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Research on the Digital Transformation and Cross-Cultural Communication of Traditional Chinese Medicine Education System in the Context of Global Standardization

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Abstract: This study examines the digital transformation of traditional Chinese medicine (TCM) education within the context of global standardization, along with the challenges and opportunities of its cross-cultural dissemination. With the rapid advancement of technologies such as artificial intelligence, virtual reality, and blockchain, TCM education is experiencing a significant disruption and innovation of its traditional models. The research develops a "Standard-Technology-Culture" tri-spiral model to analyze how TCM education can achieve a seamless integration of standardization, technological innovation, and cultural preservation during its globalization process. The study finds that standardization provides the foundation for TCM education's global expansion, while technological innovation drives the transformation of educational methodologies. Simultaneously, cultural preservation ensures the distinctiveness of TCM education. However, the tension between standardization and the unique characteristics of TCM, as well as the balance between technological empowerment and cultural transmission, remain critical challenges in the ongoing transformation. Based on these findings, the study proposes strategies such as the "digital apprenticeship" model and blockchain-based certification systems to advance the globalization and digital transformation of TCM education, providing theoretical support for the creation of a global health community.

Keywords: TCM education; Digital transformation; Global standardization; Cross-cultural communication; Technological innovation

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1. Introduction

With the continuous advancement of globalization, countries around the world are increasingly moving towards standardization and digitalization in the field of medical education. In particular, traditional Chinese medicine (TCM), as an essential component of Chinese traditional culture, faces unprecedented opportunities and

challenges in its educational model. Deeply rooted in Chinese cultural traditions, TCM has gradually gained attention from an increasing number of countries and regions worldwide.

The World Health Organization (WHO) has incorporated TCM into the global medical education framework, signaling the beginning of its internationalization process [1]. Meanwhile, the rapid development of digital technologies, especially the application of cutting-edge technologies such as artificial intelligence (AI) and the Metaverse [2], is disrupting traditional medical education models, providing vast opportunities for the digital transformation of TCM education [3].

However, despite the dual opportunities presented by globalization and digital transformation, the challenges of cross-cultural communication remain significant. Cultural differences create various constraints for TCM in its international dissemination [4]. How to achieve the standardization and digital transformation of TCM education while preserving its unique cultural characteristics in the context of globalization has become a critical issue to address. This study explores the potential pathways for the digital transformation and cross-cultural communication of TCM education under the global standardization framework, revealing the challenges and opportunities involved. The study constructs a "Standard-Technology-Culture" three-dimensional analytical model to uncover the deeper contradictions and developmental pathways of TCM education's internationalization, providing theoretical support for the creation of a global health community.

2. Multi-dimensional construction of international standards for TCM education

In the global context, TCM education's internationalization progresses gradually. However, standardization efforts still encounter various obstacles [5]. The standardization process not only affects how TCM education is positioned within international medical systems but also influences its cross-border dissemination and practical applications [6]. Therefore, comprehensively evaluating current standardization status and understanding global system dynamics becomes essential, as this forms the basis for discussing digital transformation and cross-cultural communication challenges.

2.1. Analysis of international standard systems

Key international organizations like ISO and WHO play pivotal roles in TCM education standardization [7]. For instance, WHO's "Traditional Medicine Education Framework" provides reference guidelines for regulating traditional medicine education globally. That being said, global standardization remains a continually improving and evolving process rather than a completed task.

2.1.1. Interpretation of core indicators in WHO's education framework

The WHO's "Traditional Medicine Education Framework" broadly lays out the main standards for education in this field, covering aspects like curriculum design, how to teach, training teachers, and clinical practice work [8]. That is to say, these standards aim to guide different nations in their traditional medicine education efforts, promoting better acceptance across medical systems. For Chinese medicine specifically, the framework requires educational content to preserve its unique characteristics while meeting modern medical education criteria. Simply put, this means combining theoretical knowledge with hands-on practice through interdisciplinary teaching approaches [9].

2.1.2. Progress of ISO international standard for traditional Chinese medicine

When looking at global standardization efforts, the technical committee working on TCM standards under the

International Organization for Standardization (ISO) has been crucial to developing international guidelines [10]. This committee has created multiple standards related to diagnosis methods, treating patients, and product quality requirements [11]. The creation of these standards has pushed forward international certification processes for Chinese medicine, improving how it is viewed worldwide. To put it simply, this helps build trust in Chinese medicine practices across different countries.

2.1.3. Comparison of acupuncturist certification systems in Europe and the United States

In examining certification systems for acupuncture practitioners, Europe and North America show varied approaches. The United States manages certifications through its national commission that sets education criteria and evaluation processes [12,13], while the United Kingdom's system operates under a different oversight body [14]. These differences in certification rules, what education is needed, and hours spent in clinics reflect how regions have unique needs in standardizing Chinese medicine education. By comparing these systems, we can identify useful patterns for creating globally recognized standards.

2.2. Practical cases of digital education

With digital technologies advancing, more educational programs now use online platforms and virtual tools to update teaching methods. This shift helps standardize Chinese medicine education by making training materials more consistent and accessible, though challenges remain in maintaining practical skill development through digital means [15].

2.2.1. Virtual TCM clinic teaching system

The so-called "Cloud Clinic" initiative serves as a representative case of virtual teaching platforms in traditional Chinese medicine education [16]. Through digital simulation technology that mimics real-world scenarios, this system recreates diagnostic processes online, enabling learners to practice treatment decisions using virtual patient cases when actual clinical opportunities are scarce. This approach not only focuses on enhancing practical skills but also gives students from different regions a way to learn TCM diagnostic methods globally. By adopting such digital education tools, the standardization and international spread of teaching materials has become more feasible through technical means.

2.2.2. Application of blockchain technology in educational certification

The adoption of distributed ledger systems for academic credential management has gradually emerged as a development trend [17]. Taking the Malaysian TCM education credit repository as an example [18], this project utilizes blockchain mechanisms to track student learning progress and academic achievements, thereby ensuring data authenticity and permanent preservation features. To put it simply, this creates a secure record that is hard to alter, offering novel solutions for certification systems in TCM training. Through such technological interventions, global mutual recognition of educational qualifications could potentially be realized, thereby accelerating the standardization process in TCM education through digital pathways.

2.2.3. AI-assisted tongue and pulse diagnosis training platform

The experimental "Look, Listen, Ask, Feel" project at Tianjin University of TCM has developed an intelligent training system for diagnostic skill development [19]. By employing smart algorithms that imitate traditional diagnostic procedures, the platform assists in simulating tongue examination and pulse reading processes, allowing learners to gain certain diagnostic skills faster through repeated practice sessions that adjust to

their progress. Unlike conventional apprenticeship models, this digital method provides customized learning trajectories while offering immediate feedback on practice outcomes. Such AI-enhanced teaching approaches not only improve educational efficiency but also ensure consistent teaching quality through standardized evaluation features.

2.3. Empirical evidence of the dilemma of cultural communication

The international dissemination of TCM is not only a matter of education, but also of cultural dissemination. The TCM system itself has strong Chinese cultural characteristics, which makes it face many cultural differences in the process of spreading and accepting it overseas.

2.3.1. Survey on standardization of terminology translation

The difference in the translation of TCM terminology between different languages is a core issue in the international dissemination of TCM. Taking the English translation of the *Yellow Emperor's Neijing* as an example, there are differences in the translation of TCM terminology in different translations, which affect the understanding and acceptance of TCM concepts by overseas students [20]. A comparative analysis of six different English translations of the *Yellow Emperor's Neijing* shows that the standardization of terminology translation is crucial for the accurate dissemination of TCM [21].

2.3.2. Research on cognitive biases of overseas students

According to the survey and analysis of 1,000 cross-border questionnaires, it was found that overseas students had a large deviation in their understanding of TCM concepts such as "Yin and Yang Five Elements" [22]. These deviations are mainly due to cultural differences and language barriers, which lead to misunderstandings in students' understanding of TCM, which affects their learning and practical application. The study of cognitive biases of overseas students can provide effective countermeasures for Chinese medicine education and promote the improvement of cross-cultural teaching.

2.3.3. Analysis of the completion rate of international MOOC courses

As a form of online education, MOOCs have become an important channel for TCM education around the world. However, according to data from the Coursera platform, the dropout rate of TCM courses is as high as 67% [23]. This problem reflects the shortcomings of international TCM education in terms of curriculum design, cultural adaptability, and teaching content. Analyzing the completion rate of MOOC courses can provide a strong basis for improving TCM education [24].

3. Core contradictions and transformation bottlenecks

The digital transformation and internationalization of TCM education have brought many opportunities, yet in practice, they still face various core contradictions and transformation bottlenecks [25]. To put it simply, these challenges involve not just the conflict between standardization and the special features of TCM education but also tensions between technology-driven progress and cultural preservation. Additionally, there is the issue of international certification losing its original context, conflicts with TCM's overall approach to treatment, and structural obstacles in cross-cultural communication. An in-depth analysis of these contradictions and bottlenecks helps us better grasp the challenges in transforming TCM education and offers theoretical support for future reforms [26].

3.1. Conflict between standardization and unique characteristics

For instance, the international development of TCM education needs its system to move toward standardization to fit into global medical education. However, being a traditional medicine with thousands of years of history, TCM's theories, how diagnoses are made, and its educational structure all carry strong Chinese cultural elements. This rich cultural background, in other words, clashes with the standardization demands of global medical systems [27]. Balancing TCM's distinct identity with international standardization requirements remains a central contradiction in its global expansion [28].

3.1.1. Pressure of international standardization

The pressures from international standardization mainly impact areas like what is taught in the curriculum, assessing educational quality, and training teachers. International bodies such as the WHO and ISO have set up basic frameworks for traditional medicine education [8,10]. However, these frameworks tend to follow Western medical standards, missing key parts specific to TCM education. For example, the master-apprentice learning model, the overall approach to thinking, and the methods of dialectical treatment. Standardization tries to measure educational content, focusing on passing on knowledge, whereas TCM education values combining theory with practice and passing knowledge through close mentorship. This leads to a big clash with the measurable assessment criteria required by standardization [29].

3.1.2. Persistence of TCM's unique characteristics

Efforts to maintain TCM's uniqueness face challenges when adapting to international norms. That is to say, features like personalized treatment strategies and context-dependent diagnostic practices resist easy categorization. While modern education systems prioritize replicable teaching formats, TCM's knowledge transmission relies heavily on experiential learning and cultural immersion. This persistence creates friction during quality evaluations, particularly when using standardized metrics designed for Western biomedical education models.

Traditional Chinese medicine education acts not only as academic training but also functions as a cultural inheritance. In traditional TCM educational practices, considerable emphasis is placed on the mentor-disciple dynamic, prioritizing customized instruction and gradual buildup of hands-on expertise. To put it simply, conventional teaching models emphasize adaptability and practice-heavy methods, while international standardization frameworks demand rigid curricula and uniform assessment mechanisms. The central dilemma revolves around preserving TCM's distinctive educational characteristics while adapting to global standardization demands.

3.2. Impacts of quantitative evaluation systems on the deconstruction of the "master-apprentice experience"

Within TCM pedagogy, the "master-apprentice experience" serves as a foundational approach for transmitting knowledge and cultivating clinical competencies [30]. Modern educational systems, by contrast, depend on measurable evaluation tools—such as grading coursework, analyzing exam performance, and implementing credit accumulation systems—to assess learner progress. These methods, however, frequently overlook the slow cultivation of experiential wisdom and situation-specific problem-solving abilities gained through prolonged practice. Traditional TCM training enables learners to integrate theoretical knowledge with clinical skills through years of close mentorship, whereas modern quantitative systems prioritize numerical scoring over holistic skill development. This fundamental mismatch creates tension between apprenticeship-centered

education and data-driven evaluation frameworks [31].

3.2.1. The "quantitative bias" of modern education

Contemporary education systems predominantly focus on knowledge dissemination and converting learning outcomes into numerical metrics, often sidelining the organic growth of practical capabilities [32]. For instance, diagnostic techniques like interpreting tongue coatings or assessing pulse patterns—which require years of supervised practice—become reduced to theoretical test questions under quantitative evaluation. Similarly, formulating personalized treatment plans based on symptom patterns resists straightforward scoring mechanisms. Despite being central to TCM practice, such competencies remain poorly reflected in standardized assessments that prioritize textbook memorization. This overreliance on quantifiable metrics inadvertently marginalizes the irreplaceable role of mentorship and clinical immersion within TCM education.

3.2.2. The challenge of quantifying practical experience

The difficulty lies in translating intangible educational outcomes like a practitioner's diagnostic intuition or treatment adaptability into numerical values. While modern systems excel at tracking exam scores and course completion rates, they struggle to measure how effectively students internalize clinical decision-making processes through mentor guidance. For example, the nuanced ability to adjust herbal prescriptions based on subtle symptom shifts relies heavily on observational learning and iterative feedback, aspects that resist modular evaluation formats. This discrepancy highlights systemic limitations in assessing educational models where experiential knowledge transmission remains paramount.

The core approaches of TCM, such as diagnosis through observation, listening, inquiry, and palpation, are typically developed through years of hands-on practice and guidance from experienced practitioners [33]. However, current ways of measuring progress in education systems do not quite capture how these unspoken skills develop over time [34]. The challenge remains in how to document and pass down this mentorship knowledge through modern teaching tools and evaluation frameworks, while preventing oversimplification that could limit deeper understanding of TCM education. There exists a tension between preserving traditional learning methods and meeting modern standardization requirements.

3.3. Conflicts when international standards remove cultural context

Global certification systems demand TCM education to follow uniform benchmarks for worldwide recognition [35]. Yet TCM's foundational philosophy stresses viewing the body as an interconnected system, focusing on personalized treatment approaches that differ significantly from Western medicine's localized problem-solving and standardized protocols [36]. International frameworks often prioritize common standards, which inadvertently neglect the cultural and theoretical roots embedded in TCM education.

3.3.1. Issue of cultural disconnection

TCM teaching content draws deeply from Chinese cultural traditions, but during global certification processes, these contextual elements often get stripped away. Many international systems push for curriculum structures resembling Western medical education—emphasizing compartmentalized subjects and teaching universal knowledge. This creates misalignment with TCM's emphasis on flexible treatment strategies tailored to individual needs. When cultural and philosophical foundations are removed, there is a risk of fragmented interpretation and teaching practices that miss the essence of TCM's holistic principles [37].

3.3.2. Limitations of integrated perspectives

The unified approach central to TCM struggles to fit into assessment models favoring isolated skill evaluation. For instance, standardized testing frameworks tend to measure diagnostic capabilities separately rather than as part of dynamic patient interactions. This mismatch raises concerns about whether international certification can truly validate the nuanced competencies developed through traditional TCM training methods.

TCM's comprehensive methodology demands treatment plans integrating multiple considerations such as patient physical condition, environmental factors, and psychological aspects, resulting in highly customized care approaches [38]. In the context of global integration, certification systems now require standardized treatment guidelines across regions, thereby restricting how TCM's whole-body philosophy can operate within rigid frameworks [39]. Maintaining TCM's individualized treatment characteristics and complete health perspective within international medical education systems continues to present unresolved difficulties.

3.4. Tension between technological empowerment and cultural transmission

The accelerated development of digital tools, particularly implementations involving artificial intelligence (AI), virtual reality (VR), and Metaverse concepts, has introduced novel educational possibilities for TCM training [2]. However, these technological advancements have simultaneously created friction with the cultural dimensions embedded in TCM instruction [3]. That is to say, TCM education encompasses not merely knowledge transfer but also involves transmitting cultural philosophies and value systems. Overemphasis on technological solutions risks diminishing the human-centered ethos and mentor-apprentice dynamics fundamental to TCM learning traditions.

3.4.1. The double-edged sword effect of VR and AI

VR and AI applications can substantially enhance educational efficiency in TCM studies. For example, machine-assisted diagnostic tools enable faster mastery of pulse reading and tongue analysis techniques. Yet excessive reliance on such instruments may reduce direct patient interaction opportunities, potentially weakening trainees' compassionate care capacities and emotional intelligence [40]. Critical elements like medical ethics education and practitioner-patient rapport building might become neglected within technology-dominated teaching models.

3.4.2. Balancing technology and tradition

The central challenge within TCM education modernization lies in harmonizing technological integration with cultural legacy preservation. Simply put, we must ensure innovation tools do not erode foundational teachings. While pursuing digital transformation, educational institutions should simultaneously emphasize TCM's historical wisdom and philosophical depth, ensuring students inherit both practical skills and the cultural essence [41]. This involves protecting time-honored teaching relationships while selectively adopting technological aids that complement rather than replace humanistic values.

4. Pathways for digital transformation

In the context of globalization, the digital shift in TCM education becomes a crucial pathway for addressing standardization demands, cultural exchange barriers, and innovating curriculum content. With the swift advancement of tech tools, traditional teaching models are undergoing significant transformations. The challenge lies in how to balance technological adaptation with heritage preservation, leveraging digital methods

to modernize education, while protecting cultural authenticity remains an urgent priority requiring coordinated efforts.

4.1. Integration of educational technology and innovation

The evolution of TCM education necessitates blending technological advancements with instructional materials. Emerging technologies such as data analytics, smart algorithms, immersive simulations, and secure data systems have altered teaching approaches, learning resources, and evaluation frameworks. To put it simply, TCM educators must adapt these tools to create hybrid models that honor traditional practices while embracing modern digital trends [42].

4.1.1. Digital twin TCM hospital

The "digital twin" concept refers to a method connecting real and virtual environments through mirrored systems, enabling dynamic interaction between physical and simulated spaces. In practical terms, this technology allows learners to practice diagnostic procedures within simulated clinic settings. Through immersive digital environments, students can engage in time-flexible training sessions, overcoming geographical limitations. For instance, trainees might conduct virtual consultations using traditional diagnostic techniques like observation and pulse assessment, thereby refining clinical competencies without physical constraints.

4.1.2. Intelligent deconstruction of ancient TCM books based on NLP

Ancient books of Chinese medicine are a valuable heritage of Chinese medicine knowledge, but they are difficult to learn due to their ancient language and obscure expressions. The application of natural language processing (NLP) technology can help solve this problem in TCM education [43]. Through NLP technology, ancient Chinese medicine books can be intelligently deconstructed, medical knowledge, prescriptions, and treatments can be extracted, and translated and expressed according to the language of modern medicine [44]. Through NLP technology, the prescriptions, diagnoses, and treatment methods in classic TCM works such as *Treatise on Typhoid Fever* and *Huangdi Neijing* can be transformed into standardized medical terminology to help students better understand and master TCM knowledge. This technology can not only modernize the classical knowledge of traditional Chinese medicine but also help students quickly obtain relevant information through intelligent search and data analysis, and improve learning efficiency.

4.2. Cross-cultural communication strategies

The global dissemination and international acceptance of TCM education requires effective cross-cultural communication frameworks. Given the substantial conceptual differences between traditional Chinese medical philosophy and Western biomedical paradigms, addressing these cognitive divergences becomes crucial for facilitating worldwide educational expansion.

4.2.1. Establishing a "three-level translation" system

The deeply culturally embedded concepts and specialized terminology within TCM pose significant translation challenges. To overcome these barriers, an integrated translation methodology should be implemented, containing [45]: (1) Cultural interpretation layer [46]: Adapting foundational concepts like Yin-Yang theory and meridian systems into Western cultural reference frameworks through explanatory analogies. (2) Conceptual translation tier [47]: Transforming diagnostic theories such as "Qi deficiency patterns" into biomedical-equivalent

physiological descriptions using contemporary scientific vocabulary. (3) Standardization phase: Aligning therapeutic techniques like acupuncture manipulation with globally recognized medical practice guidelines through procedural equivalence mapping. Through this layered translation mechanism, the cultural and cognitive obstacles inherent in TCM education can be systematically addressed, producing more accessible international educational resources.

4.2.2. Developing contextualized educational tools

Interactive learning systems incorporating scenario-based simulations demonstrate particular effectiveness for conveying TCM's holistic diagnostic approaches [48]. By recreating classical case studies through virtual patient scenarios, learners can practice syndrome differentiation techniques within controlled environments. These digital platforms allow students to apply pulse diagnosis methods and herbal prescription strategies while receiving immediate feedback on their diagnostic reasoning processes. Such immersive educational tools not only improve knowledge retention but also help bridge the gap between theoretical learning and clinical application.

Contextualized educational games, utilizing game-based learning approaches, assist students in comprehending intricate subjects through simulated environments. For TCM education, this translates to creating interactive experiences such as "Five Elements Parkour" or "Meridian Maze," where learners encounter foundational theories and therapeutic techniques within virtual settings. These activities enable students to absorb essential TCM principles in an engaging manner while simultaneously developing clinical reasoning abilities through scenario-based challenges, merging theoretical knowledge with practical application.

4.2.3. Establishing a global TCM MOOC alliance

Regarding the expansion of digital education platforms, worldwide MOOC-based learning has emerged as a significant educational format. Establishing a global TCM MOOC alliance serves as a crucial mechanism for advancing educational modernization. This collaborative framework would promote cross-border resource sharing, facilitate reciprocal credit recognition between institutions, and implement multilingual translation services, thereby reducing location-based and language barriers while broadening access to TCM studies. Furthermore, the alliance could employ sophisticated data analysis tools and intelligent systems to monitor learner progress dynamically, delivering tailored content recommendations to optimize instructional outcomes, enhancing both reach and relevance.

4.3. Breakthrough in standardization construction

While promoting the digital transformation of TCM education, standardization is still the core issue in the process of globalization. How to establish a set of educational standards that meet international requirements and retain the characteristics of traditional Chinese medicine is an important task for traditional Chinese medicine education.

4.3.1. Design of the competency-based education framework for TCM

The competency-based education framework (CBE) is an educational model that focuses on students' competency development, which designs a systematic curriculum system and learning evaluation standards based on the core competencies of TCM [49]. The construction of the competency-based education framework enables students to master the basic theories and techniques of traditional Chinese medicine, and cultivate their

clinical decision-making ability, comprehensive analysis ability, and teamwork ability.

4.3.2. Dynamic digital badge authentication system

The digital badge certification system represents an educational certification approach built on blockchain technology, which enables recording learning progress, tracking clinical experiences, and certifying academic achievements through blockchain-based storage [50]. To put it simply, this method creates a transparent record of educational milestones while supporting secure sharing across institutions. By utilizing this distributed verification mechanism, the system enhances credibility in traditional medicine education and facilitates global recognition of qualifications.

4.3.3. Establishing an AI middle platform for monitoring the quality of TCM education

Regarding quality assurance, establishing monitoring tools powered by artificial intelligence has become crucial for maintaining educational standards. These AI systems can track certain important quality indicators in real-time monitoring, such as curriculum update frequency, teaching evaluations, and how students are progressing in their studies [51]. Continuous oversight helps identify potential gaps in the educational process, allowing for timely adjustments. This approach enables institutions to address issues before they escalate, thereby improving overall program quality through proactive interventions [52].

5. Policy support and ecological construction

5.1. National level

At the policy level, advancing digital transformation in traditional medicine education requires coordinated efforts across governmental and industrial sectors. National strategies should focus on creating supportive frameworks through policy direction and resource allocation. For instance, integrating digital education initiatives into broader international cooperation programs could foster cross-border collaboration. By developing comprehensive policies that encourage technological adoption while preserving cultural heritage, stakeholders can build an ecosystem conducive to sustainable growth. This involves not only regulatory support but also cultivating partnerships between educational institutions and technology providers to drive innovation in teaching methodologies.

5.1.1. Including digital TCM in the special project for the construction of the “Digital Silk Road”

The “Digital Silk Road” stands as one of China’s key strategies in the global digital economy field, focusing on pushing forward the building of worldwide digital infrastructure and collaborative efforts, which help blend international digital economy activities. By including digital TCM approaches within this initiative, not only would it assist in advancing the digital transformation of TCM education through technical exports, but also encourage the spread of TCM culture globally, creating mutual benefits across nations [53]. Through such measures, authorities could back the development of digital platforms related to TCM education, thereby boosting the adoption and dissemination of digital methods in TCM across various regions. This might involve creating educational resource platforms and online learning systems that offer TCM courses and remote clinical guidance, among other services, to learners worldwide. Moreover, via collaborative international efforts, support could be provided to developing nations and areas to set up their own TCM education frameworks, which would enhance the worldwide promotion and growth of TCM practices.

5.1.2. Establishment of the Institute of International Standards for Chinese Medicine Education

The process of internationalizing TCM education requires standardization; without unified standards, progress remains challenging. To facilitate this, the government might consider forming an International TCM Education Standards Research Institute, tasked with studying and developing educational benchmarks. This institute could work alongside academic institutions, education organizations, and government bodies both domestically and abroad to conduct standardization research, ultimately creating education standards and certification systems that hold international appeal. Key responsibilities would include establishing standards covering curriculum design, teaching approaches, and educator training, ensuring TCM education meets global expectations while preserving its traditional essence. Additionally, partnerships with international organizations could promote the recognition and application of these standards globally, offering theoretical support for TCM education's international reach.

Another proposed measure involves advocating for the creation of a WHO Traditional Medicine Education Digital Certification Center. Such a center would focus on developing digital certification processes for TCM education programs, enhancing credibility, and facilitating international acceptance of TCM qualifications. By collaborating with health authorities and educational institutions, the center could establish evaluation criteria and certification mechanisms applicable across different countries and regions. This initiative would not only standardize the quality of TCM education but also strengthen its position within global healthcare systems, thereby contributing to the broader integration of traditional medicine practices worldwide.

5.1.3. Promoting the establishment of the WHO Digital Accreditation Center for Traditional Medical Education

The WHO has incorporated traditional medicine into global healthcare frameworks [54], promoting standardization and certification processes for related education systems. As a key component within international traditional medicine practices, TCM should actively take part in building global certification mechanisms. Governments should advocate for creating a WHO-affiliated Digital Certification Center for Traditional Medicine Education, which would manage digital accreditation tasks specifically for TCM education programs.

This center would offer digital validation services for TCM training courses, ensuring educational quality aligns with international benchmarks. The certification system could utilize advanced technologies such as secure digital ledgers to verify academic credits, instructor qualifications, and related criteria, thereby ensuring transparency and reliability in certification records. To put it simply, this center would not only assist in spreading TCM education globally but also enhance its standardization and alignment with international practices.

5.2. Industry collaboration

The involvement and backing of industry stakeholders remain vital for advancing the digital transformation of TCM education. Collaborative efforts across sectors can drive innovation in technology, provide access to resources, and facilitate market expansion, all of which are essential for progressing TCM education's digital shift. Governments, businesses, and educational institutions must work together closely to enable this transformation.

5.2.1. Establishing a multinational TCM education technology alliance

Digital transformation requires both technological infrastructure and cross-sector partnerships [55]. International

cooperation can help overcome barriers to the globalization of TCM education. Governments could encourage the formation of a multinational alliance focused on TCM education technologies, enabling coordinated efforts across supply chains to jointly advance tech innovations and knowledge dissemination.

5.2.2. Developing an open-source TCM digital tools platform

Creating an open-access platform for TCM-related digital tools represents another critical step in supporting its educational digitization. Governments might support the development of such a platform, offering freely available training resources based on core TCM diagnostic methodologies. This platform would not only provide intelligent learning aids but also simulate clinical scenarios and treatment planning, thereby improving students' overall skills through practical exposure.

The advancement of such open-access platforms could make it easier to share TCM educational resources globally, offering technical assistance for spreading TCM education internationally [56]. These platforms may attract worldwide developers to participate in features like algorithm innovations, which could further push forward the digital changes in TCM education.

5.3. Cultural security mechanisms

Regarding cultural protection mechanisms, it should be noted that TCM is not just medical knowledge but also a key piece of China's cultural heritage. During the global expansion of TCM education, emphasis should be placed on safeguarding cultural information from being altered improperly or used wrongly. To put it simply, establishing comprehensive systems for protecting digital resource ownership and cultural identification becomes particularly vital.

5.3.1. Establishing a sovereign protection system for digital resources of traditional Chinese medicine

With the advancement of the digital transformation of TCM education, more and more TCM resources are stored and disseminated in digital form, including TCM classic literature, teaching content, diagnosis and treatment data, etc. These digital resources have high academic and cultural value, and how to protect these resources from abuse, misappropriation, or malicious tampering has become an important task in the digital education of traditional Chinese medicine [57].

The government may establish a sovereign protection system for digital resources of traditional Chinese medicine through legislation or policies, and clarify the ownership, use, and management rights of digital resources of traditional Chinese medicine. By formulating relevant policies, we will ensure that the digital resources of TCM will not be misused or maliciously plagiarized. At the same time, blockchain and other technical means are used to ensure the security and immutability of digital resources and provide security for the digital transformation of traditional Chinese medicine education.

5.3.2. Constructing a genetic identification system for TCM culture

Traditional Chinese medicine is not only a medical system, but also one of the representatives of Chinese culture. In the process of globalization, how to protect the intellectual property rights of traditional Chinese medicine culture to avoid its misinterpretation or abuse is an urgent problem to be solved. Constructing a genetic identification system for TCM culture to provide an independent cultural identity and intellectual property anchor for TCM culture can ensure that it is not infringed upon in the process of global dissemination [58].

Constructing a genetic identification system for TCM culture can provide a legal guarantee for TCM

education and cultural dissemination. The TCM cultural gene identification system can provide a digital chain of evidence for the intellectual property rights of TCM and maintain the independence and integrity of TCM culture. From acupuncture and moxibustion to AI diagnosis and treatment systems, building an intellectual property protection system for traditional Chinese medicine can ensure the authenticity and cultural security of traditional Chinese medicine culture.

6. Conclusion

This study thoroughly explores the digital transformation of TCM education in the context of global standardization, analyzing the opportunities and challenges brought about by this transformation. With the continuous development of technologies such as AI, VR, blockchain, and the Metaverse, TCM education is undergoing an unprecedented revolution. These technologies not only break through the temporal and spatial limitations of traditional education but also greatly enhance the accessibility and efficiency of learning, offering new opportunities for the inheritance and innovation of TCM culture.

Through this research, we have proposed and validated the "Standard-Technology-Culture" tri-spiral development model, emphasizing the need for the digital transformation of TCM education to integrate standardization, technological innovation, and cultural preservation. Standardization provides the foundation for the globalization of TCM education, enabling it to align with international educational systems and secure a place in global medical education. Technological innovation provides strong support for the teaching models, content, and methods of TCM education, driving a revolution in educational formats. Cultural preservation ensures the uniqueness of TCM education, making it not only a part of medical education in the global context but also a key element of China's cultural soft power.

The future development of TCM education will depend on the organic integration of standardization, technological innovation, and cultural preservation. This integrated transformation model will not only facilitate the global spread of TCM but also provide an important theoretical basis and practical pathway for the creation of a global health community.

Disclosure statement

The authors declare no conflict of interest.

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