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AI + Knowledge Graphs Empower the Construction of Blended Online-Offline Teaching Courses for “Botany”

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Abstract: Against the background of new quality productivity, knowledge graphs, and AI technology have opened up new paths for higher education reform, promoting the transformation of traditional teaching models to “smart classrooms.” Taking the “Botany” course as the research object, this paper explores the path of constructing a blended online-offline teaching model using AI + knowledge graphs to address the problems of a fragmented knowledge system, static teaching resources, and a single learning path in traditional teaching. Based on the technological characteristics and educational application value of AI and knowledge graphs, a “Knowledge Graph + AI Scenario Practice + BOPPPS” model is proposed: a knowledge graph is constructed by extracting knowledge points and sorting out knowledge relationships to help students consolidate basic knowledge; scenario-based practice tasks are released through an AI course assistant to stimulate students’ learning interest, and full-process blended teaching activities of “pre-class—in-class—post-class” progressive exploration are carried out, aiming to enhance students’ independent learning, communication, and teamwork abilities. Research results show that this blended teaching model can effectively realize the systematic organization and visual presentation of botanical knowledge, significantly improving students’ learning efficiency and deep learning capabilities.

Keywords: Knowledge graph; Artificial intelligence (AI); Botany; Blended teaching; BOPPPS model

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1. Introduction

“Botany” is a core basic course for majors related to life sciences. Its core goal is to help students understand and reveal the laws of plant life activities [1]. However, traditional teaching faces three major contradictions: the rapid development of disciplinary frontiers versus the relatively lagging update of textbooks, the complexity of knowledge networks versus the linearity of teaching models, and the strong practicality of the discipline versus limited teaching resources. These contradictions lead to problems of “knowledge barriers” and “cognitive overload" among students.

With the development of educational informatization, blended teaching has become an important direction of higher education reform. It integrates online digital resources with offline teaching, providing flexible and personalized learning experiences [2]. However, the current blended teaching of "Botany" still has problems such as fragmented online resources, insufficient knowledge relevance, and limited intelligence, which restrict teaching effectiveness.

Knowledge graphs structurally represent knowledge in the form of "entity-relationship-entity" triples, which can effectively solve the problem of knowledge fragmentation [3]. AI technologies such as deep learning provide support for applications in educational scenarios [4]. Based on this, this paper proposes a new blended teaching model of "Botany" empowered by "AI + knowledge graphs." By sorting out the knowledge system to construct a multi-modal botanical knowledge graph and combining the BOPPPS teaching model to design full-process blended teaching activities of "pre-class—in-class—post-class", it aims to break botanical knowledge barriers, integrate teaching resources, and improve students' independent learning and higher-order thinking abilities.

2. Current status and challenges of botany teaching

Through investigation and analysis, the current teaching of "Botany" has five core problems:

Insufficient scientificity of the knowledge system structure: Botanical knowledge has significant hierarchy and relevance, such as the kingdom-phylum-class-order-family-genus-species system in taxonomy and the functional connections between morphology and physiology. However, traditional textbooks and teaching mostly present knowledge linearly by chapters, making it difficult for students to establish an overall cognitive framework and accurately grasp the internal connections between knowledge points.

Insufficient dynamics of teaching resources: Botany research iterates rapidly, with frequent new discoveries in fields such as genomics and ecological adaptation mechanisms. However, existing teaching resources have a long update cycle, lack cutting-edge content, and are mainly static texts, lacking interactivity and adaptability, making it difficult to meet differentiated learning needs.

Weak practical teaching links: "Botany" is a discipline relying on observation and experiments [5]. However, due to constraints such as class hours and venues, the proportion of practical teaching in most colleges and universities is relatively low. Field internship opportunities are scarce, and most experiments are verification-oriented projects, which are not conducive to cultivating students' innovation and practical abilities.

Simplified evaluation methods: The current evaluation system over-relies on final written exams, ignoring the assessment of students' observation abilities, species identification skills, and practical innovation abilities. This leads students to engage in "exam-oriented learning" and affects the improvement of their comprehensive literacy.

Difficulties in interdisciplinary integration: Modern botany is deeply interdisciplinary with chemistry, ecology, agronomy, etc. Traditional teaching lacks means for integrating interdisciplinary knowledge, making it difficult for students to form systematic thinking and restricting the cultivation of their ability to solve complex problems.

The root cause of these problems lies in the mismatch between the knowledge organization form of traditional teaching and the disciplinary characteristics of "Botany." The introduction of knowledge graphs and

AI technology provides new ideas and methods for solving these problems.

3. Educational application value of knowledge graphs and AI

3.1. Educational applications of knowledge graphs

Knowledge graphs organize knowledge in a graph structure of "nodes (entities or concepts) and edges (relationships)", and have significant value in the field of education:

Knowledge structuring: Convert discrete knowledge points into an interconnected network structure, intuitively presenting the hierarchical, logical, and interdisciplinary relationships between concepts [6]. For example, in plant classification teaching, knowledge graphs clearly show the classification path from "Angiospermae" to specific species, and associate knowledge such as morphological characteristics and ecological habits.

Personalized learning paths: Dynamically generate learning paths adapted to individual characteristics by analyzing students' learning behavior data and knowledge mastery, effectively improving learning efficiency [7].

Resource integration and sharing: As an intermediate layer, knowledge graphs can integrate multi-source heterogeneous data from textbooks, scientific research literature, specimen databases, multimedia resources, etc., breaking "information silos" [8–9].

Support for intelligent applications: Provide a knowledge foundation for AI educational applications such as intelligent Q&A, virtual experiments, and automatic evaluation.

3.2. Educational empowerment of AI technology

AI technology provides strong support for the application of knowledge graphs:

Natural Language Processing (NLP): Supports the automatic parsing of textbooks and literature, realizing the automatic extraction of knowledge points and relationships, and improving the efficiency of knowledge graph construction.

Computer Vision: Applied in scenarios such as plant morphology recognition and specimen identification.

Intelligent recommendation algorithms: Precisely push suitable learning resources and practice questions by analyzing student portraits and learning behaviors.

Virtual Simulation Technology: Create immersive learning environments with VR/AR.

3.3. Theoretical basis of blended teaching

Blended teaching integrates the flexibility of online learning and the interactivity of offline teaching, and its theoretical basis includes:

Constructivist Learning Theory: Emphasizes students' initiative in knowledge construction. The blended environment provides students with more opportunities for independent exploration, helping them build knowledge systems.

Mastery Learning Theory: Ensures students reach knowledge mastery standards through formative evaluation and personalized feedback, and realizes large-scale personalized teaching with the help of AI technology.

Social Learning Theory: Offline sessions retain teacher-student and student-student interactions, promoting collaborative learning and knowledge sharing, and cultivating students' communication and collaboration abilities.

The BOPPPS model is an effective framework for blended teaching, including six links: Bridge-in, Objective, Pre-assessment, Participatory Learning, Post-assessment, and Summary, providing systematic guidance for curriculum design [10].

4. AI + knowledge graphs empower the construction of blended online-offline courses for "botany"

4.1. Overall framework design

Based on the above analysis, a blended online-offline teaching framework for "Botany" empowered by "AI + knowledge graphs" is constructed (**Figure 1**). With the botanical knowledge graph as the core, the framework integrates AI technology tools and organizes teaching activities based on the BOPPPS model, forming a "three-layer and four-dimensional" structure:

Knowledge Layer: Realize the systematic organization and dynamic update of botanical knowledge through knowledge graphs, supporting semantic association queries and visual presentation.

Resource Layer: Integrate multi-modal teaching resources such as textbooks, literature, specimen data, field photos, and experimental videos to provide a data foundation for knowledge graph construction.

Application Layer: Develop AI applications such as intelligent Q&A, scenario-based practice, and personalized recommendations to empower the entire process of blended teaching.

The "four dimensions" refer to knowledge structuring, teaching intelligence, learning personalization, and evaluation diversification.

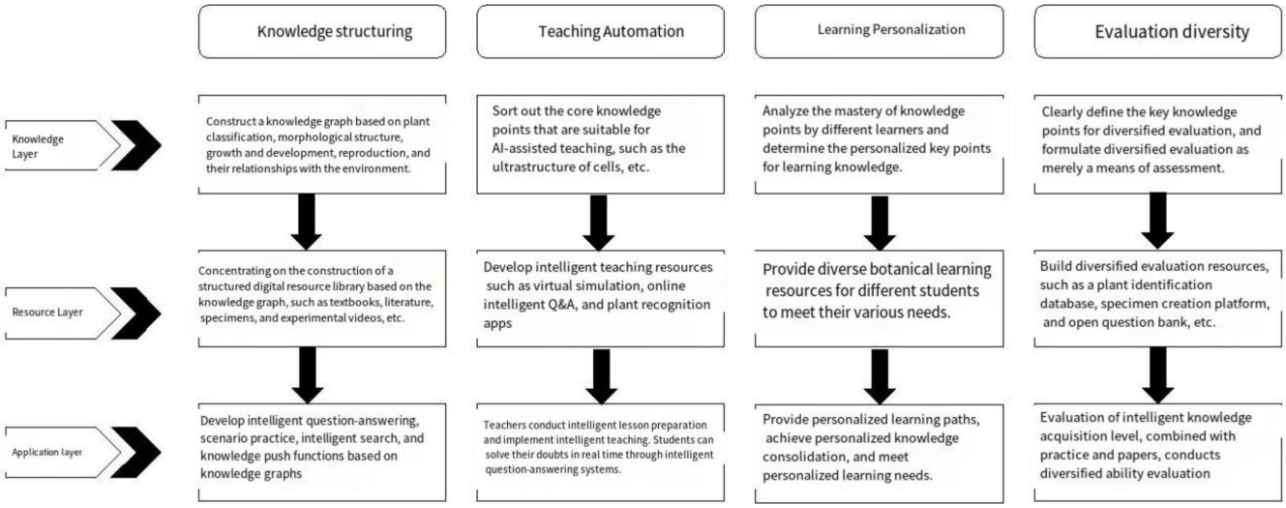

Figure 1. "AI + knowledge graph" blended teaching framework for botany

4.2. Construction of botanical knowledge graph

The construction follows a hybrid strategy combining "top-down" and "bottom-up" approaches, with core steps including [11]:

Ontology design: Construct a botanical ontology using the seven-step method, with core classes including "Plant Taxonomic Unit", "Morphological Structure", "Physiological Process", and "Ecological Environment."

Data Collection: Multi-source data covers four categories: structured data, such as the "Flora of China" database; semi-structured data, such as textbooks; unstructured data, such as scientific research papers; and multi-modal data, such as videos.

Knowledge Extraction: Team members extract entities, relationships, and attributes for knowledge in their respective fields of expertise, forming a knowledge system framework and content according to "knowledge field—knowledge unit—knowledge point" [12–13].

Knowledge Fusion: Adopt entity alignment methods based on knowledge representation to solve the problem of terminology ambiguity.

4.3. Blended teaching design based on BOPPPS

Integrating the botanical knowledge graph with the BOPPPS model, full-process teaching activities of "pre-class—in-class—post-class" are designed:

Pre-class Stage: Teachers analyze course content with the help of knowledge graphs and generate preview materials using AI lesson planning tools; students independently explore the knowledge graph, complete pre-assessments, and the system recommends personalized learning paths based on their answers.

In-class Stage: Focus on explaining core concepts and difficulties offline, using knowledge graphs to show knowledge associations; carry out inquiry activities based on knowledge graphs, such as group construction of characteristic relationship graphs for specific families and genera; assist morphological observation with AR technology.

Post-class Stage: The intelligent homework system pushes differentiated exercises based on classroom performance; groups collaborate to improve knowledge graph entries; the learning analysis dashboard visually displays knowledge mastery.

4.4. AI technology-empowered teaching applications

Intelligent Q&A System: Supports two query methods: text and image. Text Q&A uses an AC automaton to identify entities and TextCNN to classify intentions, with an accuracy rate of 83%; image recognition is based on the EfficientNet-B3 model, with an accuracy rate of over 85% for common plant recognition, and can return knowledge cards such as classification information and ecological habits. For example, students upload photos of plants taken in the wild, the system identifies them as "Taraxacum mongolicum of Asteraceae", and displays associated information such as their anatomical characteristics and medicinal value.

Virtual Experiment Platform: Construct a virtual laboratory for plant physiology, simulating the impact of light intensity and CO2 concentration on photosynthetic rate, and integrating knowledge graphs to provide real-time explanations.

Personalized Recommendation Engine: Recommend learning resources based on knowledge graphs and student models; automatically generate simplified knowledge subgraphs for students with learning difficulties, highlighting core concepts to reduce learning difficulty.

5. Implementation effects and challenges

5.1. Practical effects

Two rounds of teaching practice in the Biology Science major of Lingnan Normal University show that the average score of the experimental class is 12.6 points higher than that of the control class ($P < 0.01$), especially showing obvious advantages in knowledge-related practical questions (the difference reaches 15.3 points). 87% of students believe that knowledge graphs "help understand knowledge connections"; 92% are satisfied with the intelligent Q&A function; 79% think that personalized recommendations "meet their own learning needs." In complex tasks such as plant classification and ecological adaptation analysis, students in the experimental class show stronger systematic thinking and problem-solving abilities. Teachers' lesson preparation time is reduced by about 30%, and the AI teaching assistant handles 65% of common question consultations, allowing teachers to focus more on teaching design and higher-order guidance.

5.2. Challenges

Technical-wise: It is difficult to eliminate ambiguities in professional terminology, multi-modal data alignment is incomplete, and complex reasoning capabilities are limited. Teaching-wise: Teachers need interdisciplinary literacy, students face initial technical barriers, and it is difficult to control the classroom rhythm. Resource-wise: High-quality annotated data is scarce, knowledge graph maintenance costs are high, and hardware differences affect the operation of AI applications [14].

6. Conclusion and outlook

The "AI + knowledge graph" blended teaching model effectively solves the pain points of traditional botany teaching and improves students' learning outcomes and abilities.

In the future, educators will strengthen interdisciplinary cooperation to improve the botanical ontology and annotated dataset, explore large language models to enhance the depth of the Q&A system, develop lightweight technologies, and build an open knowledge graph community to promote the sharing of educational resources, contributing to the development of life science education.

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