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Teaching Design and Practice of Integrating AI Agents and Knowledge Graphs in Secondary Vocational "Circuit Fundamentals"

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Abstract: ***In the process of secondary vocational education reform, utilizing AI agents and knowledge graph technology to transform traditional teaching methods has become a prominent research topic. This paper addresses the long-standing practical issues in the teaching of the secondary vocational "Circuit Fundamentals" course, such as the abstract nature of its knowledge structure, significant student diversity, and a single evaluation method. Consequently, it proposes a new teaching model that integrates AI agents and knowledge graph technology. By constructing a circuit knowledge graph, knowledge is presented visually and systematically; AI agents are utilized to support personalized learning and the design of adaptive learning paths; finally, combined with an intelligent evaluation system, a multi-dimensional, process-oriented evaluation model is implemented. Teaching practice shows that this model can effectively enhance classroom teaching efficiency and effectiveness, promote personalized learning, and provide a referential implementation path for the reform of secondary vocational circuit course teaching.***

Keywords: Artificial Intelligence; Knowledge Graph; Personalized Learning.

1. INTRODUCTION

With the rapid development of artificial intelligence technology and knowledge graphs, their application in the field of education has garnered widespread attention from many experts and scholars. Research on smart teaching, leading educational development, can be broadly divided into three stages. The first is the initial stage, involving the theoretical foundations and supporting environment for smart teaching; the second is the rapid development period, involving key technologies of smart teaching and the implementation and development of smart education; the third is the application period, where smart education research shifts from primary and secondary schools to vocational education [1]. Taking the national-level teaching master's course "Computer Architecture" as an example, based on the domain learning model MDL and the COST (Content-Others-Self-Task) instructional design framework, this study systematically analyzes the theoretical and practical paths for the deep integration of artificial intelligence in teaching [2]. The transformation of education through AI, on one hand, utilizes large amounts of data to form knowledge graphs, recommend personalized educational resources, and achieve educational precision; on the other hand, through changes in teaching methods, it shifts the teacher's primary role from imparting knowledge to cultivating ways of thinking [3]. This research focuses on secondary vocational electronic specialty courses. As a foundational core course for electronic specialties in secondary vocational education, "Circuit Fundamentals" has long faced practical teaching problems such as a tightly structured and highly abstract content that is difficult to systematize; a student population with significant diversity, making personalized teaching challenging; and a single form of teaching evaluation, making it difficult to implement multi-dimensional evaluation standards. Based on this, a new classroom teaching model integrating AI agents and knowledge graph technology is designed, constructing the overall logic of the course from both curriculum structure and teaching process dimensions, and applying it in teaching practice to achieve the goal of improving teaching efficiency and effectiveness.

2. THEORETICAL FOUNDATION

2.1 AI Technology Facilitating Human-Computer Collaboration

The "Circuit Fundamentals" course utilizes the Chaoxing Learning Platform to assist teachers in conducting classroom teaching, constructing a chapter-based knowledge graph for the course through AI technology. AI agents, as extensions of individual cognition, can play multiple roles throughout the teaching assistance process, such as tutor, learning companion, and evaluator. Through active and effective interaction with the teaching assistance platform, students can achieve an adaptive learning mode, realizing the effect of human-computer collaboration and aiding student thinking and deeper exploration, thereby enabling a precise teaching model.

2.2 Educational Application of Knowledge Graphs

The concept of knowledge graphs can be divided into two major categories based on the field. The first is "scientific knowledge mapping" in the field of information resource management, primarily used for bibliometric analysis. The second, in the field of computer science, is the "large-scale knowledge graph" proposed by Google, mainly targeting scientific literature knowledge. The knowledge graphs involved in the current field of artificial intelligence also mainly refer to Google's "large-scale knowledge graph," a new form of data organization that can present knowledge frameworks in a more structured and systematic way, thereby deepening the intrinsic connections between knowledge points and forming a semantic network, greatly simplifying the process of understanding and constructing knowledge [4]. The knowledge graph for the "Circuit Analysis" course is used to organize and represent the structured, systematic, and hierarchical knowledge system of the course. Nodes represent entities in the real world, while edges represent relationships between entities, indicating various types of concepts and intrinsic connections through nodes and edges. In the circuit course, nodes represent basic circuit concepts, formulas, theorems, etc., while edges describe the logical structure and relationships between parts. For AI technology in education, a knowledge graph is the abstract representation of complex circuit knowledge; constructing a circuit knowledge graph is constructing the AI agent's overall cognition of the course. Using such a graph model can better present the intrinsic connections between knowledge points and enhance learners' cognition and understanding of the logic of knowledge composition.

2.3 Cognitive Load Theory

Cognitive Load Theory is one of the key theories for deeply understanding the teaching process. The instructional design process should fully consider the learner's cognitive load. The circuit knowledge graph presents the intrinsic connections between all knowledge points in the course through a structure of nodes and edges, enhancing the logicality and systematicity of knowledge, thereby reducing the learner's extraneous cognitive load. Utilizing the AI-assisted teaching mode of the Chaoxing Learning Platform, covering all learning stages from pre-class preview of new knowledge to post-class Q&A guidance, can effectively optimize the learner's germane cognitive load and promote schema construction.

3. DESIGNING THE COURSE TEACHING APPROACH

3.1 Integrating AI to Design a Circuit Knowledge Graph, Forming a Knowledge System

In circuit teaching, a knowledge graph designed based on the theoretical foundation of cognitive load theory can deepen the understanding of circuit knowledge. The circuit knowledge graph presents the key course content systematically, structurally, and hierarchically, helping learners intuitively understand the connections between knowledge points and form a systematic learning knowledge module. For example, the knowledge graph can break down complex circuit structures into networks of basic concepts, presenting a dynamic, visual data model that allows students to clearly see the intrinsic connections between parts. The visual characteristics deepen students' understanding of abstract concepts, while their dynamic nature increases students' initiative and autonomy during the teaching process, allowing students to autonomously choose suitable learning paths based on individual differences. When students learn a certain knowledge point, they can also be matched with exercises of comparable difficulty to promote deeper understanding of the knowledge. Simultaneously, teachers can timely arrange and adjust teaching strategies based on students' homework feedback, implementing teaching plans more targeted.

3.2 Achieving Personalized Learning

Personalized learning is not only a basic implementation path in education and teaching but also reflects educators' long-term pursuit and value of the essence of teaching. Utilizing the circuit knowledge graph combined with the learning assistance platform to carry out personalized teaching and learning modes allows for the precise analysis of each student's specific learning situation, thereby reasonably planning learning paths and methods that meet individual needs. The clear presentation of the knowledge graph enables accurate understanding of each student's mastery of knowledge points. Based on existing learning data, current teaching strategies can be timely optimized and improved to better align with actual teaching needs. This not only improves students' learning efficiency but also further enhances teachers' teaching efficiency, achieving mutual improvement in teaching and learning [5].

3.3 Implementing Multi-dimensional Evaluation

In teaching practice, accurate and effective teaching evaluation plays a positive role in improving teaching effectiveness and student learning efficiency. Modern intelligent evaluation systems are a key link in enhancing teaching and learning outcomes [6]. Utilizing the circuit knowledge graph to clearly analyze students' mastery of chapter knowledge points and weak areas can also accelerate the implementation of personalized teaching. Leveraging the powerful analytical capabilities of AI, students' overall learning progress in the course can be dynamically analyzed periodically, and detailed analysis reports can be compiled for reference in personalized evaluation. This facilitates a more comprehensive and accurate understanding of students' mastery of the course and allows for personalized improvement suggestions and requirements, enabling phased predictions for future continued learning of the course. Consequently, teachers can formulate more targeted teaching strategies to enhance teaching efficiency. Intelligent evaluation also helps students correct common misconceptions and consolidate mistakes, improving learning effectiveness and efficiency.

4. COURSE TEACHING PRACTICE

4.1 Systematic Reconstruction of Teaching Content

In the teaching process of the circuit course, besides traditional paper textbooks and teaching aids, students can acquire knowledge through intelligent learning platforms, presenting digital and diversified knowledge systems. Traditional paper textbooks are more of a pile-up and arrangement of knowledge points, and students can only understand the sequence through chapter presentation. In contrast, leveraging the knowledge graph technology of the learning platform can present knowledge in an orderly manner that conforms to students' cognitive schemas. This process involves the reorganization and deep processing of knowledge. Through intelligent analysis and processing of circuit knowledge, a deep connection is largely established between the learning content and the learners, moving beyond rote learning.

4.1.1 Clarifying Teaching Objectives, Defining Course Positioning

Teaching objectives, as pre-set expectations by the teacher before the course begins regarding the specific, measurable learning outcomes or changes in learning behavior that students should achieve after systematic classroom learning, play a crucial role in precise positioning throughout instructional design and teaching [7]. Their essence is an accurate description of the expected changes in learners, i.e., based on the learners' existing knowledge level and abilities, defining the overall level and abilities that should be attained upon completion of the entire course.

Circuit Fundamentals is a core foundational course for secondary vocational electronic specialties. This course is not only highly theoretical and logical but also considerably practical. Therefore, when formulating the teaching objectives for this course, full consideration must be given to the coordination between these two types of objectives, as well as the ability level and adaptability conditions of secondary vocational students. (1) Positioning of basic course objectives. According to Bloom's Taxonomy of Educational Objectives, course objectives are classified into cognitive, affective, and psychomotor domains. Teachers, from the student's perspective and combined with the intelligent knowledge graph, analyze each student's mastery. These objectives can exist as independent entities, separately indicating a student's mastery of a specific knowledge point, or they can be combined into multi-dimensional complex objectives, considering different levels and domains. (2) Positioning of advanced course objectives. This target group is more oriented towards students of different ability levels, also reflecting the personalized teaching model. Students need to complete more logical, systematic actual complex circuit problems or be able to design reasonable circuit models independently to achieve higher-order objectives. Of course, both basic and advanced course objectives are composed of the most fundamental teaching objectives. Therefore, clear, specific, and feasible teaching objectives are an important foundational link for effective teaching.

4.1.2 Integrating Multi-modal Resources to Construct the Course Knowledge Graph

According to the knowledge construction methods proposed by information processing theory, a single form of knowledge acquisition is no longer sufficient to satisfy the diverse learning modes of current students. Students' effective listening time is limited; thus, the integration of different senses is needed for consistent semantic representation and associative understanding of the course knowledge. Cross-media knowledge graphs analyze and acquire knowledge points through senses like vision and hearing, associate entity knowledge from different media sources, and provide corresponding technical support for the fusion of knowledge across different media. First, corresponding video, image, and text-based knowledge content needs to be processed using cross-media technology to identify the knowledge entities within. Next, the knowledge expression forms from different media are projected into a unified semantic space. Finally, classification is performed according to the structure of the knowledge graph, and similar content is fused.

4.1.3 Visualizing Knowledge Structure for Knowledge Learning

Constructivist theorists believe that knowledge is constituted by concepts, propositions, principles, and their interrelationships, emphasizing the basic concepts, principles, and methods that constitute a discipline. The essence of learning is the learner's active formation or reorganization of their own cognitive structure. Visualizing the course knowledge structure involves using intelligent knowledge graph technology to structurally present knowledge points such as concepts, principles, and method compositions in the form of schemas or charts to learners, providing them with reasonable and effective learning assistance tools. This also conforms to the general laws of student learning, providing a cognitive scaffold [8]. Currently, the visualization of circuit knowledge based on knowledge graphs has become one of the important teaching tools assisting teacher classroom instruction and student course learning. Taking the Chaoxing Learning Platform used in this course as an example, it employs knowledge graph technology to construct a knowledge system for students, thereby assisting their learning.

4.2 Integrating Intelligent Knowledge Graphs to Achieve Personalized Learning

Personalized learning not only reflects the student-centered teaching philosophy but is also the intent behind designing intelligent knowledge graphs, fully leveraging the structural function of the circuit knowledge graph. The personalized learning paths constructed based on the circuit knowledge graph can effectively integrate complex, fragmented, and non-systematic circuit knowledge into a logical, coherent, and systematic form presented to each student. While conducting learning combined with the smart platform, each student's cognitive style, existing knowledge base, and personality characteristics are comprehensively considered, thereby enabling the personalized provision of learning paths and methods suitable for each student [9].

Based on the analysis of the student learning process, the personalized learning stages can be specifically divided into the following steps. The first stage is primarily the personalized pre-assessment stage. Before the circuit course officially begins, a pre-course knowledge diagnostic test is conducted for students. Based on the test results, each student's knowledge weaknesses and unclear concepts are analyzed, and combined with the student's personality characteristics and learning style, a learning database is generated. This is then dynamically adjusted following the student's learning progress and state. The second stage is mainly the personalized cognitive analysis stage. This stage requires synthesizing the student's pre-assessment results and their state and progress during the course learning process to analyze the student's overall grasp of the course. For example, some quantitative terms can be used to accurately describe the student's current learning progress: whether they can accurately understand a certain circuit concept, clearly draw required circuit analysis diagrams, reasonably use what they have learned to solve simple circuit problems logically, and so on. The third stage is the formation of a personalized knowledge sub-graph. Based on the student's cognitive style, learning state, current learning level, etc., a learning knowledge sub-graph is extracted for the student from the existing circuit knowledge graph. This can be subdivided into several sub-knowledge graphs based on the student's mastery level of knowledge, including dimensions such as well-mastered knowledge, easily confused knowledge, and difficult-to-understand knowledge. The fourth stage is the personalized learning recommendation stage. This stage includes the recommendation of corresponding learning resources and the selection of basic learning paths, providing suitable options for students to truly implement personalized learning suited to themselves. Additionally, some extracurricular extended learning resources can be gradually provided, such as public account resources, learning videos, etc., gradually increasing the depth of students' personalized learning.

4.3 Utilizing AI and Knowledge Graphs to Conduct Intelligent Evaluation

The Circuit Fundamentals course is highly practical, requiring students to combine theoretical knowledge with practical training or operations. Improving the traditional assessment and evaluation mechanism by combining process-oriented evaluation and result-oriented evaluation pays more attention to students' dynamic changes during the learning process rather than a single dimension, achieving an intelligent multi-dimensional evaluation model [10]. Course evaluation can be divided into basic evaluation and advanced evaluation based on different standards.

Basic evaluation primarily targets general question types, such as well-structured multiple-choice questions and true/false questions. These question types are usually interspersed between chapter contents, mostly examining students' short-term memory and understanding of basic concepts. The number of questions and their difficulty levels are set according to the importance of the chapter knowledge. This can serve as an evaluation standard for students' mastery of knowledge points and also provide feedback to teachers for timely adjustment and improvement of teaching strategies. The grade distribution for each part consists of process evaluation scores and comprehensive evaluation scores, each accounting for 50%. Process evaluation can be subdivided into self-evaluation and teacher evaluation. Self-evaluation includes online video resources for self-learning, end-of-chapter unit tests, reflections, and discussions. Teacher evaluation includes online learning performance and evaluation results of staged course assessments. Comprehensive evaluation also includes self-evaluation and teacher evaluation, but compared to process evaluation, it adds a peer evaluation component. This side evaluation method can provide a more objective and comprehensive evaluation analysis of students, reflecting their comprehensive application abilities.

Advanced evaluation targets students with higher starting points and solid foundations. Students, based on having spare capacity and their actual situation, can increase the difficulty and depth of course learning, independently choose practical training projects, apply theoretical circuit knowledge in practice and training, form study groups for cooperation, use circuit simulation models, build complete circuits according to implementation goals and conduct circuit analysis. Finally, scores are given based on the completion status of each group and the contribution level of each student, graded accordingly. The entire assessment process includes self-evaluation, peer evaluation, and teacher evaluation, comprehensively evaluating students' cognitive abilities, teamwork awareness, and comprehensive capabilities from different angles. Teacher evaluation focuses more on students' cognitive abilities and comprehensive practical abilities, accounting for 60%, while student self-evaluation and peer evaluation each account for 20%, reflecting students' autonomous abilities and teamwork skills.

Such an intelligent and multi-dimensional evaluation model effectively helps students improve their paths to mastering knowledge and enhances circuit learning efficiency. Simultaneously, teachers can understand each student's current dynamics in real-time through intelligent evaluation reports and timely adjust teaching strategies, achieving improvements in class teaching efficiency and effectiveness.

5. SUMMARY

Implementing the instructional design for the "Circuit Fundamentals" course based on AI agents and knowledge graph technology has achieved significant results and improvements. Circuit knowledge graph technology, aided by the teaching and learning platform, conducts in-depth analysis of all knowledge points in the circuit course and systematically strengthens the intrinsic connections between them. Utilizing this tool not only aligns with the logic of students constructing their knowledge system but also contributes significantly to enhancing teaching and learning efficiency and effectiveness. Especially in the aspect of personalized learning, its advantages are fully demonstrated. By deeply analyzing students' learning dynamics and knowledge mastery, adjustable learning plans and arrangements are formulated, better meeting students' personalized needs, thereby effectively enhancing learning interest and outcomes. Progress made in constructing AI agents and learning feedback also provides a referential model and ideas for conducting similar courses in the future.

Future circuit course teaching will continue to undergo significant changes with the support of AI agents and knowledge graph technology. AI agents will provide students with more convenient personalized learning modes, fully leveraging student autonomy and independent abilities; knowledge graphs will profoundly reveal the intrinsic connections between knowledge points, making it easier for students to understand the logic of the knowledge structure. Throughout the teaching model, the student-centered teaching philosophy is embodied, providing students with rich learning resources and various learning tasks, which can effectively stimulate students' learning interest and thirst for knowledge, thereby enhancing their innovative thinking and problem-solving abilities.

REFERENCES

[1] Zhang Xiumei, Tian Tian, Tian Mengmeng, et al. The Evolution and Trends of Smart Teaching Research in my country in the Past Decade [J]. China Distance Education, 2020, (09): 62-69. DOI:10.13541/j.cnki.chinade.2020.09.008.
[2] Chen Juanjuan, Zhang Yuping, Zhang Zihui, et al. Exploration of Deep Integration of Artificial Intelligence into Teaching Based on Domain Learning Model—Taking a National-Level Teaching Master's Course Based on "Zhejiang University Professor" as an Example [J]. Higher Engineering Education Research, 2025, (04): 27-35.
[3] Sun Yan. From "Knowledge Graph" to "Human-Computer Collaboration"—On the Reshaping and Challenges of Artificial Intelligence Education for Teachers [J]. Higher Education Exploration, 2021, (03): 30-37.
[4] Deng Shuo, Yan Yan. The Innovation and Role of Knowledge Graphs in Teaching in the Digital Intelligence Era [J]. Journal of Hebei Normal University (Educational Science Edition), 2024, 26(05): 100-102. DOI:10.13763/j.cnki.jhebnu.ese.2024.05.012.
[5] Liu Fengjuan, Zhao Wei, Jiang Qiang, et al. Research on Personalized Learning Model and Support Mechanism Based on Knowledge Graph [J]. China Educational Technology, 2022, (05): 75-81+90.
[6] Zhang Zhenrong. Construction of Mathematical Knowledge Graph and Exploration of the Application of AI Large Models in Mathematics Education [C]//China Smart Engineering Research Association. Proceedings of the 2025 Quality Education Innovation and Development Exchange Conference (Volume 1). Qingdao Huanghai College, 2025: 297-299. DOI:10.26914/c.cnkihy.2025.024256.
[7] Wang Wenjing, He Xiaowei. Research on the Construction of New Forms of Courses Based on Knowledge Graph/AI Technology [J]. Education and Teaching Forum, 2025, (16): 48-51. DOI:10.20263/j.cnki.jyjxlt.2025.16.028.
[8] Zhang Yanning. Research on AI-assisted database course design and implementation based on knowledge graph [J]. Information Systems Engineering, 2025, (07): 48-51.
[9] Li Zhen, Zhou Dongdai, Wang Yong. Educational Knowledge Graph under the Perspective of "Artificial Intelligence+": Connotation, Technical Framework and Application Research [J]. Distance Education Journal, 2019, 37(04): 42-53. DOI:10.15881/j.cnki.cn33-1304/g4.2019.04.006.
[10] Yang Bing, Li Yiyuan, Lei Peng. Teaching Practice of "Full-Stack Development of Multimedia Websites" Course Based on AI Knowledge Graph [J]. Western Quality Education, 2025, 11(09): 133-137. DOI:10.16681/j.cnki.wcqe.202509029.