Research on the Safety Knowledge System for Experimental and Practical Training Teaching in Universities of Chinese Medicine

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Abstract: *Experimental and practical training teaching in Chinese medicine faces multi-source and composite safety risks due to its nature of integrating traditional techniques with modern science. The existing safety knowledge remains fragmented and lacks systematic construction. To address this, this study aims to establish a safety knowledge system aligned with its inherent logic. First, it identifies the unique risk spectrum arising from the blending of traditional and modern approaches, explains the pathways for integrating safety awareness between the two, and redefines the core role of safety knowledge in both inheritance and innovation. Subsequently, it analyzes the structural elements of the system, including the standardized extraction of safety knowledge units, the architecture of hierarchical modules and their logical relationships, as well as the explicit articulation of tacit knowledge. Finally, it explores the mechanism for translating the system into the teaching environment, encompassing the embedded integration of knowledge carriers, process design based on competency progression, and dynamic adjustment supported by feedback mechanisms. This study provides a systematic theoretical framework for enhancing risk prevention and control effectiveness and ensuring safety in teaching and research within Chinese medicine experimental and practical training.*

Keywords: *Universities of Chinese Medicine; experimental and practical training teaching; safety knowledge system; cognitive foundation; structural elements; transformation mechanism*

Introduction

Experimental and practical training teaching in Chinese Medicine serves as a crucial bridge linking theoretical knowledge with professional competence. Its instructional process deeply integrates traditional practical techniques such as herbal processing, formulation, and acupuncture with modern biological and chemical experimental technologies. This unique setting faces composite risks stemming from the characteristics of medicinal materials, traditional craftsmanship, and modern experimental operations, rendering general laboratory safety regulations insufficient for complete coverage. Currently, relevant safety knowledge is mostly dispersed across various courses, existing in a fragmented state. It lacks systematic integration from cognitive foundations to teaching implementation, which constrains the cultivation of safety literacy and the effective management of risks. Consequently, constructing a safety knowledge system that is rooted in the inherent logic of Chinese Medicine, connects tradition with modernity, and covers the entire process from knowledge generation to application has become an urgent requirement for deepening the reform of experimental and practical training teaching and ensuring the sustainable development of talent cultivation and scientific research activities. This study aims to systematically explore the cognitive foundation, structural elements, and transformation mechanisms of this knowledge system, in order to provide a theoretical basis for establishing a scientific and standardized safety education model for experimental and practical training in Chinese Medicine.

1. The Cognitive Foundation and Theoretical Origins of Safety Knowledge in Experimental and Practical Training Teaching

1.1 Identification and Classification of Special Risks in the Experimental and Practical Training Context of Chinese Medicine

The risk composition within the experimental and practical training teaching context of Chinese Medicine possesses inherent complexity and heterogeneity. This context is a unique space where traditional craft operations intersect with modern experimental technologies, with risks originating from three major dimensions: the intrinsic physicochemical risks of Chinese medicinal materials (such as toxic components and allergenic dust), the physical and mechanical risks associated with traditional techniques (such as moxibustion with open flame and processing equipment), and the biological and chemical risks introduced by modern experiments (such as cell contamination and organic solvents). The coexistence of multi-source risks necessitates the establishment of a contextualized risk identification framework that transcends general laboratory safety protocols and is rooted in the distinctive characteristics of the Chinese Medicine discipline.

To achieve effective risk management, it is necessary to carry out systematic classification based on their mechanisms of action. Specifically, risks can be categorized into embodied risks, material risks, and environmental risks. Embodied risks refer to those directly affecting the operator's body during procedures, such as infection from acupuncture or mechanical injuries during manual techniques. Material risks are associated with experimental materials and products, encompassing uncertainties related to the toxicity of medicinal materials, their deterioration, and by-products of reactions. Environmental risks arise from the failure of supporting systems, such as ventilation and waste disposal, constituting potential cumulative hazards. This tripartite classification regards the "human-material-environment" as an interactive whole, moving beyond isolated listings of risks, and provides a structured cognitive foundation for constructing a hierarchical and contextualized safety knowledge system[1].

1.2 Integration of Safety Cognition between Traditional Chinese Medicine Practice and Modern Experimental Science

Traditional Chinese Medicine practice contains implicit safety wisdom centered on experience and a holistic view, embodied in principles such as "incompatibility contraindications," "processing for toxicity reduction," and "treatment based on three factors." Its knowledge form is largely implicit within individual experience and oral transmission, lacking standardized expression. In contrast, the safety cognition of modern experimental science is built upon empirical analysis and systematic control, relying on material safety data, standard operating procedures, and engineering controls, aiming for quantified management and universality of risks.

The integration of the two is essentially a dialogue and reconstruction between cognitive paradigms, with the key lying in constructing mutually interpretable cognitive interfaces. This requires transforming traditional experiential descriptions, such as "dietary contraindications" and "use with caution," into explicit dose-response relationships and mechanistic explanations through modern toxicology and pharmacokinetics research. Simultaneously, it involves achieving a coherent understanding of the engineering principles underlying modern protection requirements and the operational warnings present in traditional craftsmanship (such as "keep away from fire and flame"). The resulting composite cognitive framework preserves the contextual sensitivity and holistic warning mindset of traditional wisdom while incorporating the precision and systematicity of modern science. This enables safety knowledge to synergistically support the transmission of traditional techniques and the innovative exploration of modern science.

1.3 Positioning the Cognitive Role of Safety Knowledge in Skill Transmission and Innovation

Within the lineage of Chinese Medicine skill transmission, safety knowledge serves as a core cognitive component that guarantees the continuity of transmission and the legitimacy of the techniques. It transcends mere accident prevention, evolving into an internal norm for the correct preservation of skills and their recognition within the profession. Key safety points are often deeply coupled with operational skills in the form of "contraindications" and "essential principles," constituting a protected, holistic cognitive package of the technique. Its transmission ensures both the accuracy in replicating the techniques and their ethical justification[2].

In the context of experimental innovation activities oriented towards modern research, the role of safety knowledge undergoes a significant transformation, evolving from a "regulator" in transmission to an "enabler" and a "boundary delineator" in innovation. When confronting unknown risks introduced by cutting-edge fields such as research on the complex systems of Chinese medicine and the development of new formulations, rigid safety provisions are no longer applicable. In this scenario, the safety knowledge system must provide a forward-looking risk assessment framework and adaptive management principles. By defining acceptable boundaries for exploration, it carves out a "safe space" for creative thinking while managing uncertainty. Consequently, safety knowledge has been internalized as an integral component of responsible scientific thinking, becoming a proactive cognitive element that drives sustainable research innovation.

2. Analysis of the Intrinsic Structural Elements of the Safety Knowledge System

2.1 Extraction and Standardized Expression of Core Safety Knowledge Units

Core safety knowledge units are the smallest, indivisible cognitive elements with independent meaning that constitute the safety knowledge system for experimental and practical training in Chinese Medicine. Their extraction process must be based on the decomposition of the entire practical training teaching workflow and the analysis of risk nodes. Their sources are dual in nature: first, from modern experimental safety regulations, such as chemical classification and labeling, biosafety level operational requirements, and key safety steps within standard operating procedures for instruments; second, from traditional Chinese Medicine operational procedures, such as the identification and dosage limits of specific toxic medicinal materials, critical safety parameters for traditional processing heat control, and microbial standards for the disinfection and sterilization of acupuncture needles. The goal of extraction is to strip away contextual attachments and distill the essential information regarding "what substance, under what conditions, may cause what harm, and requires what basic protective measures." This process relies on the structured analysis of historical accident cases, the modern semantic translation of safety warnings found in traditional texts, and the reverse engineering of safety elements within existing operational procedures.

The standardized expression of knowledge units serves as the foundation for achieving their transferability, reproducibility, and efficient dissemination. Standardization involves both formal and semantic dimensions. Formally, knowledge units must be encapsulated following a unified, structured template, such as employing a metadata framework of "object-risk attribute-protection baseline." Semantically, it is necessary to establish an authoritative and consistent terminology system to align traditional experiential descriptions with modern scientific concepts. For instance, this involves clearly defining the corresponding modern toxicological median lethal dose (LD_{50}) ranges for medicinal materials described as "highly toxic" or "extremely toxic," or specifying concrete flash point temperatures and ventilation rate standards for operations noted as "avoiding fire." By constructing a standardized knowledge unit repository, discrete and ambiguous safety experiences are transformed into normalized data units that can be recognized, managed, and disseminated by computer systems. This lays the underlying groundwork for dynamic and personalized knowledge organization and presentation[3].

2.2 Architecture and Logical Relationships of Hierarchical Knowledge Modules

Above the atomic knowledge units, it is necessary to organize them into hierarchical knowledge modules with internal consistency according to instructional logic and cognitive patterns. The architecture of the modules should follow principles ranging from the general to the specific, from the foundational to the comprehensive, and from cognition to application. The foundational safety modules form the base layer, encompassing general laboratory safety guidelines, emergency response plans, and an overview of safety regulations and ethics, applicable to all experimental and practical training scenarios in Chinese Medicine. The specialized domain modules reside at the middle layer, constructed according to disciplinary divisions. For example, the Chinese Medicine Chemistry Experiment Safety Module focuses on risks associated with organic solvents and extraction/separation processes, while the Acupuncture Practical Training Safety Module concentrates on aseptic techniques and the avoidance of nerves and blood vessels based on anatomical knowledge. The comprehensive application modules are positioned at the top layer, designed for complex, interdisciplinary comprehensive training projects that simulate real-world research or production situations. These modules integrate knowledge from multiple specialized modules to address nonlinear and interactive risks[4].

The various hierarchical modules do not exist in isolation but are interconnected through a rigorous network of logical relationships. These connections manifest as vertical support-progression relationships and horizontal mapping-coordination relationships. Vertically, the knowledge from foundational modules is a prerequisite for accessing specialized modules, while the in-depth understanding from specialized modules provides the tools for addressing complex problems in comprehensive modules. Horizontally, different specialized modules share some underlying knowledge units and establish knowledge mappings at specific intersection points. For example, protection against high-temperature burns in the Chinese Medicine Processing Module shares the heat protection knowledge unit with equipment high-temperature operation safety in the Pharmaceutical Engineering Module. By explicitly designing these logical connections, the knowledge system can form a nonlinear, networked structure. This supports learners in flexibly accessing and integrating relevant knowledge clusters according to different learning pathways and task requirements, thereby accommodating the highly interdisciplinary nature of the Chinese Medicine discipline.

2.3 Paths for the Explication and Systematization of Tacit Safety Knowledge

Within the experimental and practical training of Chinese Medicine, there exists a substantial body of tacit safety knowledge that is difficult to fully articulate through language, text, or formulas. This knowledge is deeply embedded in specific operational contexts, bodily perceptions, and experiential judgments. Examples include the keen awareness of changes in the texture of medicinal materials to determine the endpoint of processing and avoid scorching; the subtle balancing of moxibustion distance and the patient's sensory feedback to prevent burns; and the intuitive risk warning triggered by abnormal sounds from experimental equipment. This type of knowledge is typically transmitted through observation, imitation, and personal trial-and-error within master-apprentice relationships. Its individualized and implicit nature constitutes a blind spot for coverage by standardized knowledge systems. Neglecting such knowledge would result in a constructed system that remains superficial, incapable of addressing the multitude of non-standardized and emergent risk scenarios present in real-world settings.

Achieving the explication and systematization of tacit knowledge requires the construction of diversified transformation pathways. Cognitive task analysis can be employed to deconstruct the thought processes of experts during complex safety decision-making, externalizing their implicit judgment criteria into describable decision trees or flowcharts. The use of video annotation and scenario replay technology enables the capture and analysis of subtle movements and contextual interactions within expert operations, transforming "sensations" into observable and analyzable visual sequences. Designing structured reflection logs and critical incident discussion templates can guide learners in converting the vague experiences accumulated from personal practice into organized situational descriptions and causal analyses. Ultimately, this partially explicated knowledge is not directly converted into rigid rules. Instead, it is organically integrated into the aforementioned hierarchical modules, particularly applied within comprehensive application modules and advanced skill training, serving as case libraries, expert heuristic rules, or scenario simulation scripts. This approach preserves and constructs an institutional space for the transmission and development of practical wisdom that cannot be fully articulated, all within a systematic framework.

3. Transformation and Integration Mechanisms of the Knowledge System into the Teaching Domain

3.1 Embedded Integration Model of Safety Knowledge Carriers and Course Content

Safety knowledge carriers refer to the specific forms and media that bear and transmit core knowledge units and modules. The diversity of their forms determines the variation in integration models. Carrier forms primarily include textual (e.g., standardized operating procedures, safety data sheets), audiovisual (e.g., 3D animation demonstrations, virtual reality simulated accident scenarios), physical (e.g., actual teaching aids of personal protective equipment, typical damaged components resulting from erroneous operations), and digital interactive (e.g., augmented reality-based equipment safety operation guides). Each type of carrier has its own emphasis on the degree of knowledge explicitness, situational immersion, and interactivity. The depth of integration is not mere addition; it requires the instructional adaptation and targeted design of safety carriers according to the knowledge structure and skill training objectives of different specialized courses, thereby enabling them to become the logical link organically integrated into the course content[5].

Embedded integration primarily manifests in three modes. The first is the embedding of pre-positioned foundational modules, which involves systematically incorporating foundational and specialized safety modules strongly related to the core skills of the course at the beginning of professional practical training courses, establishing prerequisite cognition. The second is the embedding of accompanying micro-units, where specific safety knowledge units or mini-modules are precisely integrated into key steps of theoretical explanations or practical demonstrations in the form of cases, warnings, or operational points, achieving the simultaneous construction of knowledge and skills. The third is the embedding of integrated project-based elements, where in comprehensive, design-based experiments or graduation practical training, safety requirements are set as explicit project constraints and evaluation dimensions, requiring students to actively utilize and integrate multiple safety knowledge modules to plan and design experimental protocols and emergency plans. These three modes progress from specific points to broader aspects and from shallow to deep levels, collectively forming a multi-dimensional integration network that ensures safety knowledge permeates the entire teaching process.

3.2 Process Design for Knowledge Transmission and Internalization Based on Competency Progression

The design of the knowledge transmission process must follow the inherent hierarchical progression governing the formation and development of safety competencies. A competency progression model can be structured into four consecutive levels: "Cognitive Identification," "Normative Compliance," "Risk Assessment," and "Autonomous Management." At the Cognitive Identification stage, the teaching focus is on enabling students to accurately identify various hazard sources and risk indicators through diversified carriers, thereby establishing a preliminary mental map of risks. Upon entering the Normative Compliance stage, the emphasis shifts to rigorous procedural training and immediate feedback, ensuring students master standard operating procedures and the correct use of personal protective equipment, thereby forming conditioned-reflex safety behavior patterns. These first two stages prioritize the accuracy of knowledge transmission and the standardization of behavior.

The latter two stages focus on the internalization and advanced application of knowledge. The Risk Assessment stage aims to cultivate students' ability to conduct proactive safety analysis for non-standard situations or complex experimental protocols. Instruction must provide structured analytical tools and case libraries, training students to utilize existing knowledge for hazard identification, likelihood analysis, and consequence prediction. The highest level, the Autonomous Management stage, targets the construction of an internal framework of safety responsibility and a mindset of continuous improvement within the student's subjective consciousness. This enables them to actively seek information, formulate and implement safety measures in situations without supervision or when facing unknown challenges, and possess the willingness and capability to supervise and remind themselves and others regarding safety. The instructional process must design reflective assignments, simulated command scenarios, and safety planning tasks based on real-world projects to facilitate the complete transformation of knowledge from external discipline into internal competency[6].

3.3 Feedback Regulation of Knowledge Application and Risk Avoidance in the Teaching Context

The teaching context is a dynamically generated field where the effectiveness of knowledge application and the exposure of potential risks form a continuous feedback loop. The systematic collection of feedback information is a prerequisite for the regulation mechanism to take effect. The sources of this information include formative assessment data, such as in-class safety knowledge quizzes and behavioral deviations identified through the analysis of operational videos; procedural observation records, such as instructors' observations on the efficiency of safety communication within team collaborations; and facility and environmental monitoring data, such as anomalies in access control, equipment status, or waste disposal logged by the laboratory's intelligent management system. Furthermore, in-depth analysis of near-miss incidents or incidents with potential consequences occurring during simulated drills or actual practical training is key to obtaining high-quality feedback.

Feedback regulation operates at two levels. The first is the dynamic optimization of the knowledge system and teaching content. Through the clustering and analysis of feedback information, weaknesses, outdated areas, or gaps in safety knowledge can be identified. This, in turn, triggers updates to core knowledge units, supplements to the teaching case library, and adjustments to training priorities. The second level involves immediate intervention in teaching strategies and individual learning paths.

Based on performance data from students in virtual simulation training or practical operations, their current stage within the competency progression and the specific cognitive obstacles they face can be assessed. Subsequently, adaptive measures such as providing enhanced training modules, pushing targeted learning resources, or adjusting the complexity and risk level of practical training tasks can be implemented. This dual-loop feedback regulation mechanism ensures that the safety teaching system is not a static, rigid conduit for knowledge transfer. Instead, it functions as an intelligent ecosystem capable of self-diagnosis, learning, and evolution, thereby continuously improving its efficacy in risk anticipation and control.

Conclusion

This study has systematically constructed a theoretical framework for the safety knowledge system in experimental and practical training teaching at universities of Chinese Medicine. The research reveals that the construction of this system must begin with an in-depth identification of the composite risks specific to the Chinese Medicine context and achieve a paradigm integration of traditional experiential safety wisdom with modern scientific safety cognition. The core of the system lies in its inherent logical structure, which forms a dynamic and organic knowledge network through standardized knowledge units, hierarchical modules, and the effective transformation of tacit knowledge. Ultimately, the vitality of this knowledge system is reflected in its efficacy in transforming into the teaching domain. Through embedded integration, progressive competency cultivation, and feedback regulation mechanisms, it accomplishes the transformation of safety knowledge from external discipline into individual internal competency. Future research can be deepened in the following directions: first, the empirical evaluation and optimization of the system's efficacy; second, leveraging artificial intelligence and virtual reality technologies to promote the intelligent and contextualized presentation and training of knowledge; third, exploring the construction paradigms for adaptive safety knowledge systems in broader intersecting fields of traditional medicine and modern science and technology. This will continuously advance the safety, quality, and innovation levels of experimental and practical training teaching in Chinese Medicine.

Fund Projects

Heilongjiang Provincial Higher Education Association Higher Education Research Project, Project Title: "Research on the Safety Knowledge System for Experimental and Practical Training Teaching in Universities of Chinese Medicine (Project Approval Number: 23GJYBJ107)"

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