

Practice of Chemistry of Chinese Materia Medica Teaching Based on Competency by AI Technology

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Abstract: *This study introduces the practice of Chemistry of Chinese Materia Medica teaching, aiming to both strengthen the integration of theory and practice and enhance students' professional competencies through the application of AI technology. Guided by the core competency requirements for relevant professions, we have restructured the content of the course, introduced innovative teaching models, and optimized the evaluation methods. These reforms specifically include virtual simulation, knowledge graphs, and intelligent evaluation. The implementation of these practices will enhance core competencies of undergraduates in traditional Chinese medicine component analysis, quality control, and research, aligning university education with industry demands and providing a reference for the cultivation of traditional Chinese medicine professionals.*

Keywords: AI technology, Chemistry of Chinese Materia Medica, Teaching practice.

1. Introduction

Traditional Chinese medicine (TCM) refers to natural medicinal substances, and their processed products are developed based on TCM theory and through long-term clinical practice [1-2]. It mainly includes herbal drugs, animal-derived drugs, and minerals. "Chemistry of Chinese Materia Medica", guided by basic theories of TCM and clinical experience, mainly employs modern scientific theories, methods, and technologies to study chemical components of TCM. As a fundamental and professional course in TCM program, it serves as a crucial link between TCM theory and industrial application. Therefore, the pedagogical quality of this course is fundamental to students' acquisition of important skills, such as the extraction, separation, identification, and quality control of active TCM components. In turn, this mastery directly determines their professional competence in fields like TCM research, drug inspection, and clinical pharmacy.

Rapid component analysis and the integration of artificial intelligence are central to advancing TCM research. This necessitates cultivating talents who possess both TCM knowledge and proficiency in applying modern technologies, posing new challenges for chemistry of Chinese materia medica education. Nevertheless, teaching presents novel opportunities alongside these challenges. The integration of artificial intelligence (AI) into education has recently served as a major innovative driver, providing new pathways for quality teaching via personalized instruction, immersive training, and precise evaluation [3-5]. Hence, AI-assisted teaching is used to enhance core skills and innovative thinking of students in chemistry of Chinese materia medica, thereby enabling them to meet requirements for different positions in job. Accordingly, we integrate AI into teaching to strengthen students' core skills and innovative thinking in chemistry of Chinese materia medica, bridging the gap between their education and the demands of the workplace.

2. Design and Strategy of reform in Chemistry of Chinese Materia Medica

Within the TCM industry, positions are broadly grouped into several areas: TCM research and development (R&D), quality control (QC), production, and clinical affairs. Therefore, professional competency comprises three key components: professional knowledge, core skills, and professional ethics. Important competencies for chemistry of Chinese materia medica roles comprise proficiency in TCM theory, ability in separating and identifying active ingredients, skills in experimental design and data analysis, adherence to rigorous scientific practices, and dedication to the heritage and advancement of TCM.

Based on the above analysis, we attempt to reverse-engineer objectives of course based on job requirements. The objectives guide the reconstruction of teaching content, transforming students' knowledge into abilities and shifting from uniform teaching to personalized teaching. Furthermore, ideological and political education was integrated to foster a spirit of scientific inquiry. Ultimately, the effectiveness is evaluated through multiple measures. AI technology is utilized to assist teaching, enhancing students' core skills in chemistry of Chinese materia medica, innovative thinking, and professional adaptability.

2.1 Reconstructing an AI-Integrated Curriculum System

Based on competency requirements of the TCM industry, the course content is structured into three modules: "Basic Theory, Core Skills, and Job Adaptation Module". In the Basic Theory Module, AI knowledge graph technology is designed to establish a structured network that connects TCM components with their extraction methods, structural identification, and pharmacological effects, thereby enabling students systematically visualize and comprehend the logical relationships of knowledge. The Core Skills Module will incorporate AI virtual simulation experiments to train students in operations such as extraction, separation and structural identification. The Job Adaptation Module will offer elective content based on different career paths such as R&D and QC, aiming to achieve personalized cultivation of students. For instance, AI technology can be used to develop a comprehensive case tracking the research process of a TCM active ingredient like paclitaxel [6-7]. Different modules will

be set up online, covering extraction and separation, pharmacological and toxicity studies, structural modification, drug sourcing, and industrial translation. During this process, theoretical knowledge of chemistry of Chinese materia medica, experimental skills, and ideological and political education will be reasonably integrated. Students select modules of interest for a four-week period of self-study. This is followed by teacher-led group discussions, which can incorporate role-playing to facilitate knowledge integration, help students identify their research interests, and further personalize the learning experience.

In recent years, applying AI to study chemical components of TCM has become a major trend. To cultivate high-quality talent that meets societal needs, courses have introduced practical teaching content involving AI tools, such as DeepTox for toxicity prediction [8-9], AlphaFold for target prediction [10-11], and TCMSF for pharmacological activity analysis [12-13]. By integrating these AI and bioinformatics technologies, students gain a practical understanding of the transformative impact of AI.

2.2 AI-driven Teaching Methods

Theoretical knowledge serves as the essential foundation of innovation and practice. Using the AI teaching platform, learning data from students can be collected. By analyzing online engagement, exercise accuracy, and question-answer data, teachers can identify knowledge gaps and skill deficiencies among undergraduates. Based on knowledge graphs and machine learning algorithms, personalized educational content will be provided for students. For example, for students who have not mastered “alkaloid extraction and separation”, can be automatically provided with theoretical micro-lectures, videos of virtual experiments, and targeted practice questions, enabling precise, personalized instruction.

More importantly, students need to put the theories of chemistry of Chinese materia medica into practice. However, there are few experiment courses currently. Students face a dual challenge: a scarcity of dedicated experimental courses and limited lab access due to time and resource constraints. VR virtual simulation experiments offer a viable solution by precisely supplementing hands-on learning opportunities. The course can employ three-dimensional animations to recreate experimental procedures with detailed narration. The animations can show different experimental results, so that students can realize the importance of experimental design and key operations. This training can help students master more experimental skills, such as the extraction of active components of TCM, ultraviolet absorption spectroscopy, and the operation of high-performance liquid chromatography (HPLC). AI can detect procedural errors and provide corrective feedback, helping to refine students' experimental techniques.

To further integrate theory and practice, chemistry of Chinese materia medica cases can be constructed through AI technology. The online learning platform can incorporate authentic cases from R&D, QC, and clinical practice. Examples include quality control of Astragali Radix, screening of active TCM components, and elucidating the

clinical mechanism of dampness-resolving and detoxifying preparation. With the help of the AI interaction system, the problem chain can be set to guide students to conduct collaborative exploration in groups, thereby cultivating scientific thinking and teamwork ability.

2.3 Optimization of the AI-supported Evaluation System

An evaluation system based on competence can be established by using AI technology. The evaluation content covers a three-dimensional model encompassing professional skills, scientific thinking, and professional ethics. Evaluation indicators of professional skills include theoretical knowledge, experimental operations, and the ability to apply AI technology. Indicators of scientific thinking include the rationality of experimental design and analytical and problem-solving skill. Professional ethics indicators focus on scientific research integrity, quality awareness, and teamwork. Using AI, objective evaluations can be automatically generated by analyzing students' online learning data, operations in virtual experiments, and their engagement with industry case studies. At the same time, combined with evaluations from teachers and classmates, a multi-dimensional evaluation can be formed.

In addition, AI technology can also generate an individual competency development record for every student. The online platform can continuously track the trajectory of students from enrollment to graduation. By comparing the ability data at different stages, AI can accurately identify the deficiencies and timely adjust teaching strategies to ensure that students can adapt to job demands.

3. Conclusion

This study has addressed the challenges of traditional teaching in chemistry of Chinese materia medica, such as visualizing abstract knowledge and the limitations of practice, through the deep integration of AI technology. It has enhanced the intuitiveness and operability of chemistry of Chinese materia medica. Moreover, a competency-centered training system has been established, ensuring close alignment between teaching content and industry demands. Additionally, an objective evaluation mechanism has been set up, ensuring personalized talent cultivation.

In the future, it is necessary to further deepen the application of AI technology. This includes developing adaptive virtual labs and courses to meet diverse professional needs, fostering cross-sector resource sharing, and investigating the application of generative AI in chemistry of Chinese materia medica pedagogy. Large language models can be harnessed within the discipline to support the design of laboratory protocols and provide explanatory support, advancing both the personalization and educational intelligence. Simultaneously, the teaching system must be continuously refined in response to evolving industry demands, cultivating more versatile professionals equipped to advance the modernization of TCM.

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