Innovative Teaching Models for Traditional Chinese Medicine Pharmacology Guided by Artificial Intelligence in the Context of Building an Education Powerhouse

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Abstract: The construction of an education powerhouse is fundamentally driven by digital transformation, with artificial intelligence (AI) emerging as a transformative force in reshaping pedagogical paradigms. Under China's education modernization agenda, AI-enhanced specialized curricula are pivotal for fostering high-quality development. Anchored in the dual mission of moral education and talent cultivation, this study examines Traditional Chinese Medicine (TCM) Pharmacology within Henan Province's TCM revitalization initiative, identifying three critical gaps: (1) curricular rigidity, where static content lags behind dynamic clinical practices; (2) inadequate AI-aided pharmacological skill training; and (3) misalignment with occupational competency standards. To address these, we propose an AI-driven pedagogical framework incorporating: (i) adaptive learning systems for personalized knowledge delivery via machine learning; (ii) virtual simulation labs for pharmacodynamic/pharmacokinetic experimentation; and (iii) competency-based assessments with AI-evaluated indicators. This study contributes actionable strategies to bridge traditional pedagogy and technological demands, offering a model for AI integration in specialized disciplines to support national education strategies.

Keywords: Building an Education Powerhouse; Artificial Intelligence; TCM Pharmacology; Teaching Models; Personalized Education

1. Introduction

The construction of an education powerhouse is closely tied to the strategy of educational digitization, which serves as a vital indicator of such development [1]. As the core technology underpinning educational digitization, Artificial Intelligence (AI) has injected significant momentum into the pursuit of high-quality education [2]. In October 2023, the Henan Provincial Office issued the Implementation Plan for the Revitalization and Development of Traditional Chinese Medicine (TCM), emphasizing the need to promote the inheritance, innovation, and modernization of TCM, with a focus on cultivating high-level, professional Chinese medicine talents. The course of TCM Pharmacology is a fundamental course for related resource development majors, carrying the crucial mission of integrating Western and Chinese medicine, as well as advancing the modernization and internationalization of TCM. The instructional objectives of this course are designed to enable students, upon completion, to comprehensively articulate the fundamental content of pharmacology in TCM. These include the modern scientific connotations of the therapeutic effects of medicinal herbs, the pharmacological actions, mechanisms, and material bases of commonly used Chinese herbal medicines, as well as the underlying contemporary scientific principles of disease prevention and treatment by TCM. Furthermore, students should be able to practically apply pharmacological experimental skills and methodologies to conduct relevant laboratory experiments, thereby establishing a solid foundation for engaging in TCM-related

healthcare and medical activities. The course aims to cultivate high-end technical talents in TCM innovation and development, aligning with current regional development plans. In the context of future international competition, talent development is fundamentally the key factor. This underscores the necessity of nurturing highly qualified, interdisciplinary Chinese medicine professionals who are adaptable to societal progress [3], possess strong innovation and practical skills, and demonstrate enhanced global competitiveness.

Currently, however, the course faces numerous pedagogical challenges that necessitate innovative reforms leveraging advanced technologies, including AI, to meet the demands of building an education powerhouse and revitalizing traditional Chinese medicine. To achieve this, the professional teaching team must adapt to the concept of education in the intelligent era by constructing an autonomous learning ecosystem. This approach should promote a close integration of the new-era pharmacology curriculum with artificial intelligence technologies and meet the demands of national social development. The implementation of intelligent teaching methods, leveraging new media and advanced technological tools, is essential to fostering students' innovation and practical capabilities. Moreover, it is vital to uphold the fundamental task of fostering virtue through education, with the goal of cultivating high-quality talents in the field of TCM. This requires coordinated development of students' knowledge, skills, and overall qualities, thus ensuring the cultivation of well-rounded, innovative, and competent professionals aligned with the strategic needs of modern TCM development.

2. Challenges and Pain Points in Teaching TCM Pharmacology

2.1 Challenges in Updating Content and Developing Student Capabilities

TCM Pharmacology is characterized by extensive content, which rapidly becomes complex and frontier-oriented as research progresses. How to enable students to deeply understand current disciplinary developments within limited teaching hours, while cultivating autonomous learning and problem-solving skills to adapt to future scientific advancements, is critical to ensuring the course maintains high-level, innovative, and challenging standards [4]. Moreover, the era of intelligent technologies calls for higher demands on students' innovation and practical abilities. Traditional pedagogical models are increasingly insufficient, and integrating intelligent teaching modes has become an urgent need.

2.2 Pain Points in Teaching Methods and Personalization

Currently, there is a lack of differentiated teaching methods and a reliance on single-pattern personalized training approaches, which are insufficient to tailor instruction according to students' individual differences and developmental needs [5]. This results in an inability to appropriately plan pathways for students' skill progression at different levels. Due to disparities in students' foundational competencies, teachers face difficulties in fully accommodating diverse learning needs when selecting instructional content, leading to a situation where some students "cannot harvest enough peaches" while others "cannot pick any peaches" in the same classroom.

There is a shortage of teaching staff, and personalized mentorship remains inadequate. The course-guidance and support system is still underdeveloped and incapable of effectively serving personalized teaching. Although online courses have partially reflected students' overall learning status, they still fail to depict individual learning outcomes accurately. Moreover, there is a lack of advanced automated and intelligent teaching auxiliary tools to monitor individual learning processes, which hampers targeted support and ongoing pedagogical improvement.

There remains a disconnect between the curriculum and industry requirements. Students have not yet acquired an understanding of industry demands and technological trends, and they are unable to align with the needs of enterprise employers. There is also a deficiency in effective communication and resource sharing between academic institutions and enterprises. Additionally, students lack awareness of industry professional values. These issues hinder the cultivation of advanced talents in Chinese medicine production and impede the development of students' patriotic sentiments towards the protection and revitalization of the Traditional Chinese Medicine industry.

3. Innovative Pathways for AI-Enabled

Curriculum Reform

3.1 Building an Intelligent Curriculum System

Under the guidance of the national strategy for building an education powerhouse, this study aims to develop an AI-empowered curriculum system for TCM pharmacology. The system is student-centered, striving to achieve intelligent, personalized, and efficient teaching through advanced AI technologies to provide comprehensive and differentiated learning support for students.

Utilizing AI technology, this design features personalized learning pathways that integrate virtual experiments, intelligent Q&A, and capability assessment tools to cater to individual student needs. AI algorithms analyze students' learning progress, mastery of knowledge, and learning styles to tailor customized learning plans. The AI system can dynamically adjust the difficulty and pacing of learning content based on real-time data, ensuring students learn at an optimal tempo. For example, students with faster grasping abilities are presented with more challenging extension materials, while those requiring additional support receive more foundational exercises and guiding resources [6].

Taking Rain Classroom and the National Virtual Simulation Experiment Platform as the primary tools for intelligent course delivery, this approach relies on the curriculum of TCM pharmacology and its practical experiment courses to establish a new model of AI-enabled teaching. The virtual experiment platform offers immersive learning experiences, allowing students to perform laboratory operations in a virtual environment, thereby enhancing their practical skills. Students can repeatedly practice experimental procedures, familiarize themselves with laboratory workflows, reduce errors during real experiments, and ultimately improve their experimental competence. Based on sufficient virtual practice, students then undertake real project-based practical teaching to further elevate their capabilities.

Furthermore, an AI-based intelligent teaching framework is being explored to realize AI robot teaching assistants capable of providing real-time, intelligent Q&A support. These assistants can promptly respond to student inquiries, offering precise feedback and guidance to enhance learning efficiency. Additionally, a novel teaching and tutoring model that combines AI assistants with virtual collaboration with teachers and personalized mentoring is under development. While AI assistants handle common questions, teachers can monitor individual student performance in real time, adjust instructional strategies accordingly, and ensure the effectiveness of teaching and learning processes.

3.2 Realizing Student-Centered, Personalized Teaching

This research leverages big data analytics to build comprehensive student profiles through behavioral data such as learning duration, content engagement, and pathways. By establishing a dynamic student behavior tracking model, the full learning process of each individual can be monitored. Teachers will utilize this data to design personalized content and mentorship strategies, aligning instruction precisely with student needs. Concurrently, AI teaching assistants will offer targeted guidance and feedback based on students' real-time learning situations, helping learners better grasp knowledge and improve effectiveness.

3.3 Innovating Teaching Models

This study introduces project-based learning and dilemma-driven scenarios, integrating AI teaching assistants into classroom interactions to foster multi-party collaboration among teachers, students, and AI systems, thereby cultivating innovation and practical skills. Project-based learning allows students to solve real-world problems, stimulating creative thinking and hands-on capabilities. Dilemma-based approaches introduce learning obstacles, encouraging autonomous exploration and resolution. AI assistants play a crucial role during classroom activities through intelligent guidance and immediate feedback [7], fostering collaborative engagement. This multi-faceted teaching model aims to enhance student engagement, teamwork, critical thinking, and ingenuity.

3.4 Developing Industry-Academia-Research Convergence Platforms

In partnership with enterprises, this research will develop micro-courses and case studies aligned with industry needs, utilizing AI for dynamic evaluations to strengthen practical application and sector relevance. Collaborations with

industry experts and successful alumni will incorporate real-world demands and cutting-edge technologies into the curriculum. These industry-specific micro-courses and case studies will help students grasp current trends and enhance applicability. AI-driven evaluation mechanisms will provide timely feedback on learner progress, empowering instructors to refine instructional strategies in line with industry standards. Such platforms will significantly improve practical skills, broaden employment opportunities, and foster innovation in the Chinese medicine sector.

4. Pedagogical Practice and Effectiveness Evaluation

4.1 Development of Teaching Resources

This project will establish online courses and virtual laboratories, integrating AI-based intelligent Q&A and personalized recommendation features to enrich the teaching content. Utilizing platforms like Rain Classroom and national virtual simulation platforms, a layered, competency-oriented TCM Pharmacology curriculum will be built. The course system includes foundational theory, virtual experiments, reinforcement sessions, practical laboratory work, and applied projects, tailored to students across different levels. AI-powered systems will facilitate real-time question answering and resource recommendation based on individual learning status, significantly enhancing learning outcomes.

4.2 Exploration of Teaching Models

By adopting an integrated approach of problem-based, project-driven, and personalized mentorship strategies, this research aims to foster active student engagement and deepen learning. Pre-class diagnostic assessments will guide personalized instruction, with progressive practice activities such as independent assignments, virtual experiments, project selection, and team collaboration. Classroom activities will revolve around stages of knowledge construction, transfer, integration, and critical evaluation, employing inquiry-based, task-based, and collaborative learning techniques. These approaches cultivate problem-solving skills and foster a logical transition from knowledge acquisition to competency development.

4.3 Enhancement of Evaluation Systems

Coupling AI and big data analytics, a multifaceted assessment framework will be established to continuously monitor learners' development and provide personalized feedback. Through AI-powered chatbots and data analysis, student activities — such as study duration, content engagement, and progression — will be tracked, creating a comprehensive evaluation system. This system emphasizes not only knowledge mastery but also innovation, skills, and overall capacity, ensuring balanced student development throughout the learning process.

4.4 Empirical Outcomes

Preliminary implementation demonstrates that this integrated teaching mode can substantially improve students' motivation and innovative abilities, aligning them more closely with industry demands and high-quality development of TCM. Students exhibit enhanced autonomous learning, problem-solving, and practical skills. The use of AI-enabled resources and targeted mentorship allows tailored learning experiences, effectively increasing learning efficiency and quality. The alignment of curriculum content with industry needs and resource sharing mechanisms further enhances students' competitiveness. Future efforts will focus on optimizing pedagogical strategies to sustain and amplify these positive effects, providing a robust foundation for cultivating top-tier, innovative, practical talents in the field of Chinese medicine.

5. Industry Cooperation and International Exchange: An Innovative Exploration

Under the framework of building a strong educational nation, this research extends beyond campus boundaries by actively exploring industry partnerships and international cooperation. By integrating enterprise micro-courses and industry case studies, the curriculum seamlessly links education with real-world industry requirements, enriching practical relevance and providing students with frontline exposure. Additionally, the internationalization of TCM Pharmacology is emphasized by adopting advanced global pedagogical practices through collaborations with prestigious international universities and research institutions. Such initiatives broaden

students' global perspectives, foster cross-cultural exchanges, and cultivate high-caliber Chinese medicine professionals with international competitiveness.

6. Innovations and Distinctive Features

This research is anchored in constructivist educational theories, leading to innovative curriculum design. Combining AI and big data technologies, it creates a personalized, intelligent, and interactive learning environment that significantly enhances learning efficiency and precision [8-9]. A multi-dimensional evaluation system centered on competency, projects, and process assessment will be established to promote comprehensive development [10]. By advancing industry-education integration and establishing university-enterprise collaborations, the course's applicability and sector relevance are strengthened. These innovations collectively elevate the quality and modernity of Chinese medicine education, with broad implications for its international development.

7. Conclusion

In the contemporary digital era, the innovative practice of AI-empowered TCM pharmacology courses has opened new avenues for the cultivation of TCM professionals. This approach not only enriches students' learning resources and enhances learning efficiency but also substantially stimulates their interest and initiative in autonomous learning. Leveraging artificial intelligence technologies, the TCM pharmacology curriculum can transform abstract theoretical knowledge into vivid, visualized content, enabling students to grasp the mechanisms of herbal pharmacodynamics more intuitively. This visualization facilitates a deeper understanding and mastery of TCM cognition. Furthermore, AI tools provide educators with precise analytical capabilities, enabling them to monitor individual learners' progress accurately, adjust instructional strategies in real time, and consequently improve teaching quality.

The implementation of such innovative practices significantly contributes to the realization of the national strategic goal of building an education powerhouse, promoting both the inheritance and innovation of TCM disciplines. Under the guidance of this strategic framework, the education sector continually explores how to integrate modern technological advances with traditional pedagogical approaches to cultivate high-caliber talents aligned with the demands of the new era. The AI-driven innovation in TCM pharmacology courses represents a vital milestone in this endeavor. It not only offers novel methods for preserving traditional knowledge but also injects vitality into the modern development of TCM sciences. By integrating AI technology, TCM pharmacology can better intersect with disciplines such as modern medicine and biology, facilitating the interdisciplinary progress crucial for the discipline's modernization.

Looking ahead, continuous exploration of deep integration between emerging technologies and educational practices is essential for optimizing teaching systems. As technological advancements accelerate, the education landscape faces new opportunities and challenges. It is imperative to explore further ways of embedding innovative technologies into pedagogical frameworks to improve educational quality and efficiency. Likewise, refining the curriculum dynamically in response to evolving student needs and disciplinary development is critical for cultivating high-quality TCM professionals with an international perspective and innovative capabilities.

Through sustained efforts in these areas, we are confident that significant contributions can be made toward the modernization of TCM and the robust revitalization of China's traditional medicine industry. As a national treasure, TCM boasts a long history and rich cultural heritage. In this new era, it is our collective responsibility and mission to promote, innovate, and advance TCM's modern development. The AI-enabled innovation in TCM pharmacology education provides a powerful platform to cultivate outstanding talents in this field, thereby supporting the broader goals of TCM modernization and industrial revitalization. We look forward to ongoing exploration and innovation in educational practices, aiming to make even greater contributions to the development of the TCM discipline and industry at large.

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