 30% at the lowest level, and 63.14% on average, which needed to be further improved. The lowest correct rate was for the 10th question, which was only 38.2%, indicating that students had a poor grasp of the clinical manifestations of different rejection reactions of organ transplantation.

3.5. AI-assisted smart teaching

- Intelligent recommendation resource

The knowledge graph could automate the crawling of associated resources on the Internet to obtain cutting-edge multimodal teaching resources. It dynamically provided students with more timely, cutting-edge, and higher-quality resources to share so as to meet their personalized development needs as well as competency development goals. Teachers could add multimodal teaching resources with one click and link them with related knowledge points. Students also selected relevant resources for extended learning according to their interests in the Student Terminal of Learning Pass, such as open classes, journals, books, and so forth. Thus, student-centered intelligent learning was realized.

- AI-teaching assistant

In addition, an AI-teaching assistant was introduced in the online course of Surgical Nursing. The AI-teaching assistant extracted all the knowledge from micro-classes, catechisms, textbooks, lesson plans, problem libraries, and other digital teaching resources in the course system to form a powerful knowledge base. It also used large

models to train the question-and-answer bank and course materials to realize intelligent questions and answers in course content. Teachers used AI-teaching assistants to intelligently generate lesson plans, intelligently write chapter contents, intelligently generate courseware PPT, and intelligently issue questions. They also used AI-teaching assistants to complete intelligent marking of subjective questions, checking assignments, and analyzing learning conditions. Students could communicate conversationally with AI-teaching assistants in the form of text and voice, and quickly find various learning resources such as books, journals, papers, course resources, and so on at the same time. They could also complete study behavior supervision, study companion reminders, personalized study paths, personalized self-test practice, and so forth through AI-teaching assistants.

4. Limitations and Prospects

A knowledge graph serves as a structured repository that systematically represents and organizes information in graphical form. The integration and organization of fragmented knowledge have positively contributed to the systematic mastery of curriculum content and the linkage of high-quality learning resources to some extent [23-24]. Developing a curriculum knowledge map necessitates extensive medical expertise and data, alongside significant time and resource investment, complicating its construction [25]. This study achieved preliminary development of the curriculum knowledge graph; however, it was subject to certain limitations. It is essential to engage experts from relevant fields for evaluation and guidance in subsequent phases, such as ensuring that each knowledge point aligns with practical topics, clarifying phased learning tasks, and constructing problem graphs, which will be highly beneficial for further enhancement of the knowledge graph.

Moreover, this study was not comprehensively implemented in a complete cycle of teaching practice research. The evaluation of learners' learning outcomes was limited to two indicators: the completion rate of certain knowledge points and the mastery rate, which failed to provide a holistic representation of learners' profiles and necessitated further exploration and innovation. Zhao Linglang [26] explored the design and application of learner portrait models based on knowledge graphs and demonstrated that such models could facilitate functions including data acquisition and preprocessing, construction and analysis of portrait models, generation of portraits, and precise application thereof. An accurate curriculum evaluation index system should be established to assess learners' knowledge mastery, skill attainment, and learning preferences at each knowledge node in future endeavors. This may allow for separate analyses of learner groups as well as individual students, ultimately leading to the creation of personalized learner portraits alongside group portraits reflecting students' abilities, preferences, and knowledge characteristics [27].

5. Summary

The construction of a curriculum knowledge graph with the help of AI is of profound significance, as it can not only promote students' personalized learning and teachers' precise teaching but also effectively link curriculum resources [28]. The construction of online courses based on knowledge graphs helps effectively integrate the resources of

different teaching platforms, form a three-dimensional knowledge network, and improve the knowledge system of students. It no longer requires that teachers complete the relevant teaching tasks simultaneously. Students can also learn independently according to the actual learning situation. The teaching mode under this curriculum system is more flexible and free, which aligns with the new concepts of precision education and intelligent education. In addition, this model helps cultivate students' independent learning ability, logical thinking ability, and knowledge creation ability, thus laying the foundation for lifelong learning [29].

Knowledge graphs can dynamically assess students' mastery of knowledge in real time in blended learning. They provide learners with personalized learning experiences such as tailored learning paths and rich learning resources, thereby providing a new solution for tailored teaching at scale [30]. Knowledge graph-based mathematical intelligence blended teaching caters to the Smart Education trend of openness, individuality, and precision. It also sheds light on the development of online courses for other professional fields, which is worth further exploration and promotion.

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