An Exploration of Blended Teaching in Advanced Mathematics through the Integration of Knowledge Graphs and AI Teaching Assistants

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Abstract: In the context of educational informatization and higher education reform, the blended teaching model plays a crucial role in the innovation of advanced mathematics education. Research shows that the deep integration of knowledge graphs and AI teaching assistants effectively addresses the issues of fragmented knowledge systems and insufficient personalized support in blended teaching. By providing structured knowledge presentation and intelligent learning support, it significantly enhances students' autonomous learning abilities and knowledge retention efficiency. This approach offers a feasible practical path for the intelligent teaching reform of foundational courses in science and engineering.

Keywords: Knowledge graphs; AI teaching assistants; Blended teaching; Advanced mathematics

1. Introduction

In recent years, with the rapid development of information technology, the education sector is undergoing profound transformations. Professor Zhu Zhitin, Director of the Education Informatization Technology Standards Committee of the Ministry of Education, pointed out that smart education encompasses multiple dimensions, including learning environments, learning resources, teaching models, and teaching supervision. Its core goal is to provide students with high-quality learning and developmental experiences [1]. The State Council, in the "New Generation Artificial Intelligence Development Plan," emphasized the need to focus on breakthroughs in technologies such as knowledge graph construction and learning, as well as knowledge evolution and reasoning, aiming to achieve intelligent education and establish a learner-centered educational environment [2].

Knowledge Graphs have made significant progress in fields such as semantic search, intelligent question answering, and personalized recommendations, with their application range gradually expanding from general domains into the education sector [3]. As a structured form of knowledge representation, knowledge graphs can semantically link and organize massive teaching resources, constructing a panoramic view of the disciplinary knowledge system. AI Teaching Assistants have evolved from early-stage intelligent Q&A systems

to virtual learning partners, becoming more powerful and offering a wider range of applications [4]. Leveraging technologies like natural language processing and machine learning, AI teaching assistants have become a significant application of artificial intelligence in education, achieving considerable development. AI teaching assistants can provide comprehensive learning support services, including intelligent Q&A, personalized learning path recommendations, and learning effectiveness assessments.

In 2022, Jilin University launched its AI-based medical course utilizing knowledge graphs, and Beihang University launched the "Engineering Mathematical Analysis" AI-based course, which promoted the practice and research of knowledge graphs in education[4]. In research on foundational science and engineering courses, in 2023, Yang Wenxia et al.[5] took the "Linear Algebra" course at Wuhan University of Technology as an example, using the Neo4j graph database and ECharts chart library for front-end interface design, querying and displaying knowledge graphs, and designing knowledge-based Q&A and recommendation systems to meet personalized learning needs. In 2024, Liang Yongfeng proposed research on building knowledge graphs for higher mathematics courses with the help of AI engines, promoting the development and research of knowledge graphs in university mathematics [6]. Du Zhijuan, addressing issues such as students' inadequate understanding of discrete mathematics and the lack of alignment between knowledge points and problem-solving processes, conducted an in-depth analysis from the perspectives of teaching habits and course content characteristics, proposing a knowledge graph-empowered teaching approach [7]. Liu Shuang further explored the construction of a blended teaching model combining artificial intelligence (AI) and knowledge graphs for higher mathematics, aiming to meet personalized learning needs and improve teaching and learning quality [8]. In 2025, Zhang et al. summarized the design concept, construction, implementation, effectiveness, and reflection of the teacher-student-machine collaborative teaching system [9].

Blended Learning, as a new teaching model that combines traditional classroom teaching with online learning, has gradually become an important direction in higher education reform due to its flexibility and efficiency [10]. However, the promotion of blended learning faces several challenges, such as unclear learning paths for students, insufficient personalized learning support, and teachers' difficulty in accurately understanding the learning situation. These issues, to some extent, restrict the effectiveness of blended learning. Existing AI teaching assistant systems are mostly limited to single functions, lacking a deep understanding of the learning process and personalized support capabilities, making it difficult to meet the growing personalized learning needs of university students. Exploring the application of knowledge graphs and AI teaching assistant technologies in blended learning and constructing an intelligent and personalized learning support system could uncover their potential value and application pathways. This is of significant importance for enhancing students' learning efficiency and improving the effectiveness of blended learning, with the aim of providing new ideas and methods for higher education reform.

2. Knowledge graph and AI teaching assistant construction

2.1. Construction of the knowledge graph based on the Chaoxing learning platform

The course team, based on the provincial-level first-class undergraduate course "Advanced Mathematics A (II)" built on the Chaoxing FanYa platform, has transformed the course into a "data-intelligent" version by constructing a knowledge graph. The key focus of the transformation is to systematically reconstruct and integrate fragmented learning resources, and to outline a clear knowledge point structure and resource system for the course.

First, by carefully deconstructing the course content and organizing the knowledge point system, these knowledge points are used as nodes in the knowledge graph. Then, the logical relationships between these nodes are analyzed to preliminarily construct the knowledge graph.

Next, resources such as corresponding videos, pre-class self-tests, in-class quizzes, exam preparation guides, chapter quizzes, etc., are precisely linked to the knowledge points. These resources are connected through directed edges, forming a complete knowledge network structure. This allows for the structural presentation and visual display of the knowledge system (**Figure 1**).

The knowledge graph presents the networked relationships of the knowledge points in an intuitive manner, providing students with customized learning paths through pre-and post-relationships (prerequisite), associative relationships (related), and parent-child relationships (partOf), thereby enhancing the personalized learning experience.
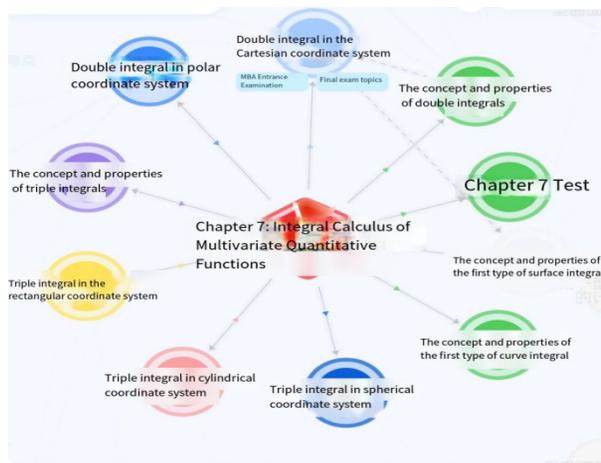

Figure 1. Framework of the knowledge graph for higher mathematics section.

2.2. The setup and functions of AI teaching assistants

The AI teaching assistant of Chaoxing is embedded in Learning Pass and is connected to Chaoxing's large model's document question-answering capabilities, enabling it to rapidly expand its knowledge base. It can provide knowledge clarification, resource recommendations, intelligent question generation, and learning supervision and reminder services based on the course content and knowledge. It also has an independent management backend. Based on this, AI teaching assistants have been set up. Course materials are uploaded to the management backend, and answers and similar question phrasings for common problems encountered by students during online learning are pre-entered into the AI knowledge base. The AI teaching assistant can, based on intelligent learning of the course materials, provide 24-hour learning clarification around the course content, and provide the source of the clarification.

3. Design and implementation of a blended teaching model based on knowledge graphs and AI teaching assistants: A case study of "the concept and properties of double integrals"

The following is the framework of the blended teaching model based on knowledge graphs and AI teaching assistants (**Figure 2**).
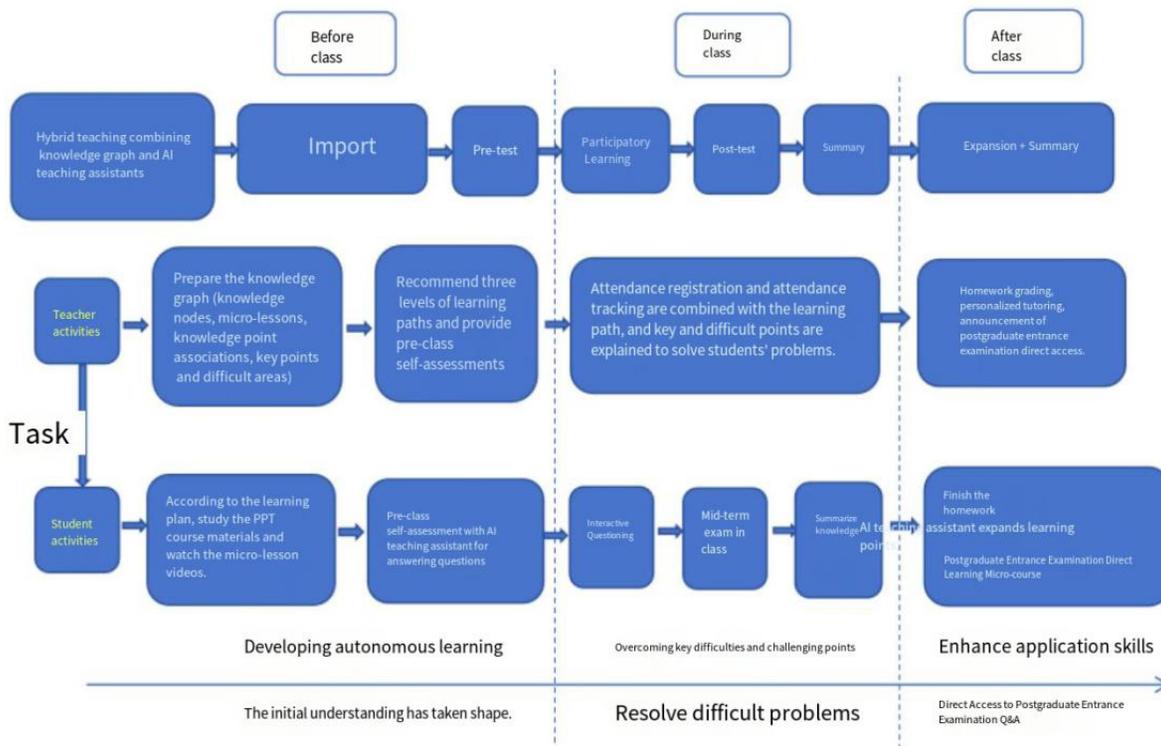
Figure 2. Framework of blended teaching mode based on knowledge graph + AI teaching assistant.

(1) Pre-class Preparation Phase

The teacher posts the learning path and knowledge map (**Figure 3** and **Figure 4**) for the study of double integral concepts and properties on the teaching platform. Pre-class self-tests are also set up. These test questions are designed to assess students' understanding of the basic concepts. Students log in to the teaching platform and study according to the pre-class learning tasks posted by the teacher. During the learning process, students can ask questions to the AI tutor at any time. The AI tutor analyzes the questions and, based on the relevant knowledge points in the knowledge map, provides detailed explanations and further learning suggestions for the students. After completing the pre-class test, the platform automatically grades the homework and provides feedback. Students can understand their own pre-class learning situation based on the feedback. For the knowledge points with more errors, they can be guided by the AI tutor for targeted re-study.

Figure 3. The learning path for understanding the concept and properties of double integrals.
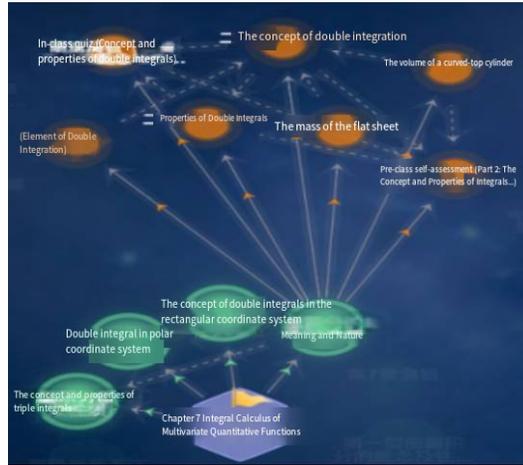
Figure 4. Knowledge graph of the concept and properties of double integrals.

(2) Interactive and Explanation Phase

During the class, the teacher starts by using the knowledge map to present the overall knowledge framework of "Concept and Properties of Double Integrals", enabling students to have a broad understanding of the content of this lesson. Then, based on the feedback from the students' pre-class tests, the teacher focuses on explaining the knowledge points that are commonly questioned by the students. During the explanation, the teacher can utilize the knowledge connections within the knowledge map to guide students to make knowledge transfer, for example, comparing the concept and properties of definite integrals to those of double integrals, to deepen students' understanding. During the teacher's explanation, students can refer to the knowledge map and integrate the new knowledge with their existing knowledge system. For the content of the teacher's explained knowledge points, they have their own labels (**Figure 5**) for each part of the knowledge point. For instance, the pre-class self-test usually marks it as ordinary questions, the in-class test marks it as ordinary and challenging questions, and the properties of double integrals mark it as key points. Students can accurately understand the key points of the exam through the knowledge map, which is beneficial for them to master the key points of double integrals in a short period of time and further review the knowledge points in a targeted manner.
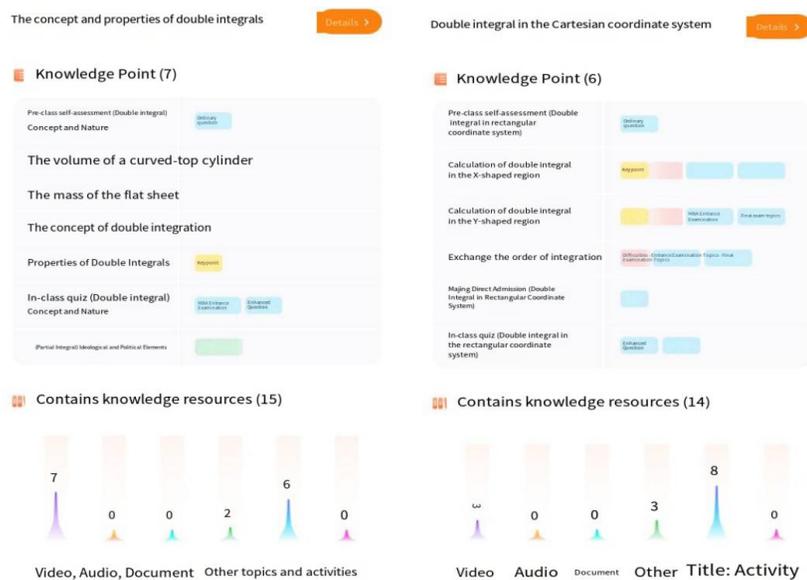

Figure 5. Tags of knowledge points.

(3) The post-class review and expansion stage

The teacher assigns post-class homework on the teaching platform. The homework covers the basic applications of the concept and properties of double integrals as well as extended questions related to the postgraduate entrance examination. These questions are closely linked to the knowledge points in the knowledge graph, aiming to consolidate the students' knowledge learned in class and expand their thinking. The teacher can also mark the students' learning progress and weak points on the knowledge graph based on their classroom performance and homework completion. During the process of completing the post-class homework, students can seek answers from the AI tutor. The AI tutor not only provides the answers but also analyzes the reasons for the students' mistakes and guides them to review the relevant knowledge points. After completing the homework, students can, based on their own learning situation, formulate personalized review plans with the help of the AI tutor. For example, for the part of the properties application they are weak in, they can choose the specialized exercises and in-depth explanation materials in the knowledge graph for study. Meanwhile, students with extra time can expand their learning through the AI tutor's recommendations, such as studying complex application cases of double integrals in physics, engineering, etc., to further enhance their knowledge application ability and innovative thinking.

4. Teaching effectiveness and questionnaire survey

During the pre-class preview stage, through platform data statistics, it was found that students spent an average of 30 minutes on the animated videos and textual materials in the knowledge graph. The AI tutor answered students' questions 50 times or more, with 60% of the questions being about concept understanding. Through a questionnaire survey of the students, it was discovered that students in the blended teaching class had a satisfaction rate of 90% for the teaching. They believed that this teaching method could better meet their learning needs, help them deeply understand the concept and properties of double integrals, and improve their autonomous learning ability and learning interest.

The combination of the knowledge graph and AI tutor significantly enhanced students' learning experience. The clear structure of the knowledge graph provided students with a comprehensive and easily understandable learning path, while the interactive AI tutor answered students' questions and provided personalized guidance, becoming a valuable learning resource for students. Therefore, students were more engaged in the learning process and became more confident in autonomous learning.

In addition, students' feedback also indicated that the combination of traditional classroom teaching and online learning resources (such as videos and interactive quizzes) promoted a more flexible and efficient learning environment. Students particularly appreciated the immediate support provided by the AI tutor, especially in clarifying difficult concepts and providing additional practice materials. Overall, the questionnaire survey results showed that blended teaching, supported by the knowledge graph and AI tools, not only improved students' understanding of mathematical concepts but also stimulated stronger learning interest among students.

5. Conclusion

With the continuous development of technology, the functions of knowledge graphs and AI tutors will be further improved, giving education greater potential for innovation and application value. The construction of knowledge graphs will become more intelligent and automated, and in the future, it will be able to update and

expand knowledge content in real time. Traditional knowledge management methods may be limited by manual updates and the constraints of dimensions, while knowledge graphs can rely on advanced artificial intelligence technologies to achieve more efficient and accurate knowledge integration and management. Through big data analysis and machine learning, knowledge graphs will be able to automatically adjust learning resources and paths based on students' learning situations and academic progress, ensuring that the learning content is up-to-date and always the most relevant. At the same time, the intelligence level of AI tutors will also continue to improve. With the advancement of natural language processing and sentiment analysis technologies, AI tutors cannot only answer students' knowledge-based questions but also better understand students' emotional needs and learning styles, thereby providing more personalized teaching support. AI tutors can adjust teaching strategies according to students' learning progress, interests, and emotional states, propose personalized learning suggestions, and help students overcome difficulties in the learning process, enhancing learning motivation and effectiveness. Through these innovative technologies, AI tutors will become indispensable auxiliary forces in the field of education, providing students with more precise and humanized learning experiences.

Looking to the future, the blended teaching model combining knowledge graphs and AI tutors is expected to be widely applied in more subjects of teaching. Especially in basic subjects such as science, technology, medicine, and linguistics, the blended teaching will promote the innovation of teaching methods, making the teaching content more flexible and interactive, and allowing students to conduct personalized learning according to their own needs and interests. Moreover, this model will help address the shortcomings of traditional education models, such as insufficient personalized support and unclear learning paths, and improve the fairness and efficiency of education. By integrating intelligent technologies into teaching, educators can more accurately grasp students' learning status, adjust teaching strategies promptly, and improve teaching quality.

In summary, the blended teaching model combining knowledge graphs and AI tutors demonstrates unique advantages and has broad application prospects. This model not only optimizes the utilization of teaching resources but also improves teaching effectiveness, but also provides more personalized learning opportunities for students, stimulating their learning interest and innovative thinking.

Disclosure statement

The authors declare no conflict of interest.

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