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TEACHING INNOVATION

Optimal design of formative evaluation method for pain diagnosis and treatment course based on post competency

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Abstract

This study aimed to construct a competency-based formative assessment system for the undergraduate Pain Diagnosis and Treatment course in anesthesiology. By integrating internationally authoritative competency frameworks and conducting systematic literature analysis, five core competency dimensions were identified: clinical pain knowledge, pain diagnosis and therapeutic procedural skills, professional responsibility, interpersonal communication and collaboration skills, as well as scientific research and innovative thinking. Based on this model, a formative assessment system incorporating various tools—such as written tests, Objective Structured Clinical Examination, Mini-Clinical Evaluation Exercise, and reflective journals—was designed. The system emphasizes ability-oriented, process-based, diverse, feedback-driven, and developmental assessment principles. It is accompanied by a phased implementation plan and training for both faculty and students. This framework aims to shift the assessment focus from knowledge memorization to competency application, thereby providing a structured reference for enhancing teaching quality and students' comprehensive clinical abilities. This paper proposes a theoretical framework and implementation plan; however, its teaching effectiveness awaits verification through subsequent empirical research.

Keywords: Post competency, Pain medicine, Formative assessment, Teaching reform, Medical education

Highlights

- Develops a competency-based framework tailored for pain medicine education, which integrates five core dimensions—clinical knowledge, practical skills, professionalism, communication, and innovative thinking—specifically aligned with anesthesiology undergraduates' training needs.
- Introduces a multi-method formative assessment system utilizing tools such as Objective Structured Clinical Examination, Mini-Clinical Evaluation Exercise, reflective journals, and case-based evaluations to enable continuous, process-oriented, and ability-focused learning feedback.
- Proposes a structured implementation strategy with phased roll-out and stakeholder training to facilitate the transition from traditional summative testing to dynamic, feedback-driven assessment, enhancing both teaching quality and students' clinical readiness.

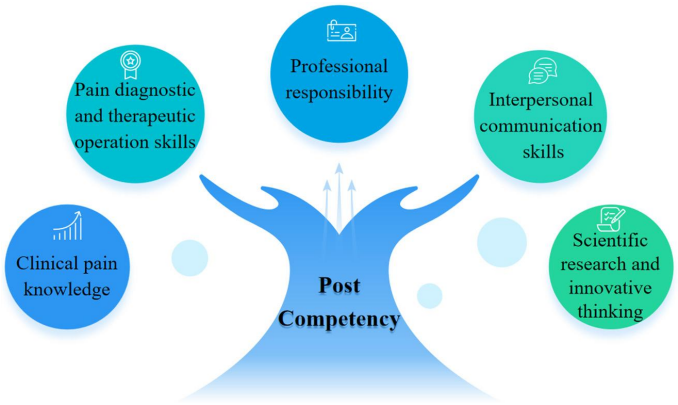

Figure 1. Five key dimensions of job competence in anesthesiology (pain diagnosis and treatment course).

1 INTRODUCTION

Post competency is derived from the concept of competency proposed by Professor McClelland of Harvard University in 1973 and regarded as the fundamental quality that resident physicians should possess [1]. The competence of medical staff is influenced by various factors such as professional knowledge, clinical skills, values and attitudes, and to a certain extent, it is an observable ability. Formative assessment is involved in all aspects of teaching process, but due to practical constraints such as limited teaching hours, it cannot be implemented in every part [2, 3]. At present, there is no unified standard for defining the post competency of anesthesiologists in China. We reviewed two key frameworks: the six core competencies for medical student defined by the American Council for Graduate Medical Education—(patient care, medical knowledge, practice-based learning and improvement, interpersonal communication skills, professionalism, and systems-based practice)—and the seven competencies outlined by the University of Minnesota Medical School based on its own educational requirements and experience, including medical knowledge, clinical skills and patient care, professionalism, scientific and clinical inquiry, interpersonal communication skills, healthcare systems, and reflective practice [4, 5]. Through a synthesis and analysis of these frameworks, we concluded that the post competency for anesthesiology (specifically within the Pain Diagnosis and Treatment course) essentially encompasses the integrated development of five key dimensions: clinical pain knowledge, pain diagnostic and therapeutic procedural skills, professional responsibility, interpersonal communication skills, as well as scientific research and innovative thinking (**Figure 1**). However, for undergraduate anesthesiology students at the collegiate level, the educational objective extends beyond acquiring solid foundational knowledge. It should also focus on developing their comprehensive professional competence, self-development potential, and awareness of lifelong learning in preparation for future professional activities [6].

Pain Diagnosis and Treatment, as a secondary discipline of anesthesiology, has been increasingly valued by clinicians for its multi-disciplinary integration (including neurology, anesthesiology, interventional radiology, and orthopedics, among others), strong practicality (such as injection therapy, minimally invasive interventional therapy, and ultrasound-guided therapy), and its emphasis on humanistic care as well as communication and collaboration in solving patients' pain problems in clinical practice [7]. Currently, the trend of globalization in medical education standards emphasizes the cultivation of medical professionals with core post competencies, rather than mere memorizers of knowledge. Traditional assessment methods for pain diagnosis and treatment focuses more on theoretical knowledge, which fails to comprehensively and dynamically evaluate students' key post competencies, such as clinical thinking, decision-making ability, and communication skills. Formative assessment of courses is an evaluative approach characterized by continuity, depth, and diversity throughout the students' learning process. It monitors and provides feedback on student learning during the course, thereby promoting learning effectiveness and autonomy, and ultimately enhancing learning outcomes [8]. Therefore, the design of post competency-based formative assessment and its value orientation hold core advantages in providing timely feedback, guiding learning direction, and promoting ability development. In this study, we propose a scientific, systematic and operational formative evaluation framework for the Pain Diagnosis and Treatment course based on post competency. This framework aims to establish a close connection between the evaluation content and clinical position demands, thereby enhancing both teaching quality and students' comprehensive clinical abilities.

2 ANALYSIS OF EXISTING EVALUATION METHODS

2.1 Current situation

In the current undergraduate anesthesiology education system in China, 91.3% of institutions offer Pain Diagnosis and Treatment course. This course is typically a required component of the anesthesiology major, with class hours ranging from 16 to 54, of which practical teaching accounts for 4 to 18 hours [9]. Consequently, the constrained curriculum time often results in students' learning remaining at a superficial, theory-focused stage.

The evaluation method employed in the Pain Diagnosis and Treatment course mainly focuses on summative assessment, which assesses students' outcomes at the end of an instructional period. The main approach consists of a final written test. The content of this exam largely focuses on the memorization and understanding of theoretical knowledge points, such as the pathophysiology of pain (e.g., pain mechanisms), diagnostic criteria for common pain diseases, principles of pharmacotherapy, and mechanisms of nerve blocks. Typical question formats include multiple-choice items, definition of terms, short-answer

questions, and case analyses. While these traditional methods have played a certain role in assessing students' knowledge acquisition and fundamental understanding, a significant gap remains between their design and the goal of "post competency-oriented" emphasized by modern medical education.

2.2 Existing problems

The evaluation content is fragmented and disconnected from the requirements for integrated clinical competence. Classroom exercises and final written examinations often deconstruct the holistic clinical knowledge system into isolated, fragmented knowledge points for assessment. For example, students are required to recite definitions of pain and related diseases, list diagnostic methods for pain conditions, memorize side effects of certain analgesic drugs, or individually enumerate diagnostic criteria for specific diseases. Consequently, pain case analysis questions have been reduced to mere formalities, lacking genuine assessment of critical thinking in the diagnosis and treatment of pain cases.

Formative assessment is predominantly teacher-centered, lacking diversity in participation. During practical evaluations and classroom exercises, the decision-making authority is entirely concentrated with the teachers. Consequently, students—the primary learners—are deprived of opportunities for self-assessment, peer evaluation, and simulated patient feedback within the current evaluation system. This limitation leads to several issues: students often lack self-awareness and passively accept external evaluations, showing insufficient initiative in reflecting on their own strengths and weaknesses. The absence of peer evaluation prevents them from understanding their communication and collaboration skills from a colleague's perspective, hindering the cultivation of teamwork. Furthermore, the lack of feedback from simulated patients makes it challenging to assess students' levels of humanistic care, empathy, and communication skills.

Emphasizing learning outcomes while neglecting the learning process leads to the oversight of students' efforts, progress, and cognitive growth. Key formative elements, such as participation and contribution in PBL/CBL discussions, improvement in simulated operations, and the enhancement of medical record writing quality, are either omitted from course design or not effectively implemented and evaluated. This outcome-oriented approach reinforces undesirable learning behaviors. For instance, most students tend to resort to cramming before exams, rather than actively participating, thinking deeply, and proactively constructing their knowledge system throughout the course. Moreover, students who improve slowly may have their progress entirely negated by a single exam failure, which could undermine their learning confidence and diminish enthusiasm.

3 CONSTRUCTION AND DETAILED EXPLANATION OF THE POST COMPETENCY MODEL

Post competency is regarded as the fundamental quality that resident physicians should have. The development of competency must be strongly connected to clinical practice to guide physicians in observing and using it to assess the actual ability of the trainees [10]. Based on the above inductive analysis, the core competencies required for the anesthesiology major (specifically in the field of pain diagnosis and treatment) can be summarized as the integrated development of the following five aspects, including clinical pain knowledge, pain diagnostic and therapeutic procedural skills, professional responsibility, interpersonal communication skills, scientific research and innovative thinking. To align with this model, a clinical practice assessment will be conducted every 20 class hours. The following section will explain and elaborate on each of these core competency dimensions in conjunction with the requirements of pain diagnosis and treatment positions (see **Table 1**).

The construction of the post-competency model in this study was based on a systematic literature analysis. The research team established the core competency dimensions through the following steps:

Literature search and screening: Using Chinese and English keywords such as "pain medicine education", "anesthesiology competency", "clinical pain assessment", and "medical education curriculum design", a systematic search was conducted in the PubMed and CNKI databases for literature published between 2015 and 2025. The preliminary search yielded 314 articles in Chinese and 643 in English. Following a sequential screening process based on title, abstract, and full-text review, 28 high-quality articles relevant to pain medicine education were ultimately included (14 Chinese and 14 English articles).

Content analysis and dimension extraction: Thematic analysis and content synthesis were conducted on the included literature, with a focus on three key areas: (1) descriptions of pain-related abilities within internationally recognized general medical competency frameworks; (2) explicitly stated knowledge, skill, and attitude requirements in specialty pain medicine education literature; and (3) specific competency requirements for physicians in pain diagnosis and treatment within the Chinese clinical context. Through an iterative process of comparison, induction, and clustering, preliminary clusters of competency elements closely aligned with the pain management role were identified.

Dimension integration and model formation: The preliminary competency clusters were cross-referenced and integrated with the requirements for the pain module as outlined in China's undergraduate medical education syllabus. After mul-

Table 1. Construction of evaluation content and indicators

Core competency	Content of assessment	Specific assessment indicators	Main assessment methods and tools
Clinical pain knowledge	Mastery and application of fundamental theories and clinical knowledge in pain medicine.	Knowledge memorization: Accurately explain the pathophysiological mechanism, classification, and clinical manifestations of common pain diseases. Knowledge comprehension: Explain the mechanisms of action, indications, contraindications, and adverse reactions of different analgesics. Knowledge application: Conduct differential diagnosis, analyze complex pain cases, and interpret the results of auxiliary examinations (such as imaging and neuro-electrophysiology).	Formative written exams/tests (focusing on case analyses, short-answer questions), case analysis reports, PBL discussion performance, oral/bedside questioning
Pain diagnostic and therapeutic procedural skills	The standardization and proficiency in pain-related clinical operations and diagnosis/treatment processes.	Assessment skills: Systematically collect a pain history (using scales such as VAS, NRS) and conduct a targeted physical examination. Diagnostic skills: Document a pain medical record and propose a preliminary diagnosis with differential diagnoses. Operation skills: Demonstrate common pain intervention techniques (such as nerve block and trigger point injection) on models, reflecting aseptic concepts and patient safety awareness. Treatment skills: Formulate individualized and multi-dimensional treatment plans (including pharmacological, rehabilitative, interventional, and psychological modalities).	OSCE, direct observation of procedural skills, simulated treatment/procedures, medical record writing quality assessment
Professional responsibility	Demonstration of professional ethics, empathy, and ethical decision-making ability in pain practice.	Empathy and care: Demonstrate understanding, respect, and care for patients' pain during communication and operation. Responsibility: Exhibit rigor and accountability for diagnosis and treatment decisions, prioritizing patient first. Ethical practice: Identify and deal with ethical dilemmas in the diagnosis and treatment of pain (e.g., rational use of opioids, informed consent). Professionalism: Adhere to professional norms, protect the privacy of patients, and show a positive attitude toward study and work.	Mini clinical evaluation exercise, reflection logs (on ethical cases or challenging patients), teacher/tutor observation and evaluation, 360-degree (nurses, peer feedback)
Interpersonal communication skills	Ability to communicate and collaborate effectively with patients, family members, and healthcare team members.	Doctor-patient communication: Effectively explain the condition, treatment options, risks, and benefits to patients and their families in plain language and obtain informed consent. Teamwork: Communicate effectively with rehabilitation therapists, nurses, psychotherapists and other professionals in simulated or real scenarios to collaboratively develop treatment plans. Communication skills: Listen effectively and reassure anxious or angry patients/family members.	OSCE (communication station), mini clinical evaluation exercise, performance in simulated group case discussions/consultations, and feedback from standardized patients
Scientific research and innovative thinking	Critical thinking, information literacy, and preliminary research exploration capabilities.	Information management: Effectively retrieve, critically evaluate, and apply current best evidence to clinical problems. Critical thinking: Raise insightful questions in case discussions, challenge assumptions appropriately, and avoid blind adherence to authority. Innovation: Propose evidence-based suggestions or questions regarding existing diagnosis/treatment plans or processes. Introduction to research: Complete a small literature review or case report in a standard academic format.	Literature critique/report, quality of speeches in PBL/CBL sessions, innovative proposals (such as short course papers), quality awareness of case reports/review writing

Note: PBL, problem-based learning; CBL, case-based learning; VAS, visual analogue scale; NRS, numeric rating scale; OSCE, objective structured clinical examination.

tiple rounds of discussion within the research team, these elements were aggregated, refined, and ultimately consolidated into five core dimensions: clinical pain knowledge, pain diagnosis and therapeutic procedural skills, professional responsibility, interpersonal communication and collaboration skills, as well as scientific research and innovative thinking. These five dimensions constitute the theoretical framework of this study.

Clinical pain knowledge: This dimension requires the systematic mastery of fundamental theories, clinical knowledge, and

diagnostic-therapeutic thinking in pain medicine. It entails proficiency in the key diagnosis and treatment points of various acute and chronic pain diseases. Furthermore, it demands strong clinical reasoning skills to extract crucial information from complex clinical data, formulate accurate diagnoses, and develop individualized treatment plans.

Pain diagnosis and treatment operational skills: This dimension entails the practical ability to safely and accurately perform various pain diagnostic and therapeutic techniques. It requires proficiency in mastering and completing interventional procedures under imaging guidance, as well as the competence to properly manage related complications. Furthermore, it emphasizes the commitment to continuously learn and refine new techniques [11].

Professional responsibility: This dimension encompasses adherence to professional ethics, with an unwavering priority on patient safety and a commitment to rigorous and evidence-based practice. It involves a deep understanding of patient suffering, demonstrated through empathy and compassion in all interactions. Finally, it includes the intrinsic motivation for continuous knowledge update and the enhancement of professional capabilities.

Interpersonal communication skills: This dimension requires the ability to build trust with patients by using plain language, demonstrating attentive listening skills, and encouraging patient participation in shared decision-making. It also entails clear and efficient communication within multidisciplinary teams, as well as the competence to appropriately navigate various sensitive or challenging communication scenarios [12, 13].

Scientific research and innovative thinking: This dimension necessitates maintaining critical thinking in clinical practice. It involves the ability to identify, question, and recognize unmet clinical needs, and subsequently to explore solutions. Furthermore, it encompasses the ability to conduct research and translate practical clinical experience into academic achievements [14].

4 THE PRINCIPLES OF DESIGN

4.1 Ability-oriented principle

The core of assessment should shift from "knowledge memorization" to "competency application", focusing on whether students can integrate and apply their acquired knowledge, skills and attitudes to solve real clinical pain problems [15]. Consequently, the assessments for pain management design no longer merely focuses on the rote recall of pain classifications or drug mechanisms. Instead, it must concentrate on evaluating core competencies in pain diagnosis and treatment, such as pain assessment and diagnostic reasoning capabilities, treatment plans formulation and implementation skills, patient communication and compassionate care abilities, and multidisciplinary collaboration awareness.

4.2 The principle of process

Assessment is integrated throughout the entire teaching and learning process, rather than relying solely on a single final exam. It must emphasize the continuous observation and recording of students' learning, practice and reflection. In the Pain Diagnosis and Treatment course, evaluation points are embedded within each key instructional phase. These range from the initial simulation training in pain history-taking, to mid-term pain case analysis and discussion, and finally to the later clinical internship/simulated operation. This design enables the dynamic tracking of each student's developmental progress.

4.3 The principle of diversity

Teachers can employ diverse evaluation methods and tools to assess students' comprehensive abilities from multiple perspectives and in various contexts, providing a holistic reflection of their post competency [16]. This multidimensional approach can be structured across three levels. At the knowledge level, traditional written examinations should emphasize case analysis questions and in-class quizzes. At the skill level, a combination of tools such as the Objective Structured Clinical Examination (OSCE), simulated diagnosis and treatment scenarios, and Direct Observation of Procedural Skills (DOPS) can be utilized. At the attitude and professionalism level, evaluation can be conducted through the Mini-Clinical Evaluation Exercise (Mini-CEX), reflective journals (e.g., documenting reflections on patients with refractory pain or ethical dilemmas), and observations of performance in small-group case discussions.

4.4 The principle of feedback

The ultimate purpose of assessment is not merely to assign a score, but to provide timely, specific, and constructive feedback that helps students identify their strengths and weaknesses, thereby clarifying the direction for improvement [17]. After any evaluative activity, structured feedback should be provided by teachers, peers, and standardized patients. For instance, after an OSCE station, the teacher should offer more than just a grade. The feedback should be specific and actionable, such as noting that students' history-taking covered the nature, location, and degree of pain, but they omitted inquiry into the critically important aggravating and alleviating factors, which are essential for formulating a differential diagnosis.

4.5 The principle of development

Assessment should promote students' future career development and stimulate their motivation for autonomous and life-

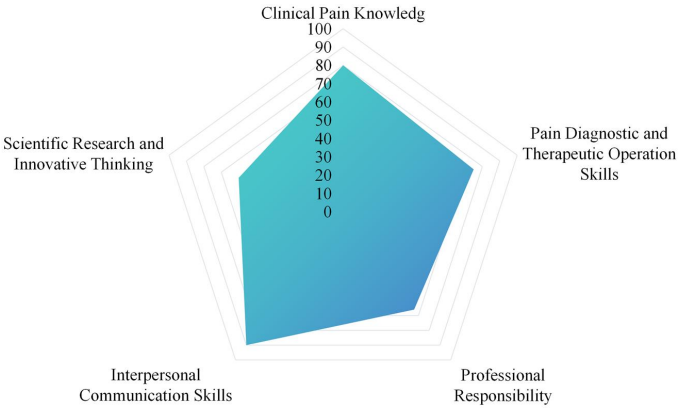

Figure 2. Post competency development radar chart (illustrative example).

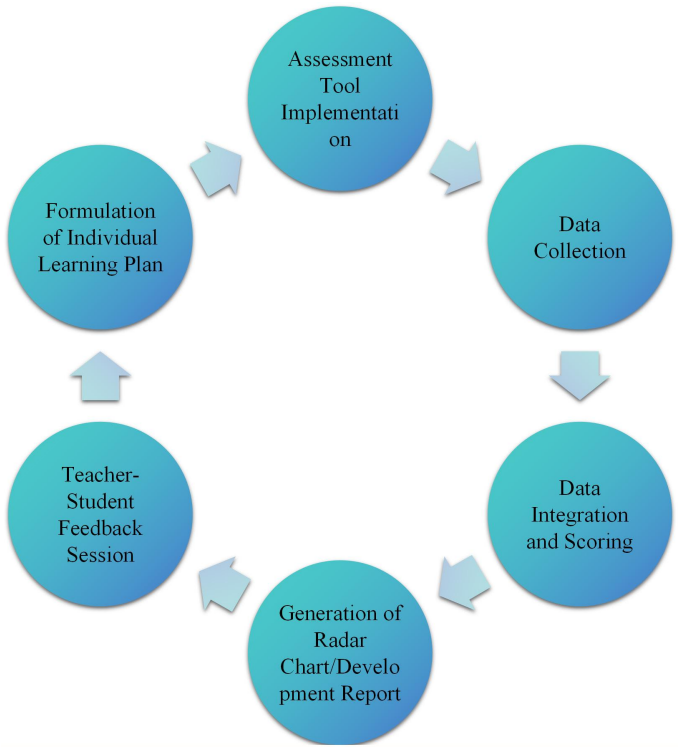

Figure 3. Flowchart of the assessment-feedback cycle.

long learning [18]. To achieve this, evaluation results should be combined with the individual development plans. A practical strategy is to establish a "learning portfolio" for each student, serving as a comprehensive repository that collects various forms of assessment evidence throughout the course. This portfolio may include their best case reports, reflection journals, video reviews of OSCE performances, and teacher feedback records. During the mid-to-late stages of the course, instructors should guide students to conduct self-assessments based on their portfolios. Subsequently, students can collaborate with mentors to develop personalized learning and development plans. These plans might target specific competencies, such as enhancing radiological image interpretation skills or improving the ability to explain the risks and benefits of interventional therapies to patients.

5 FORMATION AND UTILIZATION OF EVALUATION RESULTS

The assessment data for each student (such as OSCE station scores, Mini-CEX evaluation forms, feedback on reflective journals) will be aggregated. We will calculate a standardized score for each core competency dimension. For instance, all scores related to "Pain Diagnostic and Therapeutic Operation Skills" from different assessment tools will be integrated to derive a composite score for that dimension. Based on this data, a "Post Competency Development Radar Chart" (**Figure 2**) will be generated for each student. This chart provides a visual profile of the student's strengths and areas for development, serving as the basis for personalized feedback and development plans. Additionally, **Figure 3** illustrates the assessment-feedback cycle, detailing the process from the implementation of multiple assessment tools to data collection and integration, followed by the visualization of results (Radar Chart). The visualized profile then informs feedback and guidance, ultimately resulting in the development of individualized learning plans. The evaluation results should include assigned scores while emphasizing descriptive assessment, highlighting strengths, weaknesses and improvement suggestions. All formative assessment materials should be stored in student's personal learning portfolios for reference in the mid-term assessment or the final comprehensive grade determination. Meanwhile, teaching adjustments should be made based on student performance, peer assessment outcomes, and instructor evaluations during implementation process. And teachers dynamically adjust the teaching content, methods, and strategies by analyzing the prevalent weak links.

6 IMPLEMENTATION PLAN AND EXPECTED CHALLENGES

6.1 Selection of pilot classes

One or two representative classes should be selected for pilot programs, such as those comprising students with diverse backgrounds or varying learning abilities. It is essential to ensure that the subject teachers and teaching administrators of the pilot classes understand and support this reform. Furthermore, formal consent and active cooperation must be obtained from college, teaching and research section, as well as from the teachers and students of the pilot class. Throughout the pilot phase, experience will be accumulated, problems will be promptly identified, and the plan will be refined in collaboration with participating instructors before its implementation is gradually expanded.

6.2 Training and assessment of teachers and students

Training for teachers: (1) Understand the concept and purpose of formative assessment, emphasizing its developmental nature rather than summative nature. (2) Master the specific usage methods, scoring criteria and common misunderstandings of various assessment tools. (3) Learn how to provide effective feedback that is specific, timely, based on direct observation, and focused on improvement). (4) Develop the ability to guide students in conducting self-assessment and peer assessment. (5) Learn to use the Feedback Quality Assessment Scale, which evaluates feedback across four dimensions: timeliness, specificity, behavior-based focus, and constructiveness, to ensure the effectiveness of feedback (Supplementary Table 1).

Format: case analysis, role-playing, observation and demonstration, among other methods.

Training for students: (1) Understand the purpose and significance of competency-based formative assessment, and be clear that it is a tool to support their learning and growth. (2) Be familiar with the processes and requirements of various assessment activities. (3) Learn how to interpret and utilize feedback from teachers and peers for self-improvement. (4) Learn how to conduct objective and fair peer evaluations.

Format: course introduction, dedicated orientation meetings, distribution of explanatory materials, and live demonstrations.

6.3 Implementation in phases

Phase One (Pre-course): This phase focuses on the assessment of basic knowledge and fundamental skills. Activities may include simulated pain history collection, observation of basic communication techniques, and quizzes on the basic pain theories.

Phase Two (Mid-course): This phase emphasizes the assessment of comprehensive application and clinical decision-making. Examples encompass the analysis and discussion of complete clinical cases, simulated diagnostic and treatment processes, and basic nerve block procedures on models.

Phase Three (Late-course): This phase prioritizes the assessment of knowledge integration, reflective practice, and complex situation management. Tasks may involve handling complex and challenging cases, discussing ethical dilemmas, and reviewing and displaying learning portfolios.

Following each phase, concentrated feedback and guidance should be provided to help students clarify the learning priorities for the subsequent stage.

6.4 Expected challenges

Teacher's workload will increase significantly. Designing assessment tools, organizing implementation, observing and recording student performance, providing feedback, and managing associated data will add extra work for teachers.

Teachers' feedback skills require systematic training. Not all teachers naturally possess the professional skill to provide high-quality, learning-focused feedback. Ineffective feedback (such as vague or overly critical comments) may hinder rather than support student development.

Student may initially experience discomfort with the new assessment model. Accustomed to traditional summative assessments, they might feel unfamiliar with frequent formative evaluations, peer reviews, and self-reflection, potentially leading to anxiety or resistance.

7 DISCUSSION

The formative assessment system constructed in this study is not created in isolation; rather, it is a systematic integration and innovation based on established assessment theories in international medical education, adapted to the specific needs of pain diagnosis and treatment. The following section compares this system with several classic assessment models to clarify its theoretical grounding and practical value.

Firstly, this system comprehensively addresses the physician competency levels outlined in Miller's Pyramid [19]. At the "knows" level, students' clinical pain knowledge is assessed through formative written tests and oral questioning. At the "knows how" level, their clinical reasoning is evaluated through case analysis and PBL discussions. At the "shows how" level, their procedural and communication skills are directly observed through OSCE stations and simulated operations. Finally, at the "does" level, their integrated performance and professionalism are assessed in real or highly simulated clinical settings via Mini-CEX and DOPS. This multi-layered design ensures a continuous assessment pathway that spans from theoretical knowledge to practical application [20, 21].

Secondly, the core design philosophy of this system aligns closely with programmatic assessment. Programmatic assessment emphasizes that significant decisions about a learner's competence should be based on numerous, varied assessment activities ("small snapshots") rather than relying on a single high-stakes examination. The multiple tools adopted in this study—OSCE Mini-CEX, reflective journals, case reports—precisely embody this philosophy. By systematically collecting data from these assessment activities throughout the entire course into students' "learning portfolios" and conducting inte-

grated analyses (such as generating post-competency radar charts), a more comprehensive, reliable, and fair overall judgment of student abilities can be formed, thereby realizing the developmental purpose of assessment [22, 23].

Finally, this system organically integrates the core tools of workplace-based assessment (WBA) [24]. Mini-CEX and DOPS themselves are exemplary tools of WBA, promoting learning by directly observing trainees' performance in authentic clinical settings and providing immediate feedback. The innovation of this study lies in the proactive and systematic introduction of these WBA tools, typically used in residency training, into the undergraduate pain diagnosis and treatment curriculum. Moreover, by combining them with other assessment methods (such as written tests and reflective journals), the study constructs a formative assessment closed loop that runs through theoretical learning and early clinical practice [25]. This approach not only allows students to become familiar in advance with assessment models they will encounter post-graduation but also significantly enhances the authenticity and predictive validity of the assessment.

The effectiveness and feasibility of this system will be verified through subsequent empirical studies. After implementation in pilot classes, a mixed-methods approach will be employed to collect data: quantitatively, by comparing final OSCE scores and student course satisfaction ratings between pilot and control groups; qualitatively, through semi-structured interviews with participating students and teachers to gain an in-depth understanding of implementation barriers and facilitating factors. Long-term outcomes will be assessed through longitudinal tracking of graduates' post competency.

8 CONCLUSION

This study establishes a diversified formative assessment system that precisely aligns with the competency requirements of pain diagnosis and treatment practice and demonstrates its potential value in enhancing teaching quality. By systematically integrating a competency-based model with multiple formative assessment tools and applying them to the distinct field of pain management, the study provides a structured framework for educational improvement. Furthermore, it outlines directions for subsequent research, such as conducting empirical studies to verify the effectiveness of the system, developing standardized assessment tools and intelligent evaluation support systems, and exploring its applicability to other clinical specialty courses.

DECLARATIONS

Author contributions

Bing Liang (Co-first author): Conceptualization, Methodology, Model development, Writing - Original draft. Xiaojing Guo (Co-first author): Research design, Literature review, Evaluation indicators development, Revising the manuscript, Conceptualization, Methodology. Zhanheng Chen: Model construction, Methodological discussion. Mi Li (Corresponding author): Research supervision, Writing - Review & editing, Academic oversight. Yimin Yuan (Corresponding author): Research design, Methodological guidance, Writing-Review & editing. Zui Zou (Corresponding author): Project administration, Resource coordination, Final manuscript approval. All authors read and approved the final manuscript.

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Data availability

Not applicable.

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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Supplementary Information

Feedback Quality Assessment Scale (FQAS)

Purpose: This scale is designed to evaluate the quality of feedback provided by teachers during formative assessments. It aims to translate the abstract concept of "high-quality feedback" into observable and measurable specific behaviors, ultimately serving to enhance the effectiveness of feedback and support student competency development.

Instructions: The evaluator (e.g., teaching supervisor, peer teacher, or even trained students) should score the following items based on observations of a feedback session (e.g., after an OSCE, Mini-CEX, or assignment review) or a review of written feedback comments.

Use the Likert five-point scoring method:

5 - Excellent: Fully meets the description, exemplary.

4 - Good: Mostly meets the description, high quality.

3 - Adequate: Partially meets, but has clear room for improvement.

2 - Needs Improvement: Rarely meets, quality needs significant enhancement.

1 - Missing/Poor: Not observed or negative effect.

Dimension	Core indicator	Specific behavioral descriptions & observation points	Score (1-5)
Timeliness	Promptness of feedback	Feedback is provided as soon as possible after the assessment activity (e.g., ideally within 24-48 hours of the task/performance). Feedback is received while the student still clearly remembers the details of the task.	
Specificity	Clarity & detail of feedback	Feedback includes specific, observable examples of behavior or work product (e.g., "During the history taking, you accurately asked about the character of the pain, but did not inquire about aggravating or relieving factors"). Avoids vague, general language (e.g., "not good enough", "need to work harder"). Clearly identifies the specific context where the strength or weakness occurred.	
Behavior-based	Focus on actions, not person	Feedback focuses on the student's specific behaviors, performance, or work product, not their personal traits or character. Uses descriptive rather than judgmental language (e.g., describes "Your diagnostic rationale lacked reference to the key imaging finding", rather than "Your diagnosis was careless").	
Constructiveness	Providing a path forward	Not only identifies areas for improvement but also offers clear, actionable suggestions or strategies for improvement (e.g., "Next time, try using the 'SOCRATES' pain assessment framework to ensure you cover all key elements"). Aims to help the student understand "what to do next", not just "what was wrong".	
Interactivity	Encouraging student engagement	The teacher uses questions to prompt student self-assessment (e.g., "Which part of the procedure did you find most challenging?"). Creates a safe environment encouraging the student to clarify, ask questions, and express concerns. Feedback is a dialogue, not a one-way delivery of information.	
Goal alignment	Linking to learning objectives	Feedback is explicitly linked to course objectives, competency dimensions, or assessment criteria (e.g., "This skill maps to the 'Clinical Knowledge Application' dimension in our competency model; you demonstrated good understanding here, but could strengthen..."). Helps the student understand the gap between their performance and the expected standard.	

Overall Evaluation & Qualitative Feedback:

1. What was the most outstanding strength of this feedback session?

2. What is the single most important aspect needing improvement?

3. What was the student's overall reaction to the feedback? (e.g., Did they understand? Appear to accept it? Show willingness to improve?)
Total Score: _____/30 points (Sum of scores across all six dimensions)

Guidelines for Use

For Faculty Development: Can be used as a training tool during workshops for peer observation and evaluation of feedback skills, fostering self-awareness.

For Teaching Supervision: Academic leaders can use this scale periodically to observe faculty feedback practices, using the results as a basis for personalized teaching guidance and professional development support.

For Formative Improvement: The primary purpose of this scale is formative development of teaching skills, not for summative performance evaluation. It is recommended that results be discussed with faculty constructively.

Triangulating with Student Feedback: This scale can be complemented with simple student satisfaction surveys (e.g., "Did you find the teacher's feedback helpful for improving your learning?") to assess feedback effectiveness from multiple perspectives.

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RESEARCH ARTICLE

The practice and exploration of argument-based pedagogy through academic controversy in an eight-year medical immunology program: A case study of the "Nobel Prize Controversy Involving Liping Chen"

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Abstract

Eight-year medical programs aim to train physician-scientists capable of critically evaluating evidence and navigating complex ethical dilemmas. Medical Immunology, straddling multiple disciplines, can nurture these abilities. We hypothesized that a structured academic controversy (SAC), centered on a high-profile scientific dispute, could simultaneously reinforce conceptual understanding and foster higher-order thinking. A two-hour, debate-based seminar was conducted one week following the lectures on B-lymphocyte and antibody-mediated immunity. The case focused on the "Lieping Chen Nobel Prize controversy" concerning priority in the discovery of the PD-1/PD-L1 pathway. A pre-class micro-package—including an original article from *Proceedings of the National Academy of Sciences of the United States of America*, excerpts from the Nobel white paper, and a three-minute animation—was provided to prime students. In class, students were randomly assigned to pro or con teams and engaged in a 50-minute timed debate, followed by rebuttals after switching sides. Real-time scoring rubrics, a 6-item Likert scale (assessing critical thinking and ethical sensitivity), and 60-second post-class audio reflections provided multi-source evaluation data. The mean critical-thinking score rose from 3.2 to 4.1 ($p<0.01$), and the ethical-sensitivity score from 3.4 to 3.8 ($p<0.05$). A one-month transfer test showed that 83% of students accurately applied PD-1/PD-L1 concepts to novel immunological contexts, while 47% extended their critical inquiry to new targets (e.g., CD47, LAG-3). Qualitative analysis revealed an increased appreciation for collaborative credit and a decrease in ad hominem language. In conclusion, a single, tightly integrated 2-hour SAC debate significantly enhanced conceptual mastery, critical appraisal, and ethical reasoning without requiring additional curriculum time. This model can be scaled to other contentious scientific discoveries as a practical method for developing evidence-based and ethically-minded physician-scientists.

Keywords: Eight-year medical program, Medical Immunology, Debate-based instruction, PD-1/PD-L1, Lieping Chen, Nobel Prize, Critical thinking

Highlights

- A single two-hour, debate-based seminar embedded within an eight-year medical immunology curriculum significantly improved students' critical thinking (Cohen's d=2.3) and ethical sensitivity.
- Utilizing the high-profile "Liping Chen–PD-1/PD-L1 Nobel priority controversy" as a structured academic controversy (SAC) case enabled students to master key immuno-oncology concepts without requiring additional curricular time.
- The scalable SAC model provides an efficient, evidence-based pathway to cultivate ethically-minded physician-scientists within the constraints of crowded medical curricula.

1 INTRODUCTION

Dual-process theory holds that within eight-year medical programs, students need to develop the ability to "evaluate the weight of the evidence". In practice, we have come to understand that Medical Immunology is inherently suited to developing this capacity [1-3]. Compared to other medical disciplines, immunology more frequently intersects and integrates with many fields [4, 5]. For example, the autoimmune destruction of pancreatic β-cells in type 1 diabetes demonstrates an immunology-endocrinology connection; the blockade of neural signals by anti-acetylcholine-receptor antibodies in myasthenia gravis illustrates nervous system-immunology interactions; and the engulfment of low-density lipoprotein by macrophages to form foam cells in atherosclerosis links the cardiovascular and immunological systems. Consequently, the cases encountered in a medical immunology curriculum require students to analyze and explain phenomena with multidisciplinary, multiangular, and multifaceted views. In such a complex mental structure, students must learn how to think.

Incorporating debate-based pedagogy into Medical Immunology seminars has been shown to be an effective medium for accomplishing educational goals [6, 7]. According to the revised Bloom's Taxonomy, an effective lesson starts with knowledge, through analysis, and culminates in evaluation [8, 9]. At the knowledge level, students must master the research areas and particular achievements of Lieping Chen's team—namely, the PD-1/PD-L1 pathway—which reinforces their recall of co-inhibitory molecules found in the T-lymphocyte unit. At the analysis level, students study on their own the Nobel Prize-winning work of James Allison and Tasuku Honjo, comparing the different paths taken regarding the CTLA-4 and PD-1 targets. Finally, at the evaluation level, an in-class debate allows students to construct and critique competing arguments, thereby developing their organizational skills and verbal agility. In summary, debate-centered instruction confers significant benefits by reinforcing theoretical knowledge and fostering the development of critical thinking skills in medical students.

The eight-year medical program is a combined "bachelor's-to-doctorate" track that confers a doctoral degree upon completion [10]. It aims to train physicians with profound medical knowledge and robust clinical and research capabilities. Consequently, students are required to develop a foundational understanding across various medical disciplines [11]. In comparison to shorter programs, this extended format strongly fosters independent learning. Students have to figure out when to study on their own, make a plan that suits them, and keep improving their own methods [12]. Over eight years of hard work and practice, they get used to working with classmates who have different kinds of expertise and personalities. This integration of everyone's best skills for collective improvement lays the foundation for effective teamwork in future hospital settings [13].

2 CURRICULUM DESIGN

2.1 Overall framework

2.1.1 Positioning and distinctive features

The study included 48 third-year students (26 females and 22 males) from the eight-year medical program. Among them, 11 (22.9%) had prior formal debate experience (e.g. university-level debate competitions), and 37 (77.1%) had no structured debate training. The debate-centered module, based on the "Lieping Chen Nobel Prize Controversy", serves as a signature case within the eight-year medical immunology curriculum. Focusing on the main arguments—concerning who made the first discovery of PD-1/PD-L1, the omission of a Nobel prize, and the unequal contributions of the involved teams—it brings together four different viewpoints: basic science, clinical application, ethical issues, and social influence.

2.1.2 Objective architecture

• Knowledge dimension: Mastery of the molecular mechanism of the PD-1/PD-L1 pathway and the principle of tumor immunotherapy.

• Competency dimension: Training in critical reading, evidence synthesis, academic debate, and ethical reasoning in research.

• Affective dimension: Fostering the development of a scientific ethos characterized by openness, truth-seeking, pluralism, and an appreciation for diverse contributions.

2.1.3 Schedule allocation

A two-hour seminar will be held one week after the lectures on B lymphocytes and antibody-mediated humoral immunity are completed.

Module	Time/Duration	Key Content	Learning Activities & Tasks	Deliverables	Evaluation Focus
Pre-class Micro-preparation	T-7 to T-1 day (extracurricular, fragmented)	Excerpts from Lieping Chen's PNAS paper & 2 pages of the Nobel White Paper	Students learn via mobile app; post a 50-character "biggest doubt" in the forum and upvote others	Top 3 most-liked doubts generated by the system	Focus of doubt; number of upvotes
In-class Rule Launch	0′–5′ (face-to-face)	SAC debate rules; timing; role descriptions	One flowchart & 40-second countdown GIF from instructor	Students understand steps and roles	Immediate classroom compliance
Position Building	5′–15′ (small-group, face-to-face)	Random draw to form Pro/Con sides	Form two opposing teams	Students confirm their stance	Immediate classroom compliance
Formal Debate	15′–65′ (whole class, face-to-face)	Opening statements 2′ × 2	Timer displayed & real-time bullet-screen voting	Live performance rubrics & word clouds	Radar chart from critical-thinking scale
Lightning Reflection	65′–80′ (face-to-face & online)	Six 5-level items (3 CT & 3 ES)	Scan QR code → instant radar chart	Class radar chart & individual scores	≥90 % completion; upward trend in radar
Post-class Micro-extension	T+1 to T+7 days (extracurricular)	60-second voice answer: "How to improve the Nobel selection?"	Upload voice on Rain Classroom & peer upvotes	"Golden-quote" posts with ≥5 upvotes	Originality of voice; number of upvotes

Figure 1. Overview of the debate-based teaching module design and assessment framework based on the "Lieping Chen Nobel Prize Controversy". PNAS, Proceedings of the National Academy of Sciences of the United States of America; SAC, Structured Academic Controversy; CT, Critical Thinking; ES, Ethical Sensitivity; GIF, Graphics Interchange Format; QR, Quick Response.

2.1.4 Pedagogical logic

The module follows an "online-offline-online" closed-loop structure, consisting of preparatory online learning, face-to-face debate, and online consolidation. The model's main framework is the SAC, which incorporates the strengths of Problem-Based Learning (PBL) and case-based instruction [14].

2.2 Breakdown of teaching modules

A comprehensive table details the structure and evaluation criteria of the debate-based teaching module centered on the Liping Chen Nobel Prize academic controversy (**Figure 1**). This figure shows the entire instructional process, from pre-class preparation to post-class consolidation. It specifies the timeline, core content, intended student learning activities, and expected learning outcomes. It acts as a practical guide for educators to carry out the module successfully and as a benchmark for evaluating its impact.

3 TEACHING IMPLEMENTATION

3.1 Pre-class phase: 7-day micro-preparation

The teacher releases a "Minimalist Learning Kit" via the Rain Classroom platform seven days before the discussion session. The kit contains four components: the full 2012 *Proceedings of the National Academy of Sciences of the United States of America* (PNAS) paper by Lieping Chen's team, a two-page excerpt from the Nobel Committee's 2023 white paper, a three-minute animation explaining the PD-1/PD-L1 mechanism, and a pre-filled "evidence quick-sheet" highlighting key chronological milestones. Students access the kit on their mobile devices, mark it as reviewed, and post their "biggest doubt" (under 50 characters) on the course forum. The system automatically tallies upvotes, and the top three most popular questions are identified for in-class focus.

3.2 In-class phase: 2-hour "debate sprint"

3.2.1 Time flow

The two-hour session (40 minutes × 2) is divided into four segments:

(1) 5-minute rule briefing: Using a single SAC flowchart, the instructor gives a quick briefing on the "position–rebuttal–switch" protocol.

(2) 10-minute position building: Students are randomly assigned to two groups—one supporting the Nobel Committee's decision and the other questioning Chen's omission. Each group drags key evidence from the shared "evidence quick-sheet" onto a Padlet to create a one-page A3 poster, projected on the classroom screen.

(3) 50-minute high-intensity debate: This phase includes opening statements (2 min) cross-examination (2 min), jury follow-up (5 min), position switch and rebuttal (2 min). Timing is displayed on screen, while the teacher simultaneously marks logical gaps on a digital whiteboard.

(4) 15-minute lightning reflection: Students scan a QR code to fill out a 5-level scale (assessing critical thinking and ethical sensitivity); the system instantly generates a class "cloud radar" chart. The instructor spends 2 minutes highlighting key takeaways, followed by a 13-minute open session where volunteers share their most significant insight of the day.

3.2.2 Space and staffing

A smart classroom with 48 fixed seats is used. Tables and chairs are arranged in a circular formation to create six round tables,

facilitating intra-group discussion while maintaining full visual contact among all participants. The teaching group is made up of three members: a primary instructor responsible for overall coordination and real-time feedback, one teaching assistant managing on-site timing, and another maintaining the Padlet board and rating-scale backend. Additionally, a technician from the Media Center supports audio-visual and networking functions.

3.2.3 Contingency plans

A three-tier contingency plan is in place: (1) Network failure: If the network goes down, the technician switches to a 5G hotspot within two minutes, while offline timers and paper rating scales are deployed. (2) Emotional escalation: If emotions are heightened during the debate, the ethics officer from the relevant small group raises a yellow card, triggering an immediate "30-second cool-down" pause. At this point, the lead instructor intervenes to facilitate. (3) Time overrun: If a speaker goes over their allotted time, an automatic buzzer sounds. The microphone is cut off after a 15-second grace period to keep the session on schedule.

3.3 Post-class phase: 24-hour "micro-reflection"

3.3.1 Micro-reflection and peer review

Each student has 24 hours to submit a 60-second voice message in response to the prompt: "if I were on the Nobel Committee, how would I improve the selection rules?" The system automatically transcribes the audio for peer review. Any statement receiving five or more "likes" is highlighted as a "golden sentence".

3.3.2 Data archiving

Class radar chart, Padlet posters, full debate video, and transcribed 60-second reflections are bundled and uploaded to the course cloud drive, which serves as the main data for subsequent teaching evaluation and educational research.

This process completes the integrated "pre-class, in-class, and post-class" instructional loop: students spend little time outside of class to prepare, engage in 80 minutes of high-density intellectual combat in the classroom, and complete a rapid reflection within 24 hours. This cycle not only generates reusable teaching and research data but also ensures a smooth fit with the preceding B-lymphocyte theory sessions and achieves the higher-order objectives of debate-based learning.

4 TEACHING EVALUATION

For scoring and evaluation, it is necessary to consider not only the performance of students in class but also their ability to transfer acquired knowledge to new immunological problems [15, 16]. Four aspects of evaluation, including student self-assessment, peer assessment, instructor assessment, and evaluation by two randomly selected student judges, should all be taken into account [17].

The rubric is divided into four domains:

- Knowledge mastery (30%): Gauges how thoroughly students grasp the PD-1/PD-L1 mechanism and the Nobel Prize controversy background.

- Critical thinking (30%): Assesses evidence screening, logical chains, and rebuttal strength.

- Ethical sensitivity (20%): Examines whether students recognize the tensions among scientific credit, public interest, and media narratives.

- Team collaboration & communication (20%): Measures division of labor, time control, and linguistic precision.

Temporally, evaluation spans the pre-class, in-class, and post-class phases. Ten percent of the grade comes from AI analysis of reading notes, assessing keyword density and depth of questioning. Sixty percent is derived from an eight-item, two-level rubric scored in real time by the instructor and student jury [18]. The remaining thirty percent is assigned to the 60-second post-debate voice reflection, first processed by AI for sentiment polarity and then weighted by peer upvotes.

To ensure consistent teaching methods across the cohort and uphold teaching quality, all eight-year program students participated in the debate-based instruction for this course. While this study lacked a control group using traditional seminar methods, the teaching reform yielded better results than the previous year's original teaching model. Mean critical-thinking score rose from 3.2 to 4.1 ($p<0.01$), and mean ethical-sensitivity score from 3.4 to 3.8 ($p<0.05$). Statistical analyses were performed using paired t-tests on the sample (N=48), after normality was confirmed via the Shapiro-Wilk test ($p>0.05$ for all scales). Effect sizes were Cohen's d=2.3 (critical thinking, large effect) and Cohen's d=1.1 (ethical sensitivity, medium effect), alongside Pearson's r=0.72 for the correlation between pre- and post-critical thinking scores. The 95% confidence intervals were 0.62-1.18 for critical thinking and 0.21-0.79 for ethical sensitivity.

When planning the next iteration, the instructor can refer directly to the class radar chart: if the mean ethical-sensitivity score falls below 3.5, the new case will foreground conflicts related to research integrity; if the mean logical-chain score exceeds 4.5, the complexity of the case will be increased. Thus, evaluation ceases to be merely an endpoint and becomes the starting point for the next cycle of instructional refinement.

5 TEACHING REFLECTION

After the session, the teaching team reflected on the lesson centered on the "Lieping Chen Nobel Prize Controversy", with a focus on the student debaters. Reflection was informed by multiple sources: classroom video analysis, student questionnaire results, peer observation notes, and feedback from an expert pane. The overall course reached its intended objectives, provided a positive student experience, and established a foundation for continuous improvement. However, some areas were identified as needing adjustment.

Most students correctly applied the core concepts of the PD-1/PD-L1 pathway and connected them to B-cell humoral immunity during the debate. But some relied excessively on the conclusions provided in the evidence quick-sheets without checking the experiments or statistics. To fix this, a 90-second "Methodological Zoom-In" micro-video will be added next time, focusing on the flow cytometry gating strategy from Lieping Chen's 2012 PNAS paper to help students practice their critical reading skills ahead of time [19].

Ethical sensitivity cultivation surpassed expectations, with a class mean score of 3.8 on the lightning reflection scale—an increase of 0.4 compared to a previous comparable course. Engagement with the scientific controversy was pivotal to their development of a professional identity, helping them connect ethical reasoning to their future roles as physician-scientists. They talked about how to balance acknowledging individual credit with appreciating collaborative scientific effort, an important skill for both research teamwork and hospital-based clinical decision-making. However, text analysis revealed that several students conflated "order of contribution" with "order of value", using phrases such as "just follow-up work". In order to fix this problem, the team plans to add a "contribution ladder" visualization to the next lessons. Students will categorize each scientist's work as discovery, validation, or translation, and consider how to apply principles of equitable authorship—translating abstract ethical concepts into actionable research governance practices.

One-month follow-up data revealed that 83% of students correctly used the PD-1/PD-L1 case to answer a question about antibody diversity, but only 47% could similarly apply their critical framework to novel targets such as CD47 or LAG-3. To enhance cross-case transfer, a five-minute online micro-debate will be added after the discussion of each subsequent chapter. This intervention aims to train students to expand their critical framework from a single case study toward a adaptable, lifelong thinking skill.

This study was conducted at one institution offering an elite eight-year program. Future adaptations may include implementation in 5-year medical tracks, where pre-class preparation might be reduced to three to four days and debate rules simplified to emphasize the synthesis of core evidence. For international settings, the model could incorporate region-specific scientific controversies and offer multilingual debate options, while retaining the "minimal preparation–high intensity interaction" structure to accommodate varying curriculum densities.

Observer bias is a limitation, as instructors also served as evaluators. Mitigation measures planned for future iterations include using external raters (e.g., faculty from other departments) and implementing blinded scoring (by anonymizing student identifiers in debate recordings and reflections prior to assessment).

6 CONCLUSION

This study shows that integrating a structured, debate-based module centered on the Lieping Chen Nobel Prize priority controversy into an existing eight-year Medical Immunology curriculum can enhance conceptual understanding, critical thinking, and ethical sensitivity, without requiring additional curricular time. Through a "minimal preparation–high-intensity debate–instant feedback" design, we found measurable improvements in knowledge transfer, quality of argumentation, and student engagement, while generating reusable teaching and research data. This model can be easily adapted to other controversial discoveries, providing a practical path for training evidence-based, ethically minded physician-scientists. Continuous refinement—such as adding micro-level methodological primers and cross-case transfer portfolios—are expected to further strengthen the long-term impact of this instructional approach.

DECLARATIONS

Author contributions

Liyuan Zhao and Yijie Tao drafted the main manuscript text. Sheng Xu and Min Zhang reviewed and revised the manuscript. All authors contributed to the article, reviewed the final version, and approved the submitted version.

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Data availability

Not applicable.

Ethics approval and consent to participate

This study was approved by the Ethics Committee of the Naval Medical University (Approval Number: NMUMREC-2024-02002).

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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TEACHING INNOVATION

Comprehensive pathways and strategies for reforming laboratory animal science education

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Abstract

This study investigated all-around pathways and methods of reforming laboratory animal science education in the new era. With the rapid advancement of life sciences, traditional laboratory animal science curricula have shown their limitations, failing to keep up with current research practices and satisfy the increasingly stringent demands for animal welfare and ethics. This paper provides an in-depth analysis of existing challenges in teaching and proposes a "trinity" reform model, with animal welfare ethics as the core, virtual simulation technology as support, and management and assessment system innovation as the driving force. This framework aims not only to improve teaching efficiency and quality but also to cultivate students with innovative thinking, strong practical skills, and a sense of professional ethics. In the end, this study gives a forward-looking and actionable solution for the systematic reform of laboratory animal science curricula in higher education institutions.

Keywords: Laboratory animal science, Teaching reform, Virtual simulation, Animal welfare ethics, 3R principles, Curriculum-based ideological and political education, Blended learning

Highlights

- Proposes a "trinity" reform framework: a framework that centered on animal welfare ethics, supported by virtual simulation technology, and driven by innovations in management and assessment systems.
- Enhances teaching reform and professional development: to improve the effectiveness of teaching and to cultivate future professionals in life sciences who are innovative, practical, and ethically responsible.
- Provides a comprehensive solution for curriculum reform: to provide a forward-looking, implementable solution for comprehensive curriculum reform of laboratory animal science in higher education institutions.

1 INTRODUCTION

1.1 Academic significance and contemporary challenges: the core role of laboratory animal science in life sciences

Laboratory animal science is a highly interdisciplinary and practice-oriented science. It occupies an irreplaceable core position in modern life sciences, basic medicine, and drug research and development (R&D) [1]. It makes a fundamental contribution to scientific discoveries. For example, in neuroscience, scientists discovered a vital protein, FTL1, via animal experiments; overexpression of FTL1 in the mouse brain led to memory loss and weakened neural connections, while lowering its expression restored memory function in aged mice. This

finding suggests that FTL1 may function as a "master switch" controlling the aging of the brain [2]. Similarly, in the field of regenerative medicine, a research team successfully combined 3D-printed neural scaffolds with lab-cultured spinal cord organoids in a rat model, significantly enhancing motor function recovery, bringing new hope to spinal cord injury repair [3].

Such innovative achievements are largely due to solid understanding of and practical expertise in laboratory animal science. However, it also points out a critical challenge, that is, the increasing complexity of technical requirements and ethical norms in modern scientific research is outpacing the traditional teaching models still prevalent in most universities. If educational methods don't adapt to these innovations, graduates may struggle to get involved in frontline research, therefore hindering national progress in these scientific fields [4].

1.2 Limitations of the traditional teaching model: the impetus for reform

While laboratory animal science is becoming increasingly important, its traditional teaching methods faces significant challenges. Many courses are still dependent on "verification" and "demonstration" experiments, lacking a focus on innovative experimental design training. Traditional pedagogic means, such as rote memorization or passive "stuffing" of knowledge, lacks interaction between teachers and students, resulting in lower student involvement [5]. Additionally, variations in teachers' academic background and the absence of standardized teaching guidelines contribute to inconsistent teaching quality, including differences in operational details and focus areas. Moreover, teaching resources remain scarce and expensive. Live animal experiments incur great expenses and safety issues [6]. More importantly, operational errors may cause irreversible consequences, such as death of animals or inactivation of tissues. High risk, high cost, and low repetitiveness of these practices make large-scale, individualized practical education difficult to implement, conflicting with the growing emphasis on animal welfare ethics in modern society [7].

1.3 Research background and objectives: establishing a comprehensive teaching framework for the new era

Facing such challenges, a systematic reform of laboratory animal science courses is imperative. This study proposes a teaching reform model grounded in ethics, supported by technology, and secured by management. This framework aims to integrate cutting-edge research findings, best practices, exemplary values, and advanced computational concepts into teaching practices. It fosters an educational philosophy that equips students to engage in reality while guiding them to appreciate the value of honest and intelligent learning. This strategy aligns with China's higher education requirement for "curriculum-based ideological and political education" and adheres to internationally recognized standards for laboratory animal welfare. It is dedicated to cultivate high-level specialists capable of meeting the evolving requirements of life sciences field.

2 CURRENT SITUATION AND CHALLENGES IN LABORATORY ANIMAL SCIENCE EDUCATION

2.1 Disconnection between curriculum and frontier research

The current courses lag behind disciplinary advancements and are heavily relied on verification-based experiments [1, 5]. With the emergence of highly innovative interdisciplinary research areas, such as 3D printing for spinal cord repair and exploring critical proteins for brain aging, textbook-driven teaching methods struggle to cultivate students' ability to independently design and solve difficult scientific problems [2]. If traditional curricula fail to evolve, students may lack the ability to conduct innovative experimental designs and implement the experiment after entering graduate school or the workforce [8].

2.2 Misalignment between teaching mode and student needs

Traditional "cramming" teaching mode places teachers at the central position of the classroom while students remain passive recipients. This hinders learning motivation and proactive engagement, with many students viewing course attainment merely as a means to get "credits" and some teachers regarding teaching as a task to be completed. Evaluation of teaching effectiveness is overly stringent, relying primarily on final exam score and neglecting comprehensive evaluation of student's experimental skills and innovative thinking [9, 10]. Moreover, differences in teachers' professional backgrounds lead to variations in instructional emphasis and operational approaches, making it difficult to standardize teaching quality and implement uniform training programs [11, 12]. However, the use of modern information technology, such as smart classrooms, has significantly enhanced teacher-student interaction and student engagement, providing strong empirical support for reforming traditional teaching models.

2.3 Scarcity of teaching resources and safety risks

Traditional animal-based teaching heavily relies on physical resources, including live animals, expensive equipment, and specialized laboratory facilities. This leads to high teaching costs, limits the repeatability of experiments, and restricts access to hands-on opportunities [13]. Furthermore, animal experiments inherently carry safety risks: complex surgical or dissection procedures require special protective measures [14].

Table 1 compares traditional and innovative teaching models in experimental animal science, clearly demonstrating the necessity and feasibility of reform.

Table 1. Traditional versus innovative LAS teaching models

Dimension	Traditional	Innovative
Pedagogy	Didactic, one-way	Blended learning with virtual–physical integration
Content	Verification-oriented, outdated	Innovative, frontier-focused
Resources	Live animals, physical devices	Virtual platforms, digital resources
Cost	High	Low
Safety	Potential safety hazards	Risk-controlled, repeatable
Learning outcome	Low engagement, limited practice	High engagement, enhanced practical skills & ethical awareness

Note: LAS, laboratory animal science.

Table 2. Core animal welfare principles and their applications in laboratory animal science education

Principle	Definition (teaching context)	Application example
Replacement	Substituting live animals with non-animal models or lower-sentience species whenever possible	Virtual reality–based canine anatomy; human physiology simulation kits
Reduction	Minimizing the numbers of animals used while maintaining educational validity and statistical reliability	Pre-lab virtual rehearsal to reduce procedural errors; avoid redundant trials
Refinement	Modifying procedures to minimize pain, suffering, and distress	Proper handling, standardized anesthesia, humane euthanasia
Five Freedoms	Basic welfare rights	Curriculum modules on Five Freedoms, cultivating empathy

By analyzing the challenges confronting traditional laboratory animal science teaching in China, this study proposes a new "trinity" teaching framework centered on animal welfare, supported by virtual simulation technology, and linked by an innovative evaluation system.

Unlike earlier reforms that merely addressed isolated components, the trinity framework integrates three parallel tracks into a mutually reinforcing engine. Traditional models treat ethics, technology, and assessment as add-ons: welfare as a side lecture, simulation as an optional lab, and evaluation as a final numeric stamp. We knit them into a unified braid: animal welfare ethics establish the non-negotiable target, virtual simulation supplies a risk-free space for ethical decision-making practice, and the revamped assessment system converts every welfare-centered action into credit-bearing evidence. These parts are not stacked but interlocked: remove one, and the other two collapse. This ensures moral concerns drive software design, while the software instantly feeds back into scoring logic. This interlocking mechanism makes the trinity framework a new species of reform, not an incremental upgrade.

3 ETHICS FIRST: DEEP INTEGRATION OF ANIMAL WELFARE AND THE 3R PRINCIPLES

3.1 Legal and ethical framework: from regulation to practice

In the new era, laboratory animal science education must prioritize ethical education. In recent years, China has established an increasingly comprehensive system for laboratory animal management and ethical review. For example, the *Sichuan Provincial Regulations on Laboratory Animal Management* (issued in 2025) explicitly stipulate that the use of laboratory animals must adhere to the 3R principles (Replacement, Reduction, Refinement). It further requires institutions engaged in laboratory animal work to establish welfare and ethics review bodies for assessing risks and reviewing scientific activities [15, 16].

3.2 Educational application of the 3R principles: replacement, reduction, refinement

As the foundation of laboratory animal welfare ethics, the application of the 3R principle in educational settings can be viewed as a specific pathway for transformation [17]. **Table 2** provides specific strategies and examples for implementing the 3R principles in educational settings.

Replacement: replace lower-order animals or non-animal models with higher-order animals (more sensitive to pain) without sacrificing experimental objectives. Virtual simulation technology serves as an effective tool to achieve this principle [18]. Students use virtual platforms to perform dissection, surgeries, and physiological experiments without using live animals. This approach avoids ethical concerns associated with live animal experiment while overcoming teaching challenges such as animal resource shortage and operational safety risks.

Reduction: Minimize the number of experimental animals while ensuring the reliability of results. Virtual simulations enable students to repeatedly practice procedures before hands-on work, so they can mater operational procedures and technical skills. This can reduce experimental failure rates due to operational errors and minimize unnecessary animal sacrifice.

Refinement: optimize experimental design in studies requiring animal use to minimize animal suffering and stress. Animals are provided with comfortable living conditions, and students are trained in standardized anesthesia protocols and pain management practices. Additionally, students receive instruction in proper handling and restraint techniques to avoid stress or injury. Integrating these principles into fundamental curricula enhances both ethical awareness and professional competencies among students.

The 3R principles should serve as an intrinsic driver of curriculum design, rather than constrains imposed by moral needs and technological limitations. Directly adopting "alternative" experimental animals promotes the application of virtual simulation technology in education; such technological innovations offers multiple advantages in teaching efficiency, safety, and cost control.

3.3 Curriculum-based ideological education and life-centered awareness

In China's higher education system, the promotion of "curriculum-based ideological and political education" creates a good opportunity to reform the teaching of laboratory animal science [19]. By integrating explicit ethical principles—such as respect for life and compassion for animals—with professional knowledge, students can cultivate integrity and patriotic sentiment. Incorporating stories behind life science research enhances course appeal, prompting attention to the necessity of balancing scientific progress with ethical responsibility while guiding students to cultivate rigorous scientific attitudes and integrity. This model combines moral education and technical training, enabling students to recognize that learning advanced technologies is closely related to a profound life-centered consciousness. This is an important quality for cultivating life science professionals [20].

4 TECHNOLOGY EMPOWERMENT: INNOVATIVE APPLICATION OF VIRTUAL SIMULATION TECHNOLOGY IN LABORATORY ANIMAL SCIENCE EDUCATION

4.1 Comprehensive advantages of virtual simulation technology

Virtual simulation technology is a significant innovation in laboratory animal science education, offering four key advantages [21]. This technology realistically replicates practical operational scenarios, making contexts tangible and immersive. It enables students to engage deeply and persistently in experimental processes, significantly stimulating learning interest. Virtual platforms unify teaching practices to achieve standardized instruction, resolving the issue of quality inconsistencies caused by different teachers. Virtual experiments also reduce costs of experiments by minimizing the need for expensive live animals and materials. Operations within virtual environment can be repeated without error, allowing students to safely practice repeatedly until skill mastery. This minimizes errors in live animal experiments, fundamentally protecting animal welfare and mitigating potential risks.

4.2 Developing a blended virtual-physical teaching model

To maximize the value of virtual simulation resources, it is suggested to establish a blended teaching system where "virtual experiments complement physical experiments" and "virtual training integrates with physical practice".

This approach should be implemented simultaneously before, during, and after class. Through MOOC (Massive Open Online Courses) and virtual simulation platforms, students independently learn theoretical knowledge before class and master key experimental skills through Pre-assignments and simulation practices. For instance, virtual modules can guide students through the complete workflow of animal functional gene expression experiments, including knowledge learning such as nucleic acid extraction, PCR technology, DNA digestion/ligation. Pre-class virtual training significantly enhances the efficiency of hand-on experiments, allowing teachers to focus on guiding students in applying theoretical knowledge and fostering innovative thinking. Smart classrooms can further enhance classroom interaction. Post-class field trips to experimental animal center or animal breeding facilities enable students to directly observe animal behaviors and welfare measures, deepening their theoretical understanding while cultivating their respect for life.

4.3 Analysis of typical virtual simulation teaching cases

Several successful virtual simulation teaching examples have provided practical references for this reform. The College of Veterinary Medicine at Yangzhou University developed a three-dimensional digital anatomy virtual simulation platform for animals such as dogs [22]. This platform enables students to gain a more intuitive and in-depth understanding of animal anatomical structures, overcoming the limitations of traditional anatomical teaching and providing practical opportunities free from ethical constraints. Northwest A&F University introduced a virtual simulation module for molecular biology experiments, covering eight virtual projects including nucleic acid extraction, PCR, and cell transfection [23]. This allows students to learn complex procedures and precautions for molecular experiments online, thereby enabling efficient offline practice.

These cases prove that virtual simulation technology comprehensively enhances teaching efficiency, enriching instructional content, and integrating ethical education.

Table 3. Process-oriented comprehensive evaluation system

Content	Weight	Assessment objective	Performance descriptors
Pre-class MOOC study	20%	To assess mastery of basic theoretical knowledge	Excellent: Completes all modules, scores ≥90% in quizzes, submits high-quality pre-study notes. Good: Completes 80%+ modules, scores 80-89% in quizzes. Satisfactory: Completes 60%+ modules, scores 70-79% in quizzes. Unsatisfactory: Completes <60% modules or scores <70% in quizzes.
In-class discussion and Q&A	20%	To encourage active participation and cultivate communication/critical thinking skills	Excellent: Initiates 3+ questions/comments, responds logically to peers, actively advances discussion depth. Good: Participates 2-3 times with relevant viewpoints. Satisfactory: Participates 1 time with basic insights. Unsatisfactory: No participation.
Experimental operation, outcomes, and teamwork	30%	To directly evaluate practical competence and collaborative spirit	Excellent: Operates proficiently without errors, obtains valid results, collaborates effectively. Good: Minor operational flaws, results meet basic requirements, cooperates actively. Satisfactory: Completes operations with guidance, results partially valid, participates in teamwork. Unsatisfactory: Major operational errors, invalid results, or lack of collaboration.
Experimental report writing	30%	To evaluate scientific literacy, data analysis, and academic writing skills	Excellent: Clear structure, accurate data analysis, rigorous discussion, no formatting errors. Good: Logical structure, basic data accuracy, relevant discussion. Satisfactory: Complete structure, minor data flaws, simple discussion. Unsatisfactory: Incomplete content, incorrect data, or disorganized expression.

5 INNOVATION IN TEACHING MANAGEMENT AND ASSESSMENT SYSTEM

5.1 From single-dimension to multi-dimensional: building a process-oriented comprehensive assessment system

To stimulate student engagement in the classroom and foster holistic development, transforming assessment techniques is crucial—traditional systems are overly rigid and fail to provide appropriate evaluations. Therefore, the entire assessment process must focus on the process itself. Based on the above theories, the scoring model is illustrated in **Table 3**. Diverse process-oriented assessments closely correlate with the final results of students' learning, focusing on continuous efforts and holistic skill development to better cultivate comprehensive competencies required for real-world scientific research.

5.2 Strengthening teaching faculty development

Teacher self-improvement is the foundation of educational innovation. The faculty should maintain stability, possessing both teaching and research capabilities. The team should comprise multidisciplinary talents, with instructors responsible for curriculum development, instructional design, teacher training, and comprehensive quality control. Moreover, faculty members must continuously update their knowledge systems. To keep students in touch with the latest advances in science and industry, teachers need to constantly refresh teaching content and incorporate the latest research and practical achievements. Continuous professional development helps teachers maintain optimal teaching performance, thereby providing students with valuable academic advice [24].

6 CONCLUSION AND OUTLOOK

6.1 Overview of comprehensive reform pathways

The proposed curriculum reform for experimental animal science presented in this article constitutes a holistic solution grounded in ethical guidance, driven by technological innovation, and supported by management systems. Core initiatives include: deeply integrating animal welfare ethics to cultivate students' awareness of life; fully leveraging virtual simulation technology to overcome limitations existing in traditional teaching, such as high costs, significant risks, and low repeatability, thereby achieving efficient, safe, and standardized practical education. Innovating management and assessment system to shift from one-sided knowledge assessment to comprehensive competency evaluation. This multidimensional reform addresses shortcomings in traditional teaching while actively responding to the constantly evolving demands of modern scientific research and talents cultivation.

6.2 Future directions and challenges for laboratory animal science education

There remains significant room for reform. With the development of artificial intelligence (AI) and big data, future virtual simulation platforms will integrate AI tutoring systems to provide students with real-time personalized evaluation of their operations. Simulation of dynamic complex life systems will provide more customized learning experience [25]. At the same time, legislative and ethical frameworks will evolve, requiring teaching content to be continuously updated with the develop-

ment of technology. Major future challenges include: maintaining virtual simulation resources that incorporate the latest scientific progress; and expanding this novel teaching model to more universities to benefit a broader student population.

7 CONCLUSION

This study provides ways and methods for reforming experimental animal science education in the new era. Rapid advancements in cutting-edge life sciences have exposed the limitations of traditional teaching models. Through in-depth analysis of current issues, this paper constructs a novel "trinity" reform framework: centered on animal welfare ethics, supported by virtual simulation technology, and establishing a new management and evaluation system. This research provides a forward-looking and implementable comprehensive solution for the systematic reform of laboratory animal science curricula in higher education. By adopting this reform framework, educational institutions will be better prepared to help students enter the modern life sciences field, equipping them with the knowledge and skills needed to be influential contributors while adhering to the highest standards of animal welfare and ethical norms.

DECLARATIONS

Author contributions

Min Zhang wrote the manuscript, Yijie Tao and Sheng Xu investigated the current teaching methods of "Laboratory Animal Science" in China, Liyuan Zhao revised this manuscript, Shufang Cui formulated the research direction and confirmed final manuscript. All authors reviewed the manuscript. All authors contributed to the article and approved the submitted version.

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Competing interests

The authors declare that they have no competing interests.

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RESEARCH ARTICLE

Application of a distance teaching system combined with case-based learning to anesthesiology experimental teaching

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Abstract

Objective: To explore the application and effectiveness of a teaching method combining a distance teaching system with case-based learning (CBL) in clinical anesthesiology experimental teaching. This study aims to provide a reference for reforming practical teaching in the anesthesiology curriculum. **Methods:** Sixty undergraduate students majoring in anesthesiology from the Class of 2021 at Wannan Medical College were randomly divided into two groups. The control group (30 students) received traditional classroom teaching combined with a procedural demonstration. The observation group (30 students) was taught using the distance teaching system integrated with the CBL method. Epidural anesthesia was used as the teaching topic. After the course, the teaching effect was evaluated through a theoretical examination, a clinical skills assessment, and a satisfaction questionnaire. **Results:** The observation group scored significantly higher than the control group in both the theoretical knowledge examination (93.93±2.99 vs. 87.80±5.52) and the clinical skills assessment (90.43±8.88 vs. 82.73±6.65) (both $P<0.05$). Furthermore, the student satisfaction rate in the observation group (96.67%) was significantly higher than that in the control group (83.33%) ($P<0.05$). **Conclusion:** The combination of a distance teaching system and the CBL teaching method effectively addresses the common disconnect between clinical practice and experimental learning, as well as the limited operative view in traditional teaching. By integrating live broadcasts of real clinical scenarios with case-driven learning, this approach significantly enhances students' theoretical application ability, clinical operation skills, and learning satisfaction. This model offers a promising and scalable innovation for clinical anesthesiology experimental teaching.

Keywords: Case-based learning, Distance teaching system, Clinical anesthesiology, Experimental teaching

1 INTRODUCTION

Clinical anesthesiology is a highly practical discipline [1, 2]. Core operations such as epidural puncture and endotracheal intubation must be adapted dynamically in real clinical scenarios based on individual patient conditions [3, 4]. Traditional practical teaching mostly follows a "theoretical explanation + model demonstration" model, which presents two prominent problems: first, the demonstration is constrained by the physical space and viewing perspective, preventing most students from clearly observing key details such as puncture positioning and drug administration timing; second, most teaching cases are derived from textbooks and are disconnected from real clinical anesthesia workflows and complication management, thus limiting the development of students' clinical thinking [5, 6]. Although case-based learning (CBL) promotes active learn-

ing through case discussion and has been widely adopted across medical disciplines, most domestic studies still rely on text- and image-based cases [7, 8]. Although distance teaching systems can stream clinical procedures via high-definition live broadcast, when used alone they lack targeted case guidance and in-depth interaction, often resulting in passive viewing and limited learning outcomes [9, 10].

CBL is an educational model derived from integrating problem-based learning principles with clinical practice [11]. It guides students to carry out learning activities such as problem analysis, decision-making and solution formulation through real or fictional cases. This teaching method emphasizes students' active participation and independent learning, and cultivates their problem-solving ability and thinking ability. However, in most current domestic studies on CBL education, the problems or cases in the teaching design are generally derived from textbook knowledge, and the cases used are usually sorted out by teachers and presented in words and pictures, which are different from the actual clinical anesthesia treatment process [12]. The distance surgical teaching system can transmit various clinical operations to the classrooms where students are located through high-definition cameras, enabling students to watch various operations and technical details of clinical anesthesiologists during the perioperative period in real time [13]. At the same time, students can also conduct real-time interaction with clinical anesthesiologists through the system, ask questions and get answers, so as to further promote communication and learning.

In recent years, foreign studies have attempted to combine distance technology with case teaching. Gupta et al. improved the skill retention rate of anesthesiology students through the "practical operation + case" mode, but there are still few systematic combined teaching studies targeting clinical anesthesiology experimental courses [14]. Therefore, this study integrates the live-scene transmission capability of the distance teaching system with the case-driven approach of CBL. Using epidural anesthesia as the instructional content, it investigates the effects of this combined model on students' theoretical knowledge, clinical skills, and teaching satisfaction. The findings aim to provide an empirical foundation and practical strategies for reforming clinical anesthesiology education.

2 OBJECTS AND METHODS

2.1 Research participants

Sixty undergraduate students majoring in anesthesiology (enrolled in 2021) at Wannan Medical College were recruited as participants. Using a random number table, they were equally divided into two groups: a control group (n=30) receiving traditional teaching, and an observation group (n=30) receiving instruction through the distance teaching system combined with CBL. The course content focused on the clinical anesthesiology experiment of epidural anesthesia. All instructors were physicians with intermediate or senior professional titles and had over five years of clinical teaching experience.

2.2 Teaching design and implementation

2.2.1 Control group

The traditional teaching method, namely classroom teaching + operation demonstration, was adopted. According to the content of the clinical anesthesiology experimental teaching syllabus, teachers explained the basic knowledge of epidural anesthesia, the operation steps of epidural puncture and related clinical anesthesia management knowledge in accordance with the experimental textbook. After watching the teacher's operation demonstration, students completed the epidural puncture operation and filled in the experimental report.

2.2.2 Observation group

The distance teaching system combined with CBL teaching method was adopted.

(1) Case selection: Elective lower abdominal surgery patients in our hospital (American Society of Anesthesiologists grade I-II, aged 45-60 years) without epidural anesthesia contraindications were selected. The cases included teaching key points such as puncture space selection, anesthesia plane adjustment and hypotension prevention. Preoperative visits were completed and informed consent was obtained.

(2) Distance teaching system equipment: The operating room was equipped with 4K high-definition cameras (focusing on puncture sites and operation techniques) and wireless sound transmission equipment; the teaching room adopted high-definition projection (split-screen display of surgical operation pictures and case information) with a network bandwidth of ≥10 Mbps to ensure no delay in live broadcast.

(3) CBL problem design: Core questions were preset around the teaching syllabus: ① What is the optimal space for epidural puncture in this patient and its anatomical basis? ② What are the treatment principles when cerebrospinal fluid reflux occurs during puncture? ③ What are the causes and coping measures for hypotension when the anesthesia plane reaches T6? ④ What are the differences in clinical application between epidural anesthesia and spinal anesthesia?

(4) Teaching implementation: Before class, students in the teaching room were divided into 5 groups (6 students in each group), and each group was assigned a student with solid professional basic knowledge, active thinking and strong communication ability to play a leading role. According to the CBL teaching method, teachers live broadcasted the perioperative anesthesia management and corresponding operations of the

Table 1. Scoring criteria for epidural puncture skill assessment

Assessment items	Score	Scoring criteria
Preoperative preparation	10 points	Patient assessment (3 points), equipment preparation (4 points), sterile concept (3 points)
Puncture position placement	15 points	Correct position (10 points), stable fixation (5 points)
Puncture operation	35 points	Puncture site positioning (10 points), skin disinfection and draping (8 points), puncture technique (10 points), judgment of ligamentum flavum penetration (7 points)
Anesthetic drug administration	15 points	Drug selection (5 points), dosage calculation (5 points), administration speed (5 points)
Emergency treatment of complications	15 points	Identification of complications (5 points), treatment measures (10 points)
Postoperative record	10 points	Complete record (5 points), standardized writing (5 points)

selected cases according to the course arrangement, guided students and put forward case-related questions, and students analyzed the current cases through group discussion. At the same time, students in the teaching room carried out simulation training synchronously, following the operations of the teachers in the operating room, and the instructors in the teaching room assisted in solving the problems encountered by students and answering questions.

2.3 Evaluation of teaching effectiveness

After the experimental course, the teaching effects of the two teaching methods in this study were evaluated by an epidural-related theoretical knowledge examination, a clinical operation skill assessment, and a teaching satisfaction questionnaire [15]. Both the theoretical knowledge examination and clinical skill assessment scores were based on 100 points. The content of the clinical operation skill assessment was epidural puncture, and the clinical operation ability of medical students was scored by the instructors in the teaching room. The teaching method satisfaction questionnaire was filled out anonymously by all students.

2.3.1 Theoretical knowledge examination

The duration was 90 minutes. The question types and scores were as follows: multiple-choice questions (30 questions, 1 point each), short-answer questions (4 questions, 10 points each), and case analysis questions (1 question, 30 points). The assessment content covered the anatomical basis, operation process, drug selection, complication management of epidural anesthesia, etc.

2.3.2 Clinical skill assessment

Taking epidural puncture as the core, the scoring criteria are shown in **Table 1**. Two senior physicians scored independently and blindly, and the average value was taken as the final score. To ensure the validity of the assessment tool, the scoring criteria (**Table 1**) were formulated based on the "Clinical anesthesiology experimental teaching guidelines" issued by the Chinese Medical Association, combined with the core operational requirements of epidural anesthesia in clinical practice. The criteria were reviewed and revised by 3 senior anesthesiologists with more than 10 years of clinical and teaching experience to confirm their relevance and comprehensiveness to the teaching objectives. For inter-rater reliability, the two senior physicians responsible for scoring received unified training before the assessment: they jointly reviewed 5 sets of standard operation videos of epidural puncture, calibrated the scoring standards item by item, and resolved differences in judgment through group discussion. The intraclass correlation coefficient of the two assessors was calculated as 0.92 (95% confidence interval: 0.86-0.96), indicating excellent inter-rater consistency.

2.3.3 Teaching satisfaction questionnaire

This questionnaire was self-designed based on the research objectives and relevant literature, aiming to comprehensively evaluate students' recognition of the teaching method [16]. The content framework was constructed around 4 core dimensions closely related to experimental teaching effectiveness: practicality of teaching content, interactivity of teaching process, help in skill improvement, and stimulation of learning interest, with 2 items under each dimension (8 items in total). To ensure content validity, the initial questionnaire was reviewed by 3 senior professors in the field of medical education and 2 clinical anesthesiologists with more than 10 years of teaching experience. Their suggestions on the clarity, rationality and relevance of the items were adopted to revise ambiguous expressions and adjust the logical order of questions. The content validity index of the final questionnaire was 0.93, indicating good content validity. Before formal application, a pre-survey was conducted among 20 anesthesiology undergraduate students from the Class of 2020 (not included in the formal research objects) to test the reliability of the questionnaire. The Cronbach's α coefficient of the total questionnaire was 0.87, and the Cronbach's α coefficients of the four dimensions were 0.82 (practicality), 0.85 (interactivity), 0.83 (skill improvement) and 0.81 (learning interest), respectively, all >0.7, confirming that the questionnaire had good internal consistency. The questionnaire adopted a 5-point Likert scale (1 = very dissatisfied, 2 = dissatisfied, 3 = neutral, 4 = satisfied, 5 = very satisfied). A total score of ≥4 points was defined as "satisfied" to calculate the overall satis-

Table 2. Comparison of general information between the two groups of students

Group	Age (years)	Gender		Clinical anesthesiology score
		Male	Female	
Control group	20.10±0.61	16	14	89.67±4.92
Observation group	20.03±0.62	13	17	90.03±5.12
t/χ^2	0.422	0.610		0.042
P	0.777	0.438		0.839

Table 3. Comparison of examination scores between the two groups of students

Group	Number of cases	Theoretical score	Skill score
Control group	30	87.80±5.52	82.73±6.65
Observation group	30	93.93±2.99	90.43±8.88
t/χ^2		5.979	6.753
P		0.018	0.012

faction rate. All students filled in the questionnaire anonymously after the course to ensure the authenticity of the data.

2.4 Statistical methods

SPSS 26.0 software was used for statistical analysis of data. Measurement data were expressed as mean ± standard deviation, and t-test was used for intergroup comparison. Count data were expressed as n (%), and χ^2 test was used for intergroup comparison. $P<0.05$ was considered statistically significant.

3 RESULTS

3.1 Comparison of general data between the two groups

In the observation group, there were 30 students, including 13 males and 17 females, aged 19-23 years, with an average age of (20.03±0.62) years. In the control group, there were 30 students, including 16 males and 14 females; aged 19-23 years, with an average age of (20.10±0.61) years. There were no statistically significant differences in age, gender, professional course scores and other aspects between the two groups of students (all $P>0.05$), and the data were comparable (see **Table 2**).

3.2 Theoretical knowledge examination scores and clinical operation skill assessment scores

The assessment results showed that the theoretical examination scores and clinical operation skill assessment scores of the students in the distance teaching system combined with CBL teaching method group were significantly higher than those in the traditional teaching method group (93.93±2.99 vs. 87.80±5.52; 90.43±8.88 vs. 82.73±6.65) (both $P<0.05$) (see **Table 3**).

3.3 Results of student satisfaction survey

The questionnaire results showed that the average scores of the observation group in the four dimensions of practicality of teaching content, interactivity, help in skill improvement and stimulation of learning interest were significantly higher than those of the control group (all $P<0.05$) (see **Table 4**). The overall satisfaction rate of the observation group was 96.67% (29/30), and that of the control group was 83.33% (25/30), with a statistically significant difference ($\chi^2=9.387$, $P=0.009$).

4 DISCUSSION

As a discipline emphasizing the combination of theory and practice, clinical anesthesiology covers a variety of complex clinical operations such as endotracheal intubation, nerve block and central venous catheterization in its teaching content [17, 18]. In the teaching of anesthesiology, simulation training is widely used to improve students' clinical skills [19]. Simulation training provides a safe environment for students to practice and master complex operational skills without endangering patient safety [19]. Studies have shown that simulation training can significantly improve the skill level of anesthesiologists and help improve the quality of patient care [20]. In summary, the teaching of clinical anesthesiology not only requires solid theoretical knowledge but also needs to improve students' practical operation ability through various methods such as simulation training and anatomy courses. This comprehensive teaching method helps to cultivate more qualified anesthesiology professionals.

The CBL teaching method is an instructional approach that is problem-based and involves students discussing and learning around actual clinical cases [11]. In CBL teaching, students will discuss in groups, and the instructor will guide and promote communication and cooperation among students [12]. By discussing and analyzing actual cases, students can gradually improve their ability to independently solve clinical problems. However, a limitation of relying solely on the CBL teaching method is that students may focus excessively on the cases themselves, leading to inconsistencies between the teaching content and actual clinical operations. This can result in a disconnect between laboratory teaching and clinical practice.

The application of the distance teaching system not only improves communication between teachers and students but also deepens students' understanding of abstract concepts and theories in textbooks, which is essential for medical students when they enter the clinical learning stage in the future. This study combines the distance teaching system with the CBL teaching model. Through videos, students can observe real patients and anesthesia scenarios, and the anesthesiologist's perspective shows every step of the anesthesia process completely and clearly to students, enabling them to fully under-

Table 4. Comparison of teaching satisfaction between the two groups of students

Group	Number of cases	Practicality of teaching content	Interactivity	Help in skill improvement	Stimulation of learning interest	Overall satisfaction rate (%)
Control group	30	3.82±0.51	3.65±0.48	3.71±0.53	3.58±0.55	83.33
Observation group	30	4.65±0.32	4.58±0.35	4.62±0.38	4.71±0.29	96.67
t/χ^2		7.892	8.125	7.963	8.531	9.387
P		0.003	0.002	0.003	0.001	0.009

Note: Overall satisfaction rate = (number of very satisfied + basically satisfied cases)/total number of cases × 100%; each dimension adopts a 5-point Likert scale (1 = very dissatisfied, 5 = very satisfied).

stand the clinical anesthesia procedures and operation points. This learning method creates an interactive learning community by combining information technology with the teaching environment, allowing students to transform from passive learning to active knowledge construction, thereby improving learning outcomes.

The results of this study showed that the theoretical examination scores and clinical operation skill assessment scores of students in the distance teaching system combined with CBL teaching method group were significantly higher than those in the traditional teaching method group, with statistically significant differences (both $P<0.05$). These findings indicate that the combination of distance teaching system and CBL teaching method can improve the quality of experimental teaching for medical students and make clinical anesthesiology experimental teaching closer to clinical internship teaching. This study is consistent with the research of Fang et al., in which students' operation skill scores were significantly improved through the application of distance live broadcast in anesthesiology teaching [13]. However, this study further integrated the CBL teaching method, added case-driven in-depth interaction, and resulted in a more significant improvement in satisfaction rate (96.67% vs. 88.2% in their research). Wen et al. found in oncology teaching that the CBL teaching method can improve students' problem-solving ability, but due to the lack of real operation scene support, the effect on skill improvement is limited [21]. This study supplemented the operation scene through distance teaching, achieved a closed-loop of "theory - case - operation", and further verified the advantages of the combined model in teaching practical disciplines.

The results of this study showed that through the combination of distance teaching system and CBL teaching method, students' satisfaction was significantly higher than that of the traditional teaching method group. The flexibility and convenience of the distance teaching system allow students to learn according to their own pace and schedule, reducing time pressure and restrictions. Studies have shown that the CBL teaching model has significant value in improving the achievement rate, practical ability, and psychological quality of medical students [7]. By observing students' actions and expressions during internships to evaluate their psychological quality, and using questionnaires to assess their performance in future planning, occupational health, and team spirit, the results showed that the CBL teaching model significantly improved the training compliance rate of medical students and enhanced their confidence in future role transitions to a certain extent.

This study has certain limitations: ① The sample size is small (60 students) and only from a single college, which may introduce selection bias. In the future, the sample size needs to be expanded to multiple colleges of different levels to further verify the generalizability of the research results; ② This model has shown certain advantages in small-class teaching (30 students). However, in large-class teaching, it may face difficulties in organizing group discussions and reduced interaction efficiency; ③ The implementation of the distance teaching system relies heavily on a stable network and advanced technical support. When the network is unstable or technical failures occur, this dependence may lead to interruptions or degradation in the quality of clinical skill teaching; ④ The distance teaching system is becoming increasingly popular in medical education, especially in the context of the global epidemic.

5 CONCLUSION

In conclusion, the application of the distance teaching system combined with the CBL teaching method in clinical anesthesiology experimental teaching can significantly improve the teaching effect and students' satisfaction by providing high-quality content and an interactive learning environment. This approach further enriches the traditional teaching system, effectively stimulates students' interest in independent learning, and helps cultivate anesthesiology professionals who meet clinical requirements.

DECLARATIONS

Author contributions

Huaichang Wen conceived the research idea, designed the study protocol, collected and analyzed the research data, and completed the drafting of the original manuscript. Yi Wang participated in the design of this study, carried out the teaching practice and implementation work, assisted in data collation,

and critically revised the manuscript to polish its core intellectual content. Kaichen Zhang completed the statistical analysis of research data, participated in the formulation of teaching evaluation tools, and enriched and improved the discussion section of the article. Wenjun Guo assisted in organizing the teaching practice, collected feedback information from teachers and students, and verified the accuracy of all experimental data in this study. Meijing Lu supervised the whole process of the research, provided professional academic guidance for teaching design, revised and finalized the manuscript for official submission, and ensured the overall integrity and standardization of the research.

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Data availability

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Ethics approval and consent to participate

This study was exempted from ethical review by the Ethics Committee of Wannan Medical College, because the research was a non-invasive educational teaching reform study, no human biological samples or confidential clinical data were involved, and all participants' information was kept anonymous.

Consent for publication

All authors have reviewed and approved the final manuscript.

Competing interests

The authors declare that they have no competing interests.

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TEACHING INNOVATION

A time-axis-based teaching framework for sepsis management in intensive care training

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Abstract

Sepsis remains challenging to teach in the intensive care unit (ICU), not due to a lack of guidelines, but because clinical priorities must be continually reassessed as patient physiology evolves. Although trainees are familiar with guideline recommendations, they often hesitate at the bedside when multiple time-sensitive decisions compete for attention. To address this gap, we implemented a time-axis-based framework to structure sepsis case discussions during routine ICU teaching, including bedside rounds and formal case reviews. This approach organizes management into four sequential yet overlapping decision phases, helping maintain focus on immediate priorities while anticipating subsequent changes. In our experience, trainees demonstrated improved ability to articulate decision prioritization and escalation of care. Rather than introducing new guideline content, the framework enhances the visibility of temporal prioritization and clinical reasoning during discussion. By centering on timing and prioritization, it complements guideline-based teaching and provides a clearer structure for time-critical decision-making in ICU training.

Keywords: Sepsis, Medical education, Intensive care unit, Clinical reasoning, Teaching framework

1 BACKGROUND

Sepsis remains a major contributor to global morbidity and mortality and represents a core competency in intensive care medicine [1, 2]. In practice, effective management requires early recognition, timely prioritization of interventions, and continuous reassessment as patient physiology evolves [2, 3]. These same features also make sepsis difficult to teach. Trainees must make rapid decisions under uncertainty while responding to alarms, incoming laboratory data, and competing demands in the intensive care unit (ICU).

Sepsis education is commonly delivered through lectures, guideline summaries, or algorithm-based teaching [3, 4]. While these approaches establish diagnostic criteria and recommended therapies, they may appear static when applied to patients whose conditions change dynamically. In clinical settings, experienced intensivists continuously re-prioritize actions based on evolving physiology, resource constraints, and anticipated downstream risks [5, 6]. Although guidelines specify what should be done, they rarely make explicit how experts determine sequencing, deferment, or escalation.

In routine teaching, this decision-making process often remains implicit. Faculty may perform appropriate actions without consistently articulating the rationale for prioritization or escalation at a given moment. As a result, trainees observe outcomes but struggle to reconstruct the temporal organization of decisions [7, 8]. This expert–novice gap is well described in the clinical reasoning literature and is particularly pronounced in fast-paced environments such as intensive care [9, 10].

When early sepsis management is presented as a checklist, learners may focus on task completion rather than sequencing.

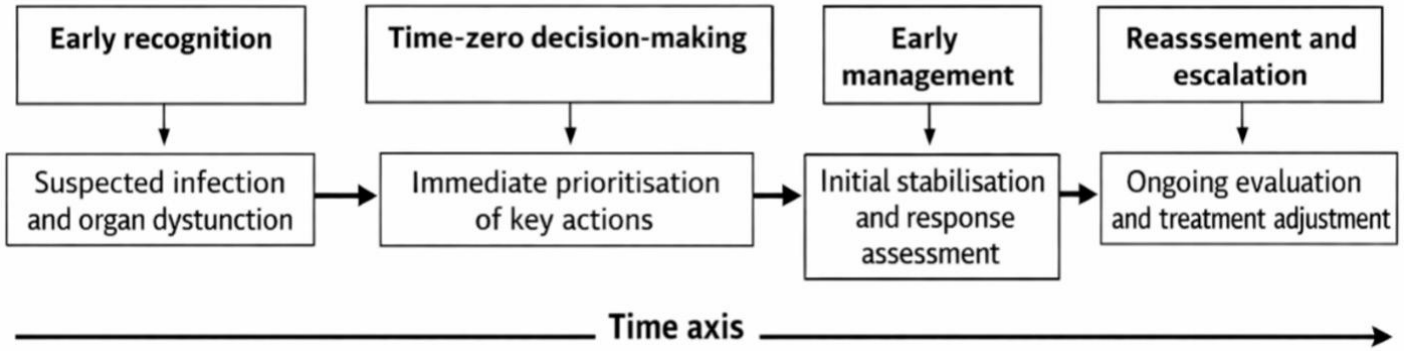

Figure 1. Time-axis–oriented teaching framework for sepsis management in intensive care training. The framework organises sepsis management into four sequential but overlapping phases—early recognition, time-zero decision-making, early management, and reassessment with escalation—highlighting how clinical priorities and decision-making evolve over time during routine ICU practice.

This can lead to indiscriminate action without clear prioritization or escalation logic. Over time, such patterns may hinder the development of adaptive reasoning required in situations of diagnostic uncertainty or treatment failure [7, 11].

Case-based learning is widely used to support clinical reasoning by linking knowledge to authentic clinical contexts [12, 13]. However, case discussions vary across instructors and may drift toward retrospective explanation rather than real-time decision logic. A practical organizing structure is therefore needed to anchor discussion in time and make shifting priorities explicit as new information emerges [5, 14].

2 CONCEPTUAL BASIS OF THE FRAMEWORK

The framework is informed by educational perspectives that emphasize learning through participation in authentic clinical practice and through expert modelling in context [12, 15]. In ICU training, clinical reasoning involves not only knowing recommended interventions but also recognizing how the "main problem" evolves over time. This requires an understanding of temporal priority—what demands immediate action, what can be deferred, and what must be reassessed following initial interventions.

Experienced intensivists develop this temporal awareness through repeated clinical exposure and feedback [9, 10]. For example, they learn when a borderline blood pressure should prompt escalation and when it can be monitored while addressing a more urgent issue. These judgements are shaped by anticipated consequences, as early decisions create constraints and opportunities for subsequent actions [6, 16]. Sepsis reasoning is therefore inherently cumulative and time-dependent.

However, such reasoning is not easily acquired through observation alone. During rounds, faculty often act rapidly, and the rationale underlying prioritization may remain implicit [7, 8]. In addition, the pace of ICU work limits opportunities for reflection. Without an explicit scaffold, trainees may struggle to organize cases in real time and to link early decisions with later escalation [11].

Accordingly, our teaching aim is to make the temporal structure of decision-making explicit. By organizing sepsis management along a time axis, the framework externalizes the questions that experienced clinicians often apply implicitly. This approach enables trainees to practice reasoning in the same sequence as bedside decision-making, rather than relying solely on retrospective explanations of care [5, 14].

3 DESCRIPTION OF THE TIME-AXIS-BASED TEACHING FRAMEWORK

The framework organizes sepsis management into four sequential yet overlapping phases. Rather than functioning as a rigid checklist, these phases serve as a scaffold to guide attention toward priorities, uncertainty, and escalation triggers during case discussion. The overall structure is illustrated in **Figure 1**.

3.1 Phase 1: Early recognition

This phase focuses on identifying suspected infection and acute organ dysfunction. Teaching emphasizes pattern recognition (e.g., evolving respiratory rate, changes in mental status), interpretation of trends, and diagnostic vigilance in non-specific presentations [1, 2]. Trainees are prompted to explain why sepsis is plausible at that moment, rather than enumerating differential diagnoses.

3.2 Phase 2: Time-zero decision-making

Once sepsis is recognized, attention shifts to time-critical actions. The focus is not only on what to do, but why a given action takes priority. Trainees are asked to justify initial decisions (e.g., antibiotics, cultures, hemodynamic support) and to consider the potential consequences of delay [3, 5]. The concept of "time zero" is also contextualized within local practice (e.g., recognition during rounds versus overnight handover).

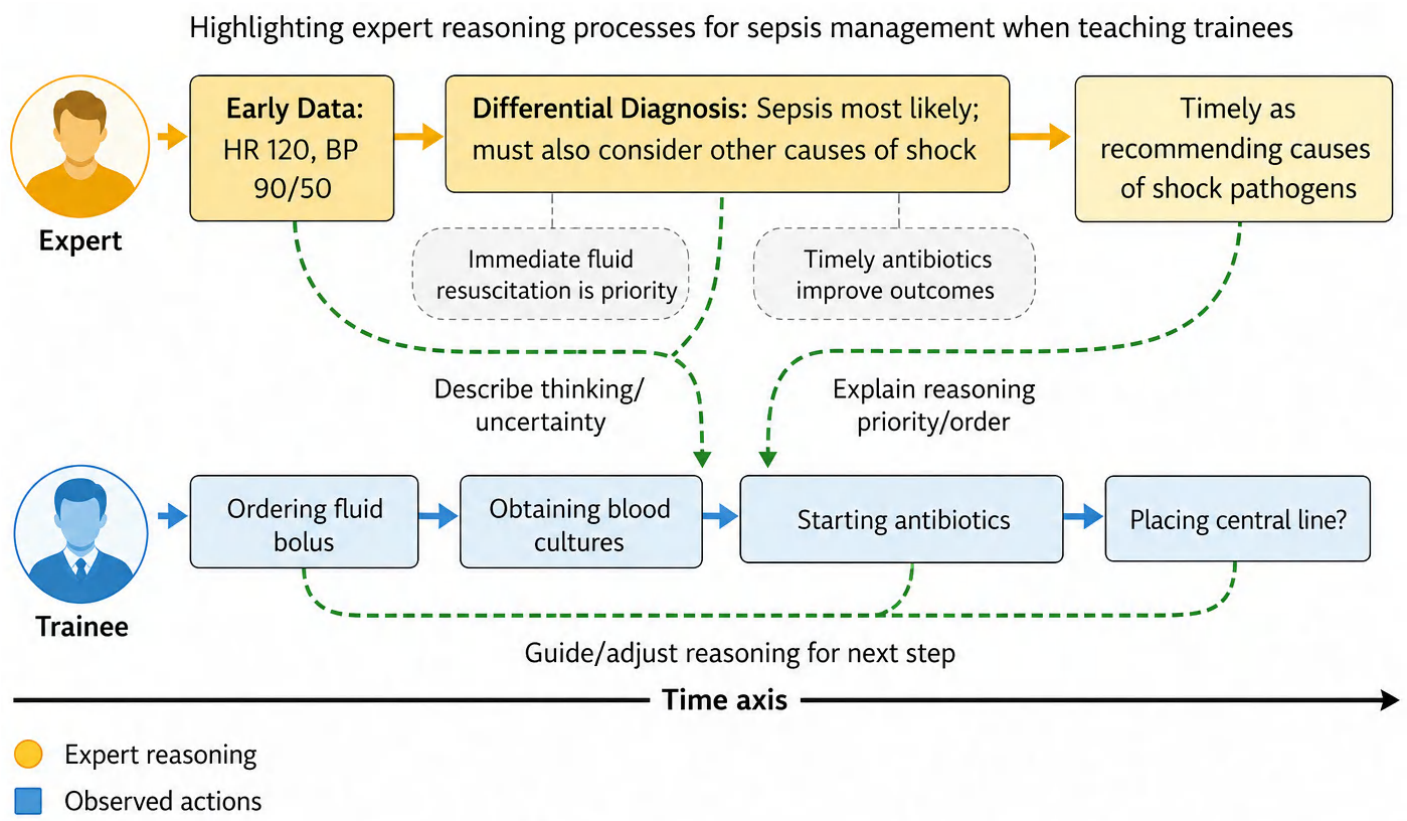

Figure 2. Making expert clinical reasoning visible to trainees in sepsis management. The figure illustrates how expert clinicians externalise temporal priorities and decision-making processes during case-based teaching, enabling trainees to observe, discuss, and gradually internalise time-sensitive clinical reasoning.

3.3 Phase 3: Early management

This phase addresses initial hemodynamic optimization, response monitoring, and interpretation of dynamic clinical data. Trainees are guided to identify expected response signals and appropriate time frames for reassessment. Discussion emphasizes linking early responses—or lack thereof—to subsequent decisions, rather than viewing interventions as isolated steps [2, 6].

3.4 Phase 4: Reassessment and escalation

Although reassessment is continuous, escalation reasoning is treated as a distinct teaching focus. Trainees are encouraged to define what constitutes an inadequate response, reconsider alternative explanations, and determine when escalation is warranted (e.g., vasopressors, source control, expanded diagnostics) [5, 16]. Particular attention is given to how early decisions constrain later options, a common challenge for novice learners.

4 EXTERNALIZING EXPERT CLINICAL REASONING

A central feature of the framework is the deliberate faculty verbalization of expert reasoning during case discussions. Faculty are encouraged to "think aloud", making explicit their prioritization, uncertainty, and anticipation of downstream consequences [7, 8]. In our experience, trainees benefit not only from hearing decisions, but from understanding the trade-offs and temporal logic underlying them.

Figure 2 illustrates how expert reasoning—often compressed into brief bedside statements—can be unpacked into explicit, sequential steps for teaching. For instance, rather than stating "*let's start norepinephrine*", an instructor might elaborate: "*Adequate fluid resuscitation has been given, mean arterial pressure remains low, lactate is rising, and further delay risks worsening perfusion; initiating vasopressors now allows time for ongoing reassessment of volume status*". Such expansions make the temporal logic of escalation visible and reproducible.

This approach is consistent with educational frameworks such as cognitive apprenticeship, which emphasize modelling, coaching, and the explicit articulation of expert cognition [15, 17]. In practice, even brief "reasoning statements" can shift case discussions from checklist-driven task completion toward prioritization-based clinical decision-making.

5 PRACTICAL IMPLEMENTATION IN ICU TEACHING

The framework is designed to integrate into routine ICU teaching rather than requiring a separate program. It is applied

in three common contexts: (1) bedside rounds, (2) brief post-admission case reviews, and (3) scheduled small-group sessions. While the same time-axis-based questions are used across settings, the depth of discussion is adapted to time constraints and trainee level [12, 13].

Teaching cases are typically drawn from recent ICU admissions to ensure clinical relevance. Each case is reviewed chronologically, with trainees asked to identify decision priorities at each phase. Faculty then makes implicit reasoning explicit, particularly with respect to time-zero priorities and escalation triggers. For junior trainees, the focus is on recognizing key clinical signals and articulating a defensible order of priorities. For more advanced learners, emphasis shifts toward trade-offs, management of uncertainty, and the downstream implications of early decisions [11, 18].

Because the framework prioritizes reasoning over assessment, it can be implemented without formal testing or additional data collection, supporting feasibility in time-constrained clinical environments. In practice, this also facilitates adoption across instructors by providing a shared structure for discussion rather than introducing a resource-intensive curriculum [14, 19]. All teaching cases were fully de-identified prior to discussion. According to institutional policy of The Affiliated Huai'an No. 1 People's Hospital of Nanjing Medical University, this study did not involve identifiable patient data and therefore did not require formal ethical approval or informed consent.

6 EDUCATIONAL IMPLICATIONS

This time-axis-based framework provides trainees with a structured approach to sepsis management that more closely reflects real-time bedside decision-making. It does not replace guideline-based teaching; rather, it addresses complementary questions: *what matters most now, what should happen next, and what would prompt a change in course?* Repeated engagement with these questions across cases may support the development of clearer prioritization and escalation reasoning in time-sensitive care [7, 9].

For instructors, the framework also serves as a shared teaching language. When multiple faculty members supervise the same cohort, variability in case discussions is inevitable. A common time-axis scaffold can enhance consistency while preserving individual teaching styles and clinical perspectives. In addition, it provides a structured basis for feedback, enabling instructors to comment not only on knowledge of guidelines but also on how trainees prioritize decisions and respond to evolving clinical information [15, 17].

Although described in the context of sepsis, this approach may be applicable to other ICU conditions characterized by time-critical decision-making and frequent reassessment, such as undifferentiated shock, acute respiratory failure, and post-cardiac arrest care [5, 16]. Across these contexts, the central educational aim remains the same: to make temporal prioritization explicit and amenable to deliberate practice.

7 LIMITATIONS

This article presents a conceptual teaching framework without empirical evaluation of educational outcomes. Accordingly, no conclusions can be drawn regarding its impact on trainee performance or patient outcomes. Implementation is also likely to vary across institutions, depending on faculty experience, clinical workflows, and local teaching culture. Future studies could examine how the framework influences clinical reasoning processes, prioritization of decisions, and transfer of learning to practice. At the same time, its flexibility may support adaptation across diverse educational settings.

8 CONCLUSIONS

We describe a time-axis-based teaching framework for sepsis management in ICU training that emphasizes timing, prioritization, and escalation reasoning. By making the temporal dimensions of expert decision-making more explicit during case discussions, the framework offers a practical approach to supporting clinical reasoning in intensive care education. Further research is needed to evaluate its effects on trainee decision-making and its potential integration into routine ICU practice.

DECLARATIONS

Author contributions

Peng Zhang conceptualized the study and drafted the manuscript. Tongkun Zuo and Ying Huang contributed to critical revision of the manuscript. All authors read and approved the final version.

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Data availability

No datasets were generated or analysed during the current study.

Ethics approval and consent to participate

This study did not involve identifiable human participants or patient-level data. In accordance with institutional policy of The Affiliated Huai'an No. 1 People's Hospital of Nanjing Medical University, ethical approval and informed consent were not required.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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RESEARCH ARTICLE

Application of a virtual simulation experiment system in teaching pain diagnostics and therapeutics in the digital-intelligent era

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Abstract

Objective: With the ongoing digital transformation of higher education in recent years, virtual simulation experiment teaching has emerged as a key direction for instructional reform in universities. Taking the course *Pain Diagnostics and Therapeutics* offered by the School of Anesthesiology at Wannan Medical University as an example, this study aimed to evaluate the effectiveness of a virtual simulation experiment system in the experimental teaching of this course. **Methods:** A total of 236 anesthesiology students from the class of 2021 were enrolled as research participants and randomly divided into a control group and an experimental group. The control group received traditional teaching combining theoretical lectures with bedside clinical observation. The experimental group underwent a blended teaching model consisting of virtual simulation teaching plus bedside clinical observation, which included three stages: online virtual pre-training, offline in-class hands-on practice, and clinical observation with virtual-real mutual verification. **Results:** The experimental group demonstrated significantly better performance than the control group across all evaluation indicators (all $P<0.001$). Regarding course scores, the experimental group achieved a mean score of 90.98±6.23, which was significantly higher than that of the control group (85.28±4.42). The experimental group also showed marked superiority in regular assessment scores (92.58±5.42 vs. 84.56±5.44) and final theoretical examination scores (90.30±6.58 vs. 85.59±3.98). In terms of clinical reasoning ability, the mean score of the experimental group reached 27.55±1.59, far exceeding that of the control group (20.42±2.87). Regarding teaching satisfaction, the experimental group had significantly higher proportions of students reporting enhanced learning interest (91.53% vs. 55.08%), in-depth understanding of learning content (80.51% vs. 63.56%), and a comfortable clinical teaching atmosphere (69.49% vs. 49.15%) compared with the control group (all $P<0.05$). **Conclusion:** The blended teaching model integrating virtual and real practice improves teaching effectiveness, helps consolidate students' professional theoretical foundation, and enhances their clinical reasoning ability. Therefore, this approach holds positive reference value for the teaching reform of *Pain Diagnostics and Therapeutics*.

Keywords: Pain diagnostics and therapeutics, Virtual simulation, Experimental teaching, Teaching reform

Highlights

- The virtual-real integrated teaching model demonstrates significant advantages. The experimental group showed significantly higher course scores, clinical reasoning ability, and teaching satisfaction compared to the control group, with all differences being statistically significant.
- Virtual simulation technology provides substantial value in medical education. It effectively addresses the limitations of traditional teaching methods, standardizes instructional outcomes, and offers a viable pathway for the digital transformation of medical education.
- Future efforts should focus on integrating virtual simulation with artificial intelligence to enable personalized and intelligent approaches to medical teaching.

1 INTRODUCTION

With the widespread adoption and continuous advancement of modern educational information technology, virtual simulation has emerged as an innovative teaching method and has become a key driver of reform in medical education [1, 2]. As an important subspecialty of anesthesiology, *Pain Diagnostics and Therapeutics* features is characterized by abstract theories and a strong emphasis on practical application [3]. Traditional approaches to teaching this course face several prominent pedagogical challenges, including limited access to typical clinical pain cases, the inability to safely and repeatedly perform high-risk procedures on real patients, and difficulties in conducting standardized evaluations of teaching effectiveness [4, 5]. These issues often result in students struggling to integrate theoretical knowledge with clinical practice, thereby hindering the development of their clinical reasoning and hands-on skills, and ultimately leading to unsatisfactory learning outcomes.

By constructing a highly realistic, interactive virtual environment that presents authentic three-dimensional clinical scenarios and simulates clinical inquiry through speech recognition, virtual simulation technology offers an effective simulated platform for clinical students to practice history-taking and procedural skills (**Figure 1**). It enables risk-free and repeatable simulation of various pain diagnosis and treatment scenarios, allowing students to engage in immersive, end-to-end training that covers disease inquiry, auxiliary examinations, diagnosis, differential diagnosis, treatment, and technical procedures. Consequently, this technology provides essential technical support for shifting the focus of teaching from knowledge transmission to competency-based training [6, 7].

Based on its own teaching practice, the School of Anesthesiology at Wannan Medical University has independently developed a Virtual Simulation Experiment Platform for *Pain Diagnostics and Therapeutics*. This platform integrates real clinical cases with the learning characteristics of clinical anesthesiology and pain diagnostics and therapeutics. It is designed to consolidate students' theoretical foundation and systematically enhance their clinical reasoning ability, standardized operational skills, and comprehensive diagnostic and therapeutic capacity through a blended "virtual-real integration" teaching model. Taking the experimental course on trigeminal neuralgia (head and face) within *Pain Diagnostics and Therapeutics* as an example, this paper summarizes how virtual simulation can be integrated with traditional experimental teaching to reinforce theoretical knowledge and improve students' clinical reasoning ability.

2 METHODS

2.1 Research subjects

A total of 236 full-time undergraduate students majoring in Anesthesiology (Class of 2021) at Wannan Medical University were enrolled as research participants. The cohort included 120 males and 116 females, aged 21 to 23 years. Sample size was calculated using the two-independent-samples t-test formula, referencing relevant findings from studies on virtual simulation teaching in medical education. With a significance level (α) of 0.05, a statistical power ($1-\beta$) of 0.80, an expected mean difference of 5 points in clinical reasoning ability scores between the two groups, and a pooled standard deviation (SD) of 4 points, the minimum required sample size for each group was calculated to be 102 students. Accounting for a potential 15% attrition rate, the final sample size was set at 118 students per group, totaling 236 students. A simple randomization method was employed using a random number table generated by SPSS 22.0 software. Each eligible student was assigned a unique serial number from 1 to 236. The software generated 236 corresponding random numbers. Students with odd random numbers were allocated to the control group, and those with even random numbers were allocated to the experimental group. No students were lost to follow-up during the entire study process; all participants completed the course learning and all relevant assessments.

This study was reviewed and approved by the Institutional Review Board of Wannan Medical University. As this study involved routine teaching evaluation with non-invasive data collection and no identifiable personal information, the requirement for written informed consent was waived by the Institutional Review Board. All participants were informed of the study purpose and agreed to participate voluntarily.

Participants were divided into two groups according to teaching modalities: a control group receiving theoretical lectures

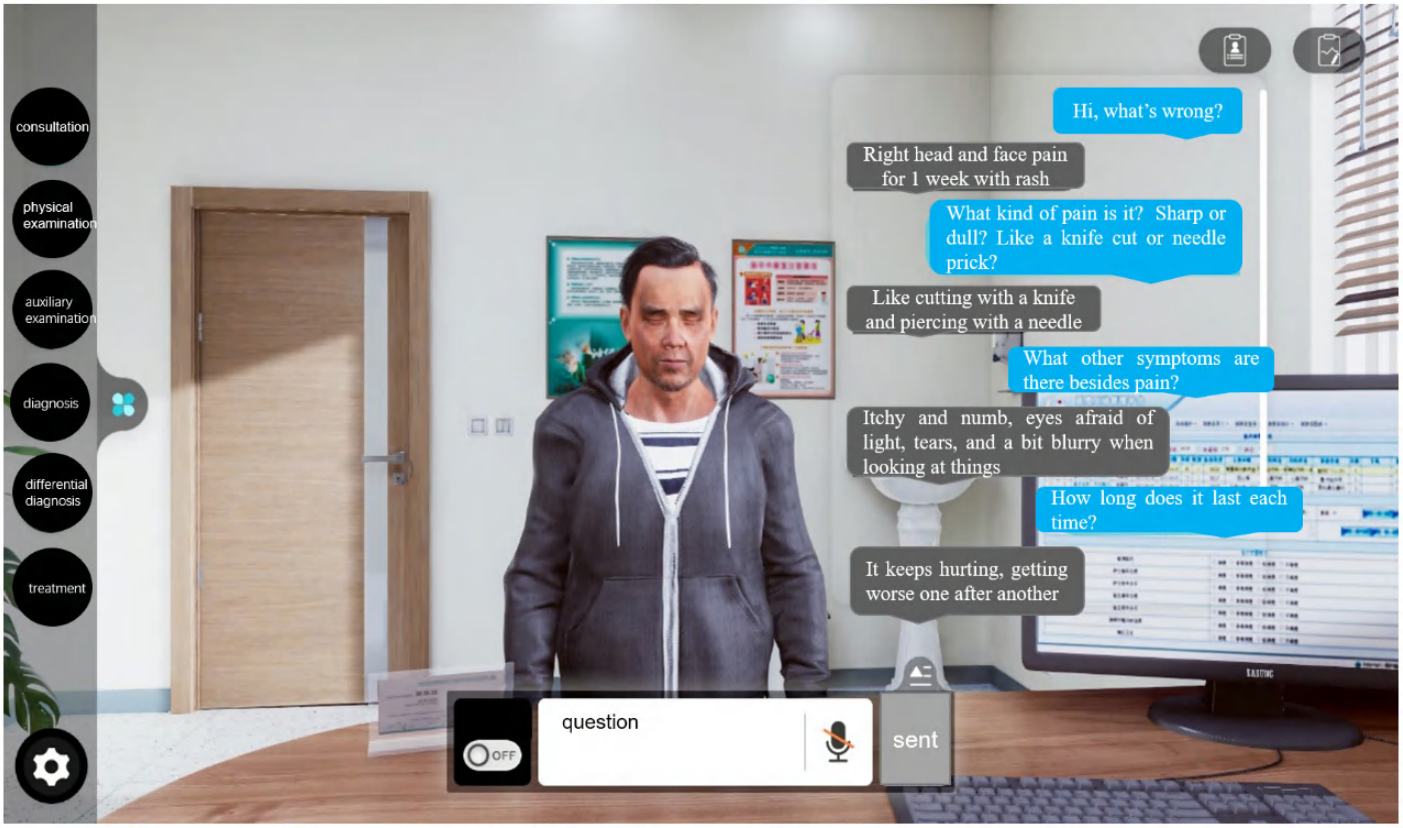

Figure 1. Three-dimensional clinical scenarios and simulated clinical inquiry. This image is from a self-developed virtual simulation experiment—"Diagnosis and treatment of trigeminal neuralgia in the head and face virtual simulation experiment" (website: *https://stu.medic-tutor.cn*).

plus bedside probation, and an experimental group taught with virtual simulation combined with bedside probation. All course instructors were from the Department of Anesthesiology at The First Affiliated Hospital of Wannan Medical University. All instructors held associate senior professional titles or higher and had more than 10 years of experience in clinical teaching.

2.2 Experimental arrangement and implementation plan

Experimental group: The virtual simulation experiment on trigeminal neuralgia was selected as the main research content from the established virtual simulation experimental projects. With information technology support from Shanghai Huayi Information Technology Co., Ltd., a virtual-real integrated experimental teaching approach was implemented for students in the experimental group. The teaching process was divided into three stages:

Online virtual pre-training: Before class, students completed previews of experimental materials and theoretical tests on the "StudyLink" platform. They then accessed the virtual simulation platform to conduct independent simulated operations, including clinical reasoning training for trigeminal neuralgia of the head and face (**Figure 1**).

Offline in-class in-depth practice: During class, the instructor first delivered targeted intensive lectures and clinical demonstrations based on learning data generated from the virtual training activities.

Clinical probation stage: Students proceeded to the pain procedures ine ward for hands-on procedures and clinical history-taking. The core objective of this stage was to consolidate and verify the results of virtual simulation, achieving "virtual-real mutual verification". Students were required to complete an experimental report integrating theoretical analysis and clinical practice using the virtual simulation system.

Control group: The traditional teaching method combining theoretical instruction with bedside probation was adopted. Before class, instructors released experimental course materials via the "StudyLink" platform, guided students to preview and clarify learning tasks, and required them to complete relevant theoretical tests to consolidate basic knowledge. During class, instructors illustrated the procedures and principles of history-taking, diagnosis, and treatment for trigeminal neuralgia of the head and face using case examples, emphasizing key aspects of clinical reasoning such as the diagnosis of trigeminal neuralgia. Subsequently, students entered the clinical probation

stage, where they conducted independent history-taking in the pain medicine ward and finally completed the experimental report on their own.

Post-course assessment for both groups: A brief flipped classroom session was conducted for both groups after each course, during which students briefly reported their mastery of the clinical knowledge learned. A final course examination was also organized for both groups upon completion of the course.

2.3 Outcome measures

2.3.1 Final course scores

In the achievement evaluation system for the *Pain Diagnostics and Therapeutics* course, the total score (full score =100) consisted of two components: the theoretical assessment score (accounting for 70%) and the experimental assessment score (accounting for 30%). The theoretical assessment score (70%) covered basic theories of pain diagnosis and treatment, disease pathogenesis, and clinical guidelines. The experimental assessment score (30%) included experimental operation, experimental report writing, and clinical probation performance.

The assessment tools and scoring criteria were standardized and applied uniformly for both groups. All examinations were conducted in a closed-book format with invigilation to ensure objectivity.

2.3.2 Clinical reasoning ability

Clinical reasoning ability was assessed using case-based analytical questions (full score =30 points) incorporated into the final course examination. These questions were developed based on real, typical clinical cases in pain medicine (e.g., trigeminal neuralgia, postherpetic neuralgia).

Question development and psychometric validation: Pretesting and psychometric verification of the case-based questions were completed three months prior to the formal assessment. The questions were piloted on 40 anesthesiology students from the Class of 2020 (who were not involved in the formal study). Item analysis was subsequently conducted to verify discriminability (discrimination index >0.30) and difficulty (difficulty coefficient between 0.50 and 0.70). The content validity index of the question set was confirmed as 0.92 by five senior experts in pain medicine and medical education.

Scoring criteria: Detailed scoring criteria were established for each dimension of the case analysis, as follows: clinical inquiry (6 points), including completeness of symptom collection and rationality of inquiry logic; physical examination (6 points), including standardization of examination items and accuracy of positive sign identification; auxiliary examinations (6 points), including rationality of examination selection and correct interpretation of results; and diagnosis and differential diagnosis (12 points), including accuracy of the definitive diagnosis and rationality of differential diagnosis reasoning and basis.

Scoring implementation and inter-rater reliability: Scoring was performed independently by two senior attending physicians from the Department of Anesthesiology, each with over 10 years of clinical and teaching experience. Both raters received uniform training on the scoring criteria prior to the assessment and were blinded to the students' group assignments. Inter-rater reliability was assessed using the intraclass correlation coefficient, which yielded a value of 0.94, indicating excellent consistency between the two raters. In cases where the scoring discrepancy between the two raters exceeded 2 points, a third attending physician (chief physician level) was invited to conduct a joint review and determine the final score through consensus [8, 9].

2.3.3 Satisfaction with teaching effectiveness

This indicator was evaluated across three specific dimensions to comprehensively reflect students' subjective perception of the teaching mode. The three dimensions were: ① Enhanced learning interest—the degree to which the teaching mode stimulated students' initiative and interest in learning *Pain Diagnostics and Therapeutics*; ② In-depth understanding of learning content—the degree to which the teaching mode helped students comprehend and master the theoretical and practical knowledge of the course; and ③ Comfortable clinical teaching atmosphere—the degree of students' sense of ease and acceptance during the teaching process, particularly in clinical probation and simulated operation sessions. After course completion, an anonymous questionnaire survey was administered to students in both groups via the SoJump platform. The questionnaire was developed by the research team. Content validity was verified by three medical education experts (content validity index =0.89), and internal consistency reliability was assessed using Cronbach's α coefficient (0.91). A 4-point Likert scale (1= Strongly Disagree, 2= Disagree, 3= Agree, 4= Strongly Agree) was adopted, with each dimension scored independently. Students completed the anonymous ratings based on their actual learning experiences. The questionnaire recovery rate was 100% for both groups [10, 11].

2.4 Statistical analysis

Data analysis was performed using SPSS 22.0 statistical software, and statistical graphs were generated using GraphPad Prism 7.0 software. Prior to formal statistical analysis, the normality of the distribution of measurement data was tested using the Shapiro-Wilk test, and homogeneity of variance was verified using the Levene's test. The results showed that all measurement data in this study followed a normal distribution

Table 1. Comparison of baseline characteristics between the two groups

		Control group (n=118)	Experimental group (n=118)	t/X^2 value	P value
Gender, n (%)	Male	58 (49.15)	62 (52.54)	0.28	0.59
	Female	60 (50.85)	56 (47.46)		
Age (years)		22.05±0.68	22.12±0.71	0.77	0.44
Mean score of professional basic courses	*Anesthesia Physiology*	84.74±4.82	83.50±5.62	1.82	0.07
	Internal Medicine	85.71±6.83	84.83±5.57	1.09	0.28

Note: Data are presented as mean ± standard deviation ($\bar{x}$±SD) for continuous variables and n (%) for categorical variables.

Table 2. Comparison of examination results between the two groups

	Control group (n=118)	Experimental group (n=118)	t value	P value
Formative assessment score	84.56±5.44	92.58±5.42	11.34	<0.001
Final theoretical score	85.59±3.98	90.30±6.58	6.65	<0.001
Course score	85.28±4.42	90.98±6.23	8.11	<0.001

Note: Data are presented as mean ± standard deviation ($\bar{x}$±SD).

Table 3. Comparison of clinical reasoning ability scores between the two groups

Dimension	Control group (n=118)	Experimental group (n=118)	t value	P value
Total score of clinical reasoning ability	20.42±2.87	27.55±1.59	23.61	<0.001
Clinical history-taking	4.14±1.22	5.54±0.47	11.63	<0.001
Physical examination	3.93±1.34	5.46±0.53	11.53	<0.001
Auxiliary examinations	3.75±1.46	5.34±0.67	10.75	<0.001
Diagnosis and differential diagnosis	8.71±2.95	11.37±0.88	9.39	<0.001

Note: Data are presented as mean ± standard deviation ($\bar{x}$±SD).

(P>0.05) and exhibited homogeneity of variance (P>0.05), thereby meeting the assumptions for parametric tests. Measurement data were expressed as mean ± SD, and the independent-samples t-test was used for intergroup comparisons of continuous variables. Categorical data were presented as n (%), and the Pearson's chi-square test was used for intergroup comparisons; continuity correction was applied when necessary. A P-value of less than 0.05 was considered statistically significant.

3 RESULTS

3.1 Comparison of general data between the two groups

There were no statistically significant differences between the experimental group and the control group in terms of gender distribution, age, or mean scores in *Anesthesia Physiology* and *Internal Medicine* (all P>0.05), indicating that the two groups were comparable in baseline characteristics. The detailed baseline data are presented in **Table 1**.

3.2 Comparison of course scores

The experimental group had significantly higher formative assessment scores, final theoretical examination scores, and overall course scores in *Pain Diagnostics and Therapeutics* compared with the control group (all P<0.001). Detailed results are shown in **Table 2**.

3.3 Clinical reasoning ability

In all four evaluation dimensions of clinical reasoning ability (clinical history-taking, physical examination, auxiliary examinations, and diagnosis and differential diagnosis), the experimental group achieved significantly higher scores than the control group, and all intergroup differences were statistically significant (all P<0.001). Notably, the experimental group demonstrated a prominent advantage in the dimension of diagnosis and differential diagnosis, which showed the largest score gap between the two groups. Detailed data on the total score and each dimension score are presented in **Table 3**.

3.4 Satisfaction with teaching effectiveness

Students in the experimental group reported significantly higher satisfaction with teaching effectiveness compared with those in the control group. Across all three evaluation dimensions, the number of students in the experimental group who reported enhanced learning interest, in-depth understanding of learning content, and a comfortable clinical teaching atmosphere was

Table 4. Comparison of satisfaction with teaching effectiveness between the two groups

	Control group (n=118)	Experimental group (n=118)	X^2 value	P value
Enhanced learning interest	65 (55.08%)	108 (91.53%)	6.33	<0.001
In-depth understanding of learning content	75 (63.56%)	95 (80.51%)	2.90	<0.001
Comfortable clinical teaching atmosphere	58 (49.15%)	82 (69.49%)	3.32	<0.001

Note: Data are presented as n (%).

significantly higher than that in the control group (all P<0.05). Detailed results are presented in **Table 4**.

4 DISCUSSION

In this study, the independently developed virtual simulation experiment platform was deeply integrated into the *Pain Diagnostics and Therapeutics* course, and a three-stage teaching model consisting of "online virtual pre-training/offline in-class intensive teaching and practice/clinical bedside practice verification" was constructed, thereby incorporating modern information technology into traditional experimental teaching [12-15]. These findings are consistent with the core conclusions of numerous domestic and international studies on virtual simulation teaching in medical education and further provide empirical evidence supporting the application of virtual simulation technology in the specialized teaching of pain medicine.

In terms of academic performance improvement, the experimental group demonstrated significant advantages in regular assessment scores, final theoretical examination scores, and overall course scores (all P<0.001), which is consistent with the findings of Bi et al. on case-based learning method in teaching postgraduate students of medical oncology and Liu L et al. on preclinical orthodontic training with haptic-enhanced VR simulation [15, 16]. The fundamental reason for this improvement is that the online virtual pre-training stage overcomes the time and space constraints of traditional teaching: students can repeatedly simulate clinical operations and apply theoretical knowledge in a risk-free virtual environment, thereby compensating for the "one-time teaching" limitation of traditional theoretical lectures and solidifying their professional knowledge foundation [17, 18]. More importantly, the virtual simulation platform generates real-time learning data for instructors, enabling them to deliver targeted intensive lectures and clinical demonstrations during offline classes. This student-centered teaching design effectively improves the efficiency of knowledge transmission and absorption, which is key to the significant academic performance improvement observed in the experimental group. This study found that the experimental group was significantly superior to the control group in terms of final course scores, quantitative scores of clinical reasoning ability, and satisfaction with teaching effectiveness. Notably, the experimental group achieved a much higher mean clinical reasoning score with a smaller SD, indicating that virtual simulation teaching not only generally improves students' clinical reasoning ability but also helps standardize and homogenize teaching outcomes, effectively reducing the variability in student competencies often seen under the traditional teaching model. This finding is consistent with the research conclusions of many domestic scholars. Ward-Gaines et al. also reported similar improvements in competency in simulation-based emergency medicine teaching, while Morel et al. highlighted the advantages of virtual systems in standardized assessment [19, 20].

In terms of teaching satisfaction, the experimental group showed significantly higher levels of recognition in enhanced learning interest, in-depth understanding of learning content, and a comfortable clinical teaching atmosphere (all P<0.05), which is consistent with the findings of Tyransky et al., who reported that integrating virtual technology with artificial intelligence can improve students' teaching satisfaction [17]. The virtual simulation teaching model changes the passive learning state of students traditionally seen in conventional teaching. Specifically, the interactive and immersive nature of virtual operations stimulates students' learning initiative and curiosity, while the "virtual-real mutual verification" during the clinical probation stage enables students to apply the knowledge and skills acquired in the virtual environment to real clinical practice, thereby enhancing their sense of achievement and recognition of the teaching process. The comfortable clinical teaching atmosphere is also closely related to the risk-free virtual pre-training: by mastering basic clinical operation skills and history-taking logic before bedside probation, students experience less anxiety when facing real patients and gain greater confidence in clinical practice, thus improving the subjective experience of clinical teaching.

5 LIMITATIONS OF THE STUDY

This study has certain limitations that need to be acknowledged and addressed in future research. First, the research subjects were limited to undergraduate anesthesiology students from a single grade at one medical college, and the sample source is relatively homogeneous, which may limit the generalizability of the research results. The teaching effectiveness of the virtual-real integrated model needs to be further verified in multi-center, multi-grade, and multi-professional samples. Second, the follow-up observation period was insufficient. This study only evaluated short-term teaching effects through final course scores and immediate assessments of clinical reasoning ability, without tracking the long-term impact of this teaching model on students' clinical practice competency after they

enter clinical practice. Third, the virtual simulation platform still has room for optimization. The current platform primarily simulates typical clinical scenarios of trigeminal neuralgia, and the coverage of pain-related disease types is relatively limited, which cannot fully meet the diverse training needs for clinical reasoning in pain medicine. Fourth, this study did not conduct subgroup analyses based on students' academic performance levels. Therefore, the differential effects of the virtual-real integrated teaching model on students with different learning foundations needs to be further explored.

6 CONCLUSION

Integrating virtual simulation technology into course teaching significantly enhanced students' learning interest, clinical reasoning ability, and overall professional competencies. Taking the virtual simulation experiment on trigeminal neuralgia as an example, this study examined the implementation of this teaching reform in specific educational practice. The results demonstrate that this reform improved students' academic performance, consolidated their professional theoretical foundation, and enhanced their clinical reasoning ability, thus providing reference value for the teaching reform of *Pain Diagnostics and Therapeutics*.

DECLARATIONS

Author contributions

Shangping Fang conceived and designed the study, developed the virtual simulation experiment system, collected and analyzed the data, drafted and revised the manuscript. Huaichang Wen participated in the implementation of teaching interventions, collected clinical assessment data, and developed the virtual simulation experiment system. Miao Zhou assisted in statistical analysis, provided critical feedback, supervised the entire research process, and finalized the manuscript for submission.

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Data availability

The datasets generated and/or analyzed during the current study are not publicly available due to privacy restrictions on student academic records. However, they are available from the first author upon reasonable request.

Ethics approval and consent to participate

This study was reviewed and approved by the Institutional Review Board of Wannan Medical University. As this study involved routine teaching evaluation with non-invasive data collection and no identifiable information, the requirement for written informed consent was waived by the Institutional Review Board. All participants were informed of the study purpose and agreed to participate voluntarily.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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Not applicable.

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TEACHING INNOVATION

Teaching reform of the *Warm Disease Studies* course in military academies: A focus on broadening clinical perspectives

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Abstract

Warm Disease Studies, a core course in traditional Chinese medicine (TCM), integrates physicians' historical experience and theoretical achievements in the prevention and treatment of warm diseases, demonstrating remarkable clinical practical value. Its theoretical system has shown distinct advantages in the management of infectious diseases (e.g., acute epidemics and febrile conditions) in modern times. To meet the demand for versatile military TCM professionals and military medical support, this study addresses the current status and challenges of *Warm Disease Studies* teaching in military medical academies. Guided by the principle of "synergy between medicine and education, combat-oriented development", a four-dimensional integrated teaching model—encompassing theory, clinical practice, research, and extension—is proposed. This model highlights the characteristics of military medical support and achieves the organic integration of professional education and ideological education.

Keywords: *Warm Disease Studies*, Teaching reform, Clinical perspective, Military academies

Highlights

- Based on the current state of teaching, a new model for reforming the Warm Disease Studies course in military medical academies is proposed.
- The reform adheres to a student-centered approach and integrates multiple dimensions into the teaching model.
- This new teaching model represents a fundamental departure from traditional Chinese medicine curriculum and instruction.

1 INTRODUCTION

As one of the four great classical courses of traditional Chinese medicine (TCM) and the core carrier for theoretical research on exogenous febrile diseases, *Warm Disease Studies* functions both as a clinical and a foundational course, embodying a tight integration of theory and practice [1]. Its theoretical system demonstrates remarkable advantages in preventing and treating infectious diseases (including various acute contagious illnesses) as well as febrile disorders. In terms of disciplinary content and nature, this course is highly consistent with the collective lifestyle of military personnel, the characteristics of military operations, and the requirements of military medical support in the new era. As the sole principal institution for cultivating TCM professionals in the entire military, the Naval Medical University undertakes the fundamental mission of nurturing high-quality, professional, and comprehensive military talents needed by the armed forces [2]. Consequently, *Warm Disease Studies* plays an irreplaceable and pivotal role in the training system for advanced TCM talents in the military. Based on the characteristics of the military TCM medical system and the demands of its mission tasks, this paper focuses on the goal of

cultivating high-quality, professional, and comprehensive TCM talents. Guided by the clinical perspective of addressing common military diseases, controlling the prevalence of military injuries and illnesses, and preventing and treating epidemics in both peacetime and wartime, this study promotes the teaching reform of the *Warm Disease Studies* course in military academies.

2 CURRENT STATUS AND CHALLENGES IN TEACHING THE *WARM DISEASE STUDIES* COURSE IN MILITARY ACADEMIES

2.1 Unidimensional teaching approach in the *Warm Disease Studies* course

In recent years, military medical academies have proactively advanced teaching reforms for *Warm Disease Studies*, extensively embracing diverse pedagogical approaches—including case-based learning, scenario-based instruction, heuristic inquiry, and flipped classroom models. However, these methods are currently confined largely to the dissemination of theoretical knowledge in classroom settings, as clinical practice teaching has not yet been fully integrated into the overall curriculum. From the standpoint of instructional design systematicity, the scope of existing teaching reforms remains relatively narrow, and a cohesive multi-dimensional integrated teaching model is still lacking [3]. As a result, such reforms present certain limitations in broadening students' clinical horizons, enhancing their practical competencies, and nurturing their scientific research and innovative capacities. More importantly, they struggle to keep pace with the evolving training demands for comprehensive TCM talents in the military in the new era, thus rendering systematic teaching restructuring and innovation an urgent imperative.

2.2 Outdated teaching philosophy in the *Warm Disease Studies* course

Within the undergraduate TCM education framework of military medical academies, *Warm Disease Studies* constitutes one of the core classical theoretical courses, distinguished by its classical and traditional attributes [1]. Correspondingly, the prevailing pedagogical philosophy is predominantly textbook-centric, emphasizing theoretical instruction that interprets classical texts through their own contextual framework. Practical training, meanwhile, is primarily conducted via clinical clerkships. Since *Warm Disease Studies* is inherently a practice-oriented discipline, the current pedagogical philosophy and instructional modalities fail to fully comply with the national core standards for classical TCM education in cultivating TCM professionals—specifically in terms of fostering students' clinical competency and scientific research innovation capacity. The study of Chinese medicine classics should run through the whole undergraduate program, from start to finish [4]. Moreover, as a classical TCM course tailored to the needs of military academies, its curriculum design and instructional process incorporate insufficient real-world case studies pertaining to common and endemic military-specific conditions, such as wartime infectious diseases, epidemic prevention and control during peacetime and combat operations, and exertional heat illness. This gives rise to a conspicuous lack of "military relevance" and "combat readiness orientation". This pedagogical lag hinders students from effectively translating their command of warm disease theory into clinical practice, thereby resulting in deficiencies when they apply traditional Chinese medicine theories and skills to solve real-world clinical problems [5].

2.3 Inadequate integration of the *Warm Disease Studies* course with ideological and political education

The formation and evolution of *Warm Disease Studies* represents an innovative development in how TCM practitioners diagnose and treat exogenous febrile diseases. While this course is rich in ideological and political educational resources, it has not yet achieved effective integration of such elements in actual teaching. First, as a core approach to moral education and talent development in higher education, ideological and political education is only stated in the general teaching objectives yet inadequately implemented in chapter-based teaching. As a result, ideological and political content remains poorly integrated with professional knowledge. Second, teachers lack sufficient ability to identify and utilize the ideological and political values embedded in the course. For instance, the scientific spirit, sense of social responsibility, and professional ethics of leading physicians in the history of *Warm Disease Studies*; the inheritance and innovation of TCM culture; and the important role of warm disease theories in the management of modern infectious diseases—all of these can serve as core themes and classic examples for ideological and political education in this course. In current teaching practice, these contents are often not fully explored. Teachers tend to focus primarily on delivering professional knowledge, which makes it difficult to embed ideological and political elements throughout the course or to achieve an organic integration of value guidance with professional instruction [6]. As a result, the educational effect of "nurturing students quietly" is hard to realize. To some extent, this also limits the broadening of students' clinical horizons and the overall improvement of their professional competence.

3 TEACHING REFORM MEASURES: FOUR-IN-ONE INTEGRATION FOR EXPANDING CLINICAL HORIZONS

3.1 Establish the four-in-one integrated teaching philosophy

In response to the current situation and challenges in the teaching of *Warm Disease Studies* in military academies, we have established a teaching philosophy fundamentally oriented

toward broadening clinical horizons. Its core objectives are to strengthen students' clinical reasoning in differentiating and treating warm diseases, as well as their ability to address practical issues in military medicine.

By reorganizing and restructuring the curriculum system, integrating three key modules—basic theories, clinical diagnosis and treatment, and classic medical works—and aligning instruction with military and research requirements, we have formed a four-dimensional integrated framework: theory, clinical practice, scientific research, and expanded competence [3]. This approach carries distinct military characteristics, embodies the concepts of "medicine-education coordination and combat-oriented education", and integrates professional education with ideological and political education, thereby enhancing the application of TCM in military medical practice.

The teaching reform follows two principles:

First, integration of "classics and modern medicine": Warm disease theory encompasses a wide range of acute infectious and communicable diseases in Western medicine [7]. We integrate classic warm disease theories from works including *Discourse on Warm Diseases*, *Detailed Analysis of Warm Diseases*, and *Treatise on Damp-Heat Diseases* with modern therapeutics in infectious diseases and epidemiology. This approach enables students to bridge ancient and contemporary knowledge, thereby forming a comprehensive cognitive framework for treating febrile diseases through integrated Chinese and Western medicine.

Second, the integration of classroom and battlefield. Grounded in real military mission scenarios, we design teaching content around practical demands such as common military diseases, epidemic control, prevention and treatment of infectious diseases in peacetime and wartime, and medical support for field operations. This firmly upholds the goal of "cultivating personnel for combat" and effectively improves students' professional competence and practical ability to serve the battlefield and support the troops [8].

3.2 Establish a four-in-one teaching model with distinctive military health service features

3.2.1 Theoretical dimension—integrating Chinese and Western medicine with a focus on military health services

Theoretical teaching constitutes the foundation and core of the entire teaching model. In line with the new standards and requirements proposed by the state and military for the cultivation of TCM talents, this module systematically integrates and reconstructs the knowledge system of *Warm Disease Studies*. First, it deeply integrates the classic theories of *Huangdi Neijing* (*The Yellow Emperor's Inner Canon*), *Shanghan Lun* (*Treatise on Cold Damage Disorders*), *Jingui Yaolue* (*Synopsis of Prescriptions of the Golden Chamber*), and *Warm Disease Studies*; combs the curriculum knowledge structure; and clarifies the key connection points between theoretical teaching, clinical practice, scientific research capability, and the expansion of military needs [9]. Second, based on practical cases such as common and frequently occurring diseases in the military, as well as modern emerging and sudden infectious diseases, it explores classic clauses and prescriptions closely related to modern medicine and military medicine, and elaborates in depth on the essential knowledge of original works such as *Discourse on Warm Diseases* and *Treatise on Damp-Heat Diseases*.

Meanwhile, in the teaching of the general introduction to *Warm Disease Studies*, as well as the syndrome differentiation, treatment, and prevention of common diseases, cutting-edge hotspots in disciplines such as modern microbiology, epidemiology, and military medicine are actively introduced to enrich teaching resources and materials, improve the two core teaching modules of basic theories and classic original works, and thus construct the theoretical dimension.

3.2.2 Clinical dimension—diversified practical training with a focus on actual combat

Clinical practice is a key link connecting theoretical teaching, clinical education, and military health service support in actual combat. To comprehensively enhance cadets' capabilities in clinical diagnosis and treatment, battlefield adaptation, and emergency rescue, this module establishes a multi-scenario integrated clinical teaching system closely aligned with actual combat, which consists of four specific interrelated aspects: First, outpatient observation with teachers is conducted to strengthen clinical thinking. Cadets are organized to follow teachers in outpatient settings for clinical practice and prescription copying, focusing on mastering clinical thinking for applying warm disease theories to differentiate and low-grade fever of unknown origin and military operations (e.g., fever, pestilence, and damp-heat diseases) [9]. Special emphasis is placed on extracting strategies for preventing and treating infectious diseases in peacetime and wartime from defense-qi-nutritive-blood and triple-jiao syndrome differentiations, laying a solid foundation for subsequent practical training. Second, independent practice of the four diagnostic methods is conducted to improve syndrome differentiation ability. Under simulated battlefield rescue and public health emergency scenarios, cadets independently perform four diagnostic data collection, comprehensive analysis, and prescription formulation. This process focuses on transforming theories into practical combat skills in complex environments and enhancing their capabilities in syndrome differentiation, treatment, and rapid decision-making under pressure. Third, ward bedside teaching is carried out, focusing on the treatment of acute, severe, and war-related injuries. Building on the previous training, this component cen-

ters on acute and severe warm diseases (e.g., high fever with coma, convulsions, macular eruption, and rashes), highlighting the comprehensive application of integrated Chinese and Western medicine rescue technologies in military medical scenarios (e.g., war wound infections and severe infectious diseases), and strengthening cadets' emergency response and team collaboration in managing acute and critical illnesses. Fourth, military and local resources are integrated to conduct multi-environment drills and training, which serves as the final practical verification link. Relying on military combat readiness hospitals, local medical institutions, and emergency drill bases, a joint rotation training mechanism is established to organize cadets in practical exercises (e.g., simulated battlefield rescue, disaster emergency response, and epidemic prevention support), tempering their abilities in warm disease differentiation and health service support through diverse tasks.

Collectively, these systematic, multi-level clinical teaching arrangements—closely aligned with actual combat and logically connected—enable cadets to deepen their understanding and application of warm disease theories while significantly improving their comprehensive adaptability in real military medical contexts, make greater contributions both to the inheritance and development of traditional Chinese medicine and to the cause of socialist modernization [10].

3.2.3 Research dimension—innovation-oriented and serving the battlefield

Research serves as an important pillar for enhancing cadets' innovative thinking and military medical research capabilities. It aims to guide cadets in identifying problems from clinical practice, exploring solutions through scientific methods, and ultimately transforming research achievements into military health service support capabilities. This dimension includes two core modules: clinical practice and research exploration. Focusing on the integration of Chinese and Western medicine, the combination of classic theories and modern technologies, and military health service needs, it constructs a multi-level, combat-oriented research training system, specifically as follows: First, consolidate research foundations and standardize scientific thinking. Through learning clinical epidemiology, evidence-based medicine, medical statistics, and related disciplines, students are able to strengthen their ability to design research, analyze data, and communicate academically, thereby cultivating a scientific mindset that values rigor and integrity [11]. Second, advocate interdisciplinary integration and innovate research approaches. Cadets are encouraged to conduct scientific research on the cross-transplantation and infiltration of warm disease theories with internal medicine, surgery, gynecology, pediatrics, and other disciplines. Relying on the TCM literature room, systematically explore and sort out classic military medical cases of warm diseases; carry out objective research on diagnostic methods with the support of the TCM four diagnostic methods teaching platform; and introduce basic laboratory research methods to deeply elaborate on the mechanisms of action of warm disease prescriptions and medicines, thus realizing multi-dimensional research training from literature to experiments and from theory to empirical evidence. Third, carry out thematic research integrating classic theories with modern medicine, and set up research on the military application of classic warm disease theories. Examples include "Study on the evolution law of defense-qi-nutritive-blood syndrome differentiation in war wound infections" and "Evaluation of the preventive and therapeutic effects of prescriptions in *Detailed Analysis of Warm Diseases* in humid and hot environments". In TCM treatment of epidemic diseases, volatile herbs play a key role in "dispelling evil qi and safeguarding the body", guiding cadets to interpret the scientific connotation of classic theories by means of modern scientific and technological methods [12]. Fourth, focus on military medical hotspots and promote application transformation. Centering on practical military needs—such as the research and development of special drugs for troops, the prevention and treatment of diseases in special environments (e.g., high temperature, high humidity, extreme cold), and TCM epidemic prevention strategies for sudden outbreaks—cadets are organized to carry out practical research explorations, including new TCM dosage forms, emergency diagnosis and treatment protocols, and intelligent auxiliary diagnosis systems. Fifth, strengthen military-civilian integration and build a collaborative innovation platform. Relying on military TCM research institutions, local TCM research laboratories, and university-enterprise cooperation projects, "undergraduate supervisor-cadet" research teams are established to participate in relevant special research. Meanwhile, cadets are encouraged to attend forums and conferences related to military TCM, thereby advancing the second classroom, expanding clinical horizons, and cultivating research ideas that promote the transformation of research achievements into actual combat capabilities.

Through systematic research training, cadets not only develop critical thinking and innovative awareness but also comprehensively improve their research capabilities in applying warm disease theories to solve practical military medical problems, providing talent support for the inheritance and innovation of TCM in the military.

3.2.4 Expansion dimension—integrating cutting-edge advances and broadening horizons

Consistent with its title "Integrating cutting-edge advances and broadening horizons", the expansion dimension serves as the fourth component of the "theory–clinical practice–scientific research–expansion" four-dimensional teaching model, with exploration as its core activity. It breaks the boundaries of traditional classrooms and comprehensively improves cadets' systematic understanding of the modern development of *Warm Disease Studies* by introducing cutting-edge academic trends and practical combat experience. First, With a focus on the

macro-condition regulation methods of traditional Chinese medicine, we aim to provide practical theories and approaches for the rapid response to emerging and sudden infectious diseases. Teaching activities are carried out in a variety of formats [13]. For example, frontline anti-epidemic experts from the military or local areas, as well as renowned scholars in *Warm Disease Studies*, are regularly invited to deeply analyze the specific strategies and efficacy mechanisms of warm disease syndrome differentiation in epidemic prevention and control through real cases, via multiple channels such as classroom lectures, online seminars, and academic conferences. Second, it introduces the application of defense-qi-nutritive-blood theory in the staging differentiation and treatment of mild, ordinary, and severe stages of modern infectious diseases and epidemiology; the research and development background and efficacy evaluation of integrated Chinese and Western medicine anti-epidemic prescriptions; and the practice of combining "disease differentiation–syndrome differentiation" in epidemic prevention and control—all of which help cadets build a bridge between theory and practice and strengthen clinical insight.

To further fulfill the goal of broadening horizons, interdisciplinary and inter-university academic exchanges are organized, and cadets are encouraged to participate in warm disease-related seminars, military medical forums, and case debates. This not only guides them to pay attention to modern research hotspots of warm diseases and military application scenarios but also broadens their clinical and scientific research horizons while stimulating their innovative thinking and ability to solve complex military health service support problems.

3.3 Adhere to the educational philosophy of placing equal emphasis on professionalism and ideological-political education

3.3.1 Systematic integrated professional teaching

Focusing on the reform of teaching models, this course aims to achieve the thorough mastery of classic TCM theories and the comprehensive cultivation of clinical thinking. To this end, it strives to promote the organic integration of *Warm Disease Studies* with other classic courses such as *Huangdi Neijing* (*The Yellow Emperor's Inner Canon*), *Shanghan Lun* (*Treatise on Cold Damage Disorders*), and *Jingui Yaolue* (*Synopsis of Prescriptions of the Golden Cabinet*), constructing a mutually referential and multi-dimensional interactive teaching system. The specific systematic integration strategies are as follows: To start, referring to the Huangdi Neijing helps strengthen the theoretical base. By integrating ideas like "if vital qi remains within, pathogenic factors cannot invade" and "the interplay of yin and yang" with the disease mechanisms of warm diseases and the wei-qi-ying-xue differentiation framework, students gain a deeper understanding of the causes, mechanisms, and treatment principles of warm diseases, thereby underscoring the coherence and integrity of the TCM theoretical system.

Second, the six-meridian differentiation in Shanghan Lun extends and develops the six-meridian syndrome differentiation in Neijing. In turn, the differentiation of wei, qi, ying, xue and sanjiao in the warm disease school continues and further develops the six-meridian differentiation [14]. By systematically comparing the six-meridian pattern differentiation with the defense-qi-nutrient-blood and triple-burner differentiations-in terms of syndrome classification, patterns of transmission and progression, and the corresponding formulas-students can better grasp how the warm disease school continues and extends the Treatise on Shang han system. In doing so, they build a more comprehensive diagnostic framework for externally contracted diseases.

Third, complementing the above two strategies, this integration strategy focuses on cross-referencing knowledge in *Jingui Yaolue* (*Synopsis of Prescriptions of the Golden Cabinet*) to expand the vision of syndrome differentiation and treatment for miscellaneous diseases. By combining the principles of treating miscellaneous diseases from *Jingui Yaolue*, this strategy explores the evolution rules and treatment approaches for pathogenic factors such as damp-heat, phlegm-fluid retention, and static blood throughout the course of warm diseases, further strengthening cadets' ability to analyze complex pathogenesis and apply comprehensive treatment methods.

In addition to realizing inter-course integration, the content of this course is organized into three core teaching modules—basic theories, clinical syndrome differentiation and treatment, and classic original works—to strengthen the logical connections and content alignment between modules. In teaching practice, module units are flexibly combined according to the training stage and objectives, allowing teachers to carry out cross-module teaching around specific themes (e.g., syndrome differentiation and treatment of damp-heat type warm diseases and warm-heat type warm diseases). This approach truly realizes a new integrated teaching pattern characterized by "integration of classic and modern, connection of theory and clinical practice, and mutual promotion of teaching and military research", which aligns with the core requirement of systematic integrated professional teaching.

3.3.2 In-depth integrated curriculum ideological and political education

In May 2020, the Ministry of Education issued the *Guidelines for the Construction of Curriculum Ideological and Political Education in Institutions of Higher Education* [15]. Subsequently, curriculum ideological and political education entered a new stage of comprehensive, systematic, and refined advancement. It is an educational philosophy that promotes the concerted development of various courses alongside ideological and political courses within the framework of "all-round education, whole-process education, and all-staff education", taking "fostering virtue through education" as the fundamental

task of education and teaching model [16, 17]. One of the key points of teaching reform is how to adhere to the foundation of excellent traditional Chinese culture and TCM philosophical thoughts, and systematically integrate curriculum ideological and political education into the entire process of *Warm Disease Studies* teaching.

In theoretical teaching, we focus on organizing the unique theoretical, prescription, and methodological systems developed by TCM in the prevention and treatment of epidemics throughout past dynasties—particularly in the context of military health service support—so as to strengthen cadets' recognition of the academic value of TCM and their cultural confidence.

We deeply explore the ideological and political resources embedded in *Warm Disease Studies*. By presenting the experiences of medical experts in their growth and academic pursuits—such as Wu Youke's innovative breakthrough in the pestilential qi theory, Ye Tianshi's comprehensive clinical achievements in warm heat theory, and Wu Jutong's systematic construction in *Detailed Analysis of Warm Diseases*—we carry forward their academic spirit of "respecting clinical practice, upholding integrity and innovating, and being diligent and sincere". Furthermore, by highlighting the important role of TCM in combating major public health events such as SARS and COVID-19 in modern times, as well as in military epidemic prevention and rescue, we introduce the advanced deeds of frontline medical workers and military medical personnel who marched forward bravely and made selfless contributions. This guides cadets to deeply understand the professional connotation of "great medical sincerity" and "healer's benevolence", establish a sense of mission and family-country feelings of "serving officers and soldiers and ensuring victory", and achieve the high unity of knowledge impartment, ability cultivation, and value guidance.

4 CONCLUSION

Set against the call for a strong and modernized military, this teaching reform of Warm Disease Theory is oriented toward broadening clinical perspectives. It integrates three major modules—basic theory, clinical pattern differentiation and treatment, and original classics—while weaving together military and research needs. A four-in-one teaching model is thus formed, combining "theory, clinical practice, research, and exploration", with equal attention to professional competence and ideological-political education [3]. This model achieves a deep synthesis of classic theory with modern medicine and military requirements, cultivating a new type of TCM talent capable of handling contemporary medical demands while also meeting the needs of health service support [18]. These reform measures are interlinked and work in synergy. They not only create a new ecosystem for teaching TCM classics that adapts to the current landscape and offer a valuable paradigm for deepening specialized course reform in military academies, but also further optimize the cultivation of military TCM personnel, providing robust support for the realization of a strong military [19, 20].

DECLARATIONS

Author contributions

Lingling Bai was responsible for the conceptualization and drafting of the manuscript. Yuan Bai performed the analysis of military education research and Completed each English translation revision task. Guoyin Zheng conducted the analysis of Warm Disease Studies teaching, and Yanlong Yang carried out the analysis of clinical practice teaching. Additionally, Jin Yu provided the English language analysis and proofreading of the manuscript, while Lina Wang contributed to the constructive discussion and analysis of the manuscript framework.

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RESEARCH ARTICLE

Effectiveness of medical dispute case analysis in undergraduate doctor-patient communication teaching: A pilot study in China

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Abstract

Objective: To evaluate the effectiveness of integrating medical dispute case analysis into doctor-patient communication training for undergraduate medical students. **Methods:** During the 2025 academic year, the Medical Humanities teaching team at Songjiang Hospital, Affiliated to Shanghai Jiao Tong University School of Medicine, redesigned the Doctor-Patient Communication course for undergraduates at Kangda College, Nanjing Medical University. The reform group (n=42, 2025 cohort) received instruction integrating medical dispute case analysis, while the traditional group (n=42, 2024 cohort) received conventional teaching. Outcomes were evaluated using satisfaction surveys, course experience questionnaires, regular assessments, final exams, and video-based analyses of classroom engagement. **Results:** Compared with the traditional group, the reform group demonstrated significantly higher rates of students reporting "very satisfied" with learning interest, teaching method evaluation, and perceived self-improvement ($P<0.05$ or $P<0.01$). The reform group also had a higher overall positive classroom experience rate [100.0% (210/210) vs. 97.1% (204/210), $P<0.05$], greater course attractiveness (97.6% vs. 92.8%, $P<0.05$), and significantly higher scores in both regular assessments and final examinations ($P<0.01$). **Conclusion:** Incorporating medical dispute case analysis into doctor-patient communication teaching may enhance educational outcomes for medical students. It provides a reference model for promoting high-quality medical teaching in China.

Keywords: Doctor-patient communication, Case analysis, Integrated teaching, Teaching effectiveness

1 INTRODUCTION

The problem of doctor-patient relationship remains unresolved in Chinese society [1]. Many medical conflicts are caused by inadequate or ineffective communication between physicians and patients during treatment [2]. Studies have indicated deficiencies in medical humanities education and patient communication skills among physicians, residents, and medical students in China [3-5]. Therefore, effective doctor-patient communication should be considered both an essential competency of healthcare workers and a skill that medical students must acquire urgently.

Currently, doctor-patient communication courses in China face several challenges, including a lack of professional instructors, insufficient use of real clinical cases in classroom teaching, and

poor overall teaching quality, all of which limit their practical applicability [2, 6, 7]. One potential approach is to focus on the training of medical students in doctor-patient communication through classroom-based teaching, emphasizing not only theoretical knowledge accumulation but also practical applications of communication skills. This approach lays a solid foundation for their professional development.

This study aims to collect and summarize clinical case studies, implement a teaching model that incorporates medical dispute case analysis into communication courses, and compare its effectiveness with that of traditional teaching methods. The objective is to introduce an efficient teaching approach for doctor-patient communication to educators and practitioners in this field.

2 DATA AND METHODS

2.1 General information

The Medical Humanities Teaching Team at Songjiang Hospital, Affiliated to Shanghai Jiao Tong University School of Medicine, is responsible for teaching the compulsory Doctor-Patient Communication course for senior undergraduate clinical medicine students in the resident program of Kangda College, Nanjing Medical University. Based on student questionnaires and feedback from the previous teaching years, starting from the 2025 teaching cycle, the team implemented an innovative design for the course. To improve the learning outcomes and student satisfaction, medical dispute case analyses were incorporated into classroom teaching for undergraduates.

The reform group (n=42) included 22 males and 20 females, aged 20–22 years, with an average age of 21.7±0.6 years. The traditional group comprised 42 students from the 2024 academic cycle, including 18 males and 24 females, aged 20–22 years, with an average age of 21.5±0.7 years. There were no significant differences in baseline characteristics between the two groups (P>0.05), indicating comparability between groups.

Inclusion criteria: All enrolled students were included as observation subjects. Exclusion criteria: Students on leave, absent from more than two classes due to illness, those failed to complete the entire course or refused to participate in the survey were excluded.

2.2 Methods

The Doctor-Patient Communication course at Nanjing Medical University consists of 30 credit hours, in accordance with the university's teaching requirements. The selected textbook is *Doctor-Patient Communication* (3rd Edition) written by Wang Jinfan and Yin Mei, published by the People's Medical Publishing House under the National Health Commission's "13th Five-Year Plan". The course is scheduled for one class per week, with each class lasting for 2 credit hours. During the first month, the course covers basic concepts, including an introduction, fundamental principles, and pre-pathways of doctor-patient communication. From the second month, practical training sessions are conducted across various clinical settings, covering outpatient and emergency department, internal medicine, surgery, obstetrics and gynecology, pediatrics, general practice, traditional Chinese medicine, and other clinical departments.

Traditional group teaching method: Teachers prepared lessons individually based on the textbook content, created PPT slides, and used a teacher-centered lecture approach. The class schedule followed the teaching syllabus, including pre-tests, lectures, teacher-student discussions, and homework assignments.

Reform group teaching method: The reform group received a refined teaching approach based on the traditional method, integrating medical dispute case analyses into classroom instruction to enhance practical communication skills.

The study protocol was approved by the Research Ethics Committee of Songjiang Hospital Affiliated to Shanghai Jiao Tong University School of Medicine. Written informed consent was waived.

2.2.1 Preliminary case preparation

A total of 442 concluded or settled medical disputes (all personal data removed) from several hospitals in a specific area of Shanghai during 2019–2023 were collected. Among these, 197 were inpatient cases and 245 were outpatient cases. The distribution of closed cases by major disciplines is shown in **Table 1**.

2.2.2 Collective lesson preparation and case-based teaching integration

During each teaching cycle, one collective lesson preparation was held per week at the end of each month to plan the next month's teaching activities. During these sessions, each teacher presented their own PPT slides outlining the course content, including what would be taught and how it would be delivered. Presentations were shared within the teaching team, which strictly followed the scheduled plan and content arrangements. Team members provided feedback to improve engagement and make the teaching content more attractive to students. Specific requirements for instructors included: releasing teaching content in WeChat groups before class for preview, and allocating approximately 50% of total class time to encouraging students to share knowledge and topics they found most interesting. Instructors provided timely feedback during student presentations, ensuring discussions remained focused on the lesson objectives.

The second task of collective lesson preparation involved categorizing and analyzing all collected medical dispute cases.

Table 1. Distribution of closed cases by major disciplines (n=442)

	Internal medicine	Surgery	Obstetrics & gynecology	Pediatrics	ENT	Outpatient clinic
Total number	76	68	16	26	11	245
Improved through effective doctor-patient communication (n, %)	31 (40.8)	27 (39.7)	6 (37.5)	12 (46.1)	3 (27.3)	29 (11.8)
Avoidable through effective doctor-patient communication (n, %)	20 (26.3)	12 (17.6)	2 (12.5)	8 (30.7)	3 (27.3)	172 (70.2)
Typical cases selected for doctor-patient communication teaching (n, %)	10 (13.1)	10 (26.0)	4 (25.0)	4 (15.4)	2 (18.2)	10 (4.1)

Note: ENT, ear, nose, and throat.

Team members reviewed each case to identify shortcomings in effective doctor-patient communication. According to this analysis, cases were divided into two categories: medical disputes that could have been improved through effective communication and disputes that could have been entirely avoided with good communication. Forty representative cases were selected as practical training materials for the course. These real-life cases provided an immersive learning experience, combining theory with practice, thereby enhancing knowledge acquisition and fostering greater student interest in this course. The duration of this section was reasonably extended to encourage active student engagement, guided by instructors.

2.3 Observation indicators

At the end of this course, students completed self-developed satisfaction surveys and course experience questionnaires to gather student-reported information. The satisfaction survey evaluated aspects including course content arrangement, knowledge acquisition, learning interest, instructor performance, teaching methods, self-improvement, and overall course satisfaction. The course experience questionnaire assessed classroom atmosphere, acquisition of new knowledge, inspiration, freedom of expression, and appropriateness of time allocation.

In addition, five randomly selected class sessions were video-recorded and analyzed. Students with more than ten minutes of inattentive or off-task behavior during a 90-minute session were classified as having ineffective attendance. Ineffective attendance was defined using observable operational criteria: (1) Head resting on desk or looking away from the presenter/screen for ≥10 minutes without engaging in task-relevant activity; (2) Using electronic devices (e.g., phone, tablet) for non-course purposes for ≥10 minutes; or (3) Other behaviors clearly unrelated to the class activities, as jointly identified and confirmed by two instructors through observation. Each student was counted no more than once per session as having ineffective attendance. The average class engagement rate was calculated using the formula: Average Class Engagement Rate = 1 − (Average Number of Ineffective Attendances per Session/Total Number of Students). This metric provides a relatively objective measure of student engagement and the effectiveness of course content in maintaining attention.

At the end of each term, students were evaluated for two parts. The first part consisted of regular tasks, including analysis and reflection on assigned clinical doctor-patient communication cases, participation in simulated doctor-patient communication practice, and attendance. The second part was a final exam designed to assess their overall learning and mastery of the course content.

2.4 Statistical methods

Statistical analyses were conducted using Stata 8.0 software. Continuous variables with normal distribution were presented as mean ± standard deviation ($\bar{x}\pm s$) and were compared between groups using independent samples *t*-tests. Categorical data were expressed as number (n) and percentage (%) and were compared using chi-square tests. A P-value <0.05 was considered statistically significant. To account for multiple comparisons, Bonferroni correction was applied, adjusting the significance level to $P<0.017$ (0.05/3).

3 RESULTS

3.1 Comparison of students' satisfaction levels between two teaching cohorts

Questionnaire survey results indicated that, compared with the traditional group, the reform group reported significantly higher proportions of "very satisfied" responses in terms of learning interest, evaluation of teaching methods, and self-improvement assessment ($P<0.05$ or $P<0.01$; **Table 2**).

3.2 Comparison of students' classroom experiences between two teaching cohorts

No statistically significant differences were observed between the two groups for individual items on the course experience questionnaires (all $P>0.05$). However, in terms of the overall score of all indicators, the reform group demonstrated a higher overall positive classroom experience rate (100.0% [210/210] vs. 97.1% [204/210], $P<0.05$; **Figure 1**).

3.3 Comparison of classroom engagement and academic performance between two teaching cohorts

Video analysis revealed that the students in the reform group were more engaged with class content compared with the traditional group (92.8% vs. 97.6%, $P<0.05$). At the end of the

Table 2. Comparison of students' satisfaction survey between two classroom teaching methods

Questionnaire	Options	Reform group (n=42)	Traditional group (n=42)	*P* value
Course content arrangement (n, %)	Very satisfied	42 (100.0)	38 (90.5)	0.116
	Satisfied	0 (0.0)	4 (9.5)	
	Dissatisfied	0 (0.0)	0 (0.0)	
Knowledge mastery (n, %)	Very satisfied	41 (97.6)	36 (85.7)	0.109
	Satisfied	1 (2.4)	6 (14.3)	
	Dissatisfied	0 (0.0)	0 (0.0)	
Learning interest (n, %)	Very satisfied	40 (95.2)	29 (69.0)	0.005
	Satisfied	2 (4.8)	10 (23.8)	
	Dissatisfied	0 (0.0)	3 (7.1)	
Evaluation of teachers (n, %)	Very satisfied	35 (83.3)	28 (66.7)	0.071
	Satisfied	6 (14.3)	14 (33.3)	
	Dissatisfied	1 (2.4)	0 (0.0)	
Evaluation of teaching methods (n, %)	Very satisfied	41 (97.6)	33 (78.6)	0.015
	Satisfied	1 (2.4)	9 (21.4)	
	Dissatisfied	0 (0.0)	0 (0.0)	
Self-improvement assessment (n, %)	Very satisfied	38 (90.5)	23 (54.8)	0.001
	Satisfied	4 (9.5)	16 (38.1)	
	Dissatisfied	0 (0.0)	3 (7.1)	
Overall teaching satisfaction (n, %)	Very satisfied	41 (97.6)	37 (88.1)	0.202
	Satisfied	1 (2.4)	5 (11.9)	
	Dissatisfied	0 (0.0)	0 (0.0)	

Note: For multiple comparisons, Bonferroni correction was applied, adjusting the significance level to $P<0.017$ (0.05/3).

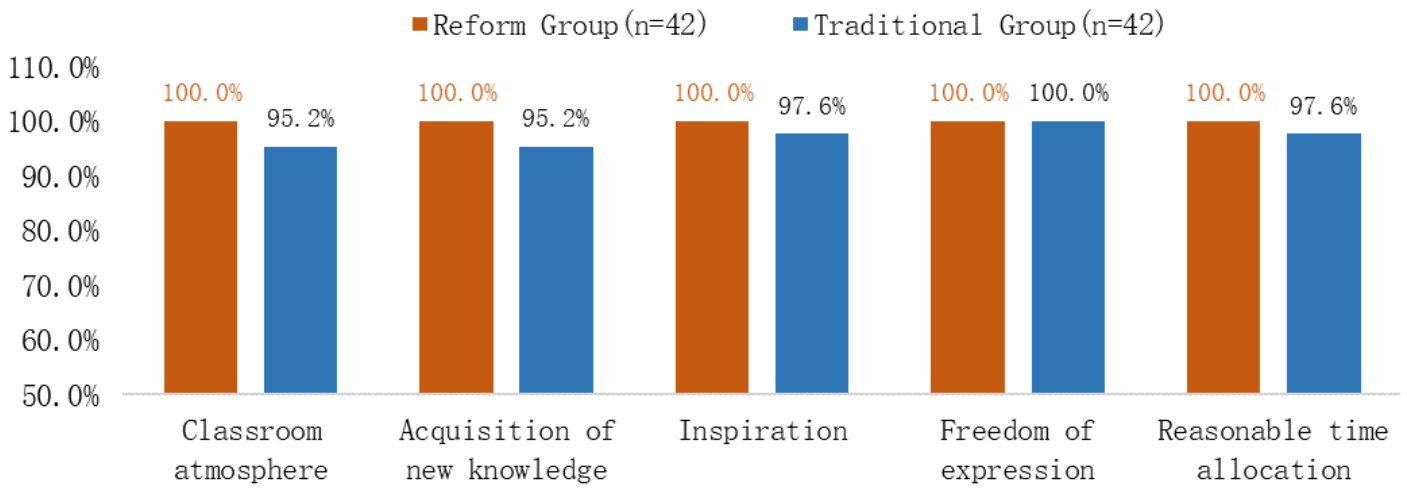

Figure 1. Comparison of students' perceptions between the two teaching models.

semester, both the regular assessment scores and final exam scores were significantly higher in the reform group than in the traditional group ($P<0.01$; **Table 3**).

4 DISCUSSION

Clinical clerkships and internships represent a critical transition in medical education, during which trainees move from students to practitioners. Developing effective doctor-patient communication skills during this period is essential. On November 1, 2005, the Ministry of Education of China included *Doctor-Patient Communication Studies* in the national plan textbook directory for medical education under the "Eleventh Five-Year Plan". Despite its inclusion in many medical courses, a substantial number of students still regard it as unimportant [8, 9]. Many students focus more on acquiring specialized medical knowledge than on developing professional ethics and communication skills. Consequently, they are often unable to

Table 3. Comparison of student engagement and academic performance between two teaching methods

	Student engagement*	Regular assessment scores	Final exam score
Reform group (n=42)	205/210 (97.6%)	95.62±9.33	95.74±7.81
Traditional group (n=42)	195/210 (92.8%)	88.68±6.34	89.86±6.72
χ^2/t	5.250	3.981	3.632
P value	0.022	<0.01	<0.01

Note: *Five class videos were randomly chosen for video recording analysis, yielding the denominator for calculating engagement of 210 (42×5=210).

communicate effectively, which may compromise the quality of their future clinical practice. Moreover, according to surveys conducted in previous years and observations by our teaching team, students exhibit low levels of active participation during lectures.

Many researchers have explored various teaching strategies to enhance educational outcomes and to guide learners in acquiring essential knowledge of doctor-patient communication, with the aim of fostering ethical behavior in clinical interactions. Nevertheless, overall outcomes remain suboptimal [10, 11]. Langewitz et al. applied standardized patients in teaching doctor-patient communication, but students' performance during training often lacked the complexity of real clinical situations [12]. In addition, standardized patients are typically healthy individuals or those with limited life experiences that are selected from their workplaces to serve in three roles: actor, assessor, and instructional guide [10]. Recruiting such individuals from the public poses practical challenges.

Simulation-based teaching has also been applied to train undergraduate students in doctor-patient communication. Although simulations can motivate students to learn actively, their implementation remains challenging [13, 14]. Furthermore, student discussions during simulations may become scattered and unable to achieve the expected teaching goals. Previous studies demonstrated that well-designed blended teaching models, which combine doctor-patient communication theory with clinical cases, can enhance students' understanding of core concepts and improve familiarity with real-world clinical situations [15, 16]. However, such blended models also have limitations. Improvement in clinical intern's communication and coordination abilities largely depends on the guidance provided by instructors. Variations in instructor's individual skills, overall qualifications, and pedagogical competence can differently affect learning outcomes.

To address this issue, our Medical Humanities teaching team has continuously innovated both the methods and forms for medical humanities education. Our objective is to make medical humanities, especially doctor-patient communication education, more engaging, to enhance students' recognition of its importance, and to actively guide their full participation in the course. Based on existing student survey results and practical explorations, we implemented the integration of medical dispute case analyses into the training plan for doctor-patient communication courses. This mode maintains the basic structure of didactic teaching while strengthening pre-class teacher preparation and enhancing the alignment between clinical practice and training content. In the first stage, about 1–4 weeks before a planned class, the designated instructor organized internal practice sessions with the entire teaching team. The team provided feedback on both content and presentation, collaboratively identifying areas for improvement. Based on this feedback, the instructor refined the teaching materials to optimize instructional outcomes. In the second stage, the teaching team jointly reviewed 442 closed clinical cases from recent years, classifying them by department, clinical scenario, and communication issues. Forty representative cases were selected for inclusion in the course. Each case was analyzed in detail to outline recommended patient-doctor communication strategies at each stage of care, specifying what, how, when, and where to communicate. This approach aims to establish procedural guidance for preventing conflicts and managing potential medical disputes proactively.

Based on the findings of this study, compared with the traditional teaching model, a significantly higher proportion of students in the reform group are highly satisfied with both the teaching methods and their own improvements and demonstrated greater interest in learning. Moreover, students rated the reformed course higher in terms of engagement, knowledge acquisition, stimulation of creativity, and freedom of expression. Objective evaluation through video analysis further confirmed that the reformed design was more engaging for students. Finally, both end-of-term exam scores and regular assessment outcomes showed that the reformed teaching method significantly improved student performance.

While traditional lectures may deliver large amounts of knowledge systematically, they often fail to capture students' attention and participation. In contrast, the reformed teaching approach incorporates clinical case studies and problem-based learning, which encourages students to discuss actively, think independently, communicate proactively, and truly master the subject matter. Analysis of selected classic cases further potentiates students to explore each case in detail and critically identify potential issues. Therefore, students can better internalize and integrate the knowledge. By integrating new knowledge with their existing understanding and experiences, students

develop individualized approaches to doctor-patient communication and clinical interaction [17-19].

This pedagogical reform integrates the analysis of medical dispute cases into doctor-patient communication training. Through a team-led class preparation method, the course content is made more relevant and engaging by leveraging the professional expertise of all instructors. This approach effectively integrates theory with practice to deepen students' understanding of theoretical concepts. Moreover, a more objective assessment metric—measuring student attentiveness through video analysis—was introduced to evaluate classroom effectiveness, providing a clearer reflection of the instructional model's appeal. The results of this study show that the reformed method achieves better educational outcomes, offering references and insights for future improvements in doctor-patient communication training.

Developing a structured teaching model for doctor-patient communication in medical education promotes students' holistic development by enhancing clinical knowledge and skills while simultaneously improving their communicative abilities, empathy, and humanistic awareness. This prepares future physicians to respond more attentively to patients' needs and emotions, thereby improving healthcare satisfaction and outcomes. Furthermore, it fosters more caring and competent communicators, strengthening doctor-patient relationships and reducing conflicts and complaints. This approach also supports a shift in medical education from focus on knowledge transmission to greater emphasis on communication skills and the cultivation of humanities. Such reorientation better responds to the demands of today's healthcare system and contributes to improved quality, service performance, and competitiveness of medical institutions. In the future, we plan to further explore and refine this model in practical settings, with the aim of systematically enhancing clinicians' communication abilities. The model offers a practical example to address persistent doctor-patient conflicts in China and offers guidance for developing effective strategies.

There were some limitations in the current study. First, the non-randomized, historical control design may introduce several potential biases, including cohort differences between year groups, instructor maturation effects, and unmeasured confounding variables. However, some unmeasured baseline characteristics, such as prior academic performance (e.g., Chinese National College Entrance Examination scores), were comparable between the two cohorts (2024 vs. 2025). The teaching team remained unchanged, and the same instructor taught the same chapters using the different teaching methods described above. Second, no formal sample size calculation or power analysis was performed in this study. Given the exploratory nature of this investigation, the sample size (42 students per group) was determined based on practical considerations and the feasibility of recruiting participants within the study period. Therefore, this study should be interpreted as an exploratory pilot study, and the results are primarily hypothesis-generating. Future studies with larger sample sizes and adequate statistical power are needed to confirm the observed effects.

5 CONCLUSION

Integration of medical dispute case analysis into doctor-patient communication teaching may enhance the educational outcomes for medical students. First, unlike most existing studies that focus on routine or "standard" clinical communication—where patient and provider goals are largely aligned—our study deliberately centers on medical dispute cases, which are inherently conflict-oriented scenarios. Second, our study utilizes a uniquely large database (n=442) of real-world, documented medical disputes, from which 40 representative cases were carefully selected. Third, the course emphasizes conflict prevention in communication training, which has been shown to increase students' engagement and interest in learning through real-world cases.

DECLARATIONS

Author contributions

Dehua Wu helped with the conception of study, design of study, analysis, interpretation of data, and manuscript drafting for intellectual content. Weixing Wang, Xiang Gao, Cuili Zhu, Yanqin Fan and Xinbao Zheng helped with design of study, acquisition, analysis, interpresation of data.

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Data availability

Data can be available from corresponding author by email.

Ethics approval and consent to participate

The study protocol was approved by the Research Ethics Committee of Songjiang Hospital (Approval No.: 2025-109), affiliated to Shanghai Jiao Tong University School of Medicine, and written informed consent was waived.

Consent for publication

All authors consent to the publication of this manuscript.

Competing interests

The authors declare that they have no competing interests.

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TEACHING INNOVATION

Thoughts on the reform of pharmacology teaching guided by curriculum ideology and politics

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Abstract

According to the requirements of curriculum-based ideological and political education, pharmacology teaching reform should address the problems existing in the traditional model, such as the disconnection between value guidance and knowledge transmission, single teaching methodology, and inadequate resource support. Specific pathways for reform implementation are proposed in this paper. Specifically, it involves identifying ideological and political elements by scientifically integrating education on the scientific spirit and social responsibility into topics such as the history of drug development, pharmacological mechanisms, and drug safety evaluation; analyzing the relationship between medical ethics and public health to construct modules addressing drug ethics; proposing the use of case-based clinical teaching and designing problem-oriented teaching scenarios to help students cultivate humanistic care in professional decision-making. Additionally, supplementary support resources such as micro-lecture videos, graphic manuals, and ideological case repositories will be created to establish a comprehensive support system.

Keywords: Curriculum ideology and politics, Pharmacology teaching, Teaching reforms

Highlights

- Problems of curriculum ideology and politics in pharmacology teaching encompass the disconnection between value guidance and knowledge imparting, the insufficient use of diversified teaching methods, and the incomplete resource support system.
- The exploration of the scientific spirit, the strengthening of social responsibility education through the module of drug ethics, and the enrichment of ideological and political teaching content are emphasized.
- The adoption of clinical case teaching and problem-based teaching diversifies teaching methods and enhances the effect of value guidance.
- The development of systematic and digital resources will comprehensively promote teaching application in curriculum ideology and politics.

1 INTRODUCTION

"Curriculum-based ideological and political education" constitutes a pedagogical paradigm emphasizing the integration of knowledge dissemination with ideological-political cultivation across disciplinary boundaries. This approach synergizes with dedicated ideological education courses to advance the fundamental educational mission of fostering virtue and cultivating talents. The publication of "Guidelines for curriculum-based ideological and political construction in higher education" has

charted the course for the initiative and has meanwhile imposed higher demands on the reform of specialized courses [1]. As a core course of pharmaceutical disciplines, "Pharmacology" not only plays a significant role in imparting knowledge about drugs and clinical skills but also bears the heavy responsibility for cultivating students' scientific spirit, professional ethics, and social accountability. Nevertheless, traditional teaching models have constantly demonstrated weaknesses characterized by "emphasizing theory over practice" and "neglecting the cultivation of moral character and a sense of responsibility", which makes it hard to meet the industrial demand for high-caliber, application-oriented professionals. It is against this background that the reform of ideological education in the teaching of Pharmacology has emerged. This paper explores ways for the organic integration of ideological education into the whole process of teaching Pharmacology, aiming to provide new perspectives for cultivating a new generation of pharmaceutical professionals who possess professional competence, innovative spirit, and a strong sense of social responsibility.

2 EXISTING PROBLEM ANALYSIS

2.1 Disconnection between value guidance and knowledge impartation

This is particularly true from the point of view of teaching content design and practice. The teaching objectives and content of the Pharmacology course focus mainly on the core knowledge of the discipline, such as the mechanism of action, clinical use, and safety of drugs. Yet there is a significant lack in the in-depth discussion of social responsibility issues, such as drug development ethics, the impact of drug abuse on society, and drug price fairness. This leads to a conspicuous disconnection between knowledge impartation and value guidance within the course content, which fails to take full advantage of the potential for ideological and political education inherent in pharmaceutical science. For example, when it comes to teaching the process of drug development, there is a lack of detailed design in embodying the value of scientists' exploratory spirit and teamwork. In teaching drug safety, ethical considerations in the doctor-patient relationship are not incorporated in teaching scenarios. The content design, targeting knowledge alone, reflects a neglect of the "value-laden" nature of scientific knowledge and fails to leverage the "hidden curriculum" embedded in pharmaceutical practice [2]. This theoretical blind spot has limited students' comprehensive understanding of pharmacology as a discipline and failed to effectively foster the social responsibility and professional values of students. This fundamental misalignment between value guidance and knowledge impartation not only constrains educational efficacy but also inevitably extends its impact to teaching methodologies where traditional instructional approaches further compound the disconnect, as discussed in the following section.

2.2 Limitations of the traditional teaching model in integrating ideological education

From a teaching methodology point of view, the curriculum of Pharmacology relies mainly on the traditional lecture-based teaching mode. In this mode, knowledge point memorization and examination scores are the primary objectives. Classroom formats are single and dull, which contradicts constructivist principles that knowledge must be actively constructed through cognitive engagement, and prevents the "deep learning" required for value internalization [3]. Consequently, the interaction between teachers and students is poor, and students' learning interest and subjective initiative cannot be effectively stimulated. More importantly, some methodology designs that can effectively integrate curriculum-based ideological and political education, such as case analysis and situational teaching, are also lacking in the course. Therefore, the practice of ideological and political education remains superficial [4]. For instance, teaching approaches such as discussions on drug abuse and public health, or case analyses of drug pricing and social equity, have not been systematically conducted in the classroom. Students lack profound humanistic care which is a critical failure given that values are cognitively constructed through experiential engagement, not transmitted via passive reception. Such teaching models diminish the educational value of the course and cannot meet higher requirements of the new era for the cultivation of medical and pharmaceutical professionals. While pedagogical limitations directly impede value internalization, their negative effects are significantly amplified by systemic gaps in curricular resource support—a critical dimension explored in the following subsection.

2.3 Incomplete teaching resource support system

Regarding teaching resources and support systems, the current teaching resources of the Pharmacology course mainly focus on the transmission of pharmaceutical science knowledge, while auxiliary resources for the development of ideological and political elements in pharmaceutical science are lacking in systematic development and utilization. For example, the development of teaching cases, micro-lecture videos, and multimedia resources related to the scientific spirit of drug development, ethical dilemmas in drug use, and the impact of drug abuse on social stability has yet to be fully developed. At the same time, the existing course evaluation system lacks effective coverage in assessing students' value concepts and comprehensive qualities, which makes it hard to quantify and verify the implementation effectiveness of curriculum-based ideological and political education. These deficiencies in resources and systems further constrain the effective integration and practical promotion of curriculum-based ideological and political education within pharmacology teaching.

In conclusion, the three challenges—the disconnection between value guidance and knowledge impartation, outdated tradition-

al teaching methods, and insufficient teaching resources—collectively reveal the structural obstacles to value education. To overcome these obstacles, targeted strategies are needed, and the following sections will focus on this [5].

3 CONTENT DEVELOPMENT AND IMPLEMENTATION PATHWAYS

3.1 Identifying ideological and political elements in pharmacology teaching content based on curriculum objectives

3.1.1 Highlighting ideological and political potential in core pharmacology knowledge points

The fundamental pharmacological knowledge domains inherently offer significant pedagogical opportunities for ideological-political cultivation, enabling students to construct a cohesive knowledge framework that integrates scientific understanding with value systems. In teaching design, the ideological and political elements inherent in core content areas—such as drug mechanisms of action, medication safety, and drug research, development, and application—should be deeply explored to reinforce the course's function of value guidance. This pedagogical strategy ensures that learners not only acquire specialized expertise but also internalize the significance of scientific integrity, social responsibility, and professional ethical frameworks.

In teaching the history of drug research and development (R&D), examples from real life should be integrated to guide students in understanding the arduousness and perseverance required in scientific exploration and to illustrate the creative problem-solving capabilities of scientists facing technical challenges. For instance, the R&D history of penicillin demonstrates Fleming's research resilience in continuously overcoming technical obstacles and highlights the significance of life-saving drugs in fostering a shared future for humanity [6]. In teaching drug mechanisms of action, the history of beta-blockers—from their discovery to widespread application and, eventually, to targeted use based on specific mechanisms—can direct students to appreciate the rigor and innovative thinking in scientific research. Regarding ethical issues in drug safety evaluation and clinical application, teaching should focus on historical lessons drawn from the thalidomide tragedy. This facilitates discussions on the critical importance of pre-marketing safety evaluation and regulation, enhances awareness of the full-cycle drug regulatory process, and reinforces the professional commitment to putting patients first [7]. Within the pharmacokinetics chapter, the explanation of how personalized warfarin dosing regimens are formulated emphasizes the impact of genetic polymorphisms on drug metabolism. On this basis, it elicits students' dialectical thinking on the balance between cost and benefit in precision medicine and helps build practical wisdom that integrates scientific decision-making with humanistic care. The entire teaching process should attach great importance to clarifying the internal logic and connections between basic knowledge and clinical practice. Cases involving improvements to post-marketing drug surveillance systems can be included in teaching about adverse drug reactions. This demonstrates the social responsibility of medical personnel in optimizing safety standards based on scientific research and fosters students' conscious adherence to professional ethics.

3.1.2 Developing ideological and political modules on drug ethics and social responsibility

Pharmaceutical ethics and societal responsibility constitute the principal pedagogical entry points for implementing ideological and political education in Pharmacology. This necessitates the adoption of structured modular pedagogical frameworks to deepen students' understanding of the intrinsic interconnectedness between pharmacological science, technological development, and population health outcomes, thereby achieving synergistic integration of knowledge transmission with value-based dimensions to ensure the coherent integration of disciplinary proficiency and ethical internalization.

Within the module on drug R&D and ethics, major historical drug R&D cases are analyzed to explore how scientists seek a balance between technological innovation and social responsibility. For instance, when teaching anti-tumor drug R&D, using PD-1 inhibitors as a case study to examine the full lifecycle from patent protection to generic drug market entry facilitates discussion of how the pharmaceutical patent system balances the conflict between incentivizing technological innovation and ensuring drug accessibility. This guides students to fully understand the significant impact of pharmacoeconomics on social equity issues and explores how policy instruments can safeguard both the impetus for innovative drug R&D and the maximization of patient benefits [8]. Meanwhile, the integration of domestic cases on national medical insurance negotiations demonstrates the challenges faced in the process of incorporating innovative drugs into the National Reimbursement Drug List and enhances the practical value of pharmaceutical economics in promoting health equity.

In the module on drug abuse and social governance, the public health hazards of antibiotic misuse can be analyzed based on antimicrobial resistance (AMR) data. This allows an exploration of the importance of responsibility in standardized clinical medication practices and patient education for the prevention and control of AMR. Specialized teaching modules incorporating specific regulations and policies enhance students' awareness of responsibility in pharmaceutical social governance. Using case studies such as opioid control policies, the module should discuss, based on scientific evidence, the rationality and necessity of addressing drug dependence. Critical discussion is required on how a balance can be struck between strict drug control measures and the need to meet legitimate patient thera-

peutic needs, in order to help students understand the important role of the drug regulatory system in social stability [9].

3.2 Reconstructing the value guidance function of pharmacology teaching methods based on curriculum ideological and political education

3.2.1 Developing ideological and political teaching resources through clinical case-based teaching

Case-based teaching in clinical practice is an important point of convergence between the practical aspect of Pharmacology and curriculum-based ideological and political education. Teaching designs should be optimized based on the philosophy of curriculum-based ideological and political education, incorporating specific clinical cases to deeply explore core values such as medical professional ethics, social responsibility, and humanistic care. This approach, through real medical scenarios, can promote the synergistic internalization of professional knowledge along with these values [10].

In case selection, real cases with significant ideological and political elements should be prioritized, highlighting how drug use affects individual health and social stability. For example, in teaching about drug abuse, cases involving social problems caused by opioid analgesics can be selected. These should be integrated with global fentanyl control policies to illustrate the safeguarding role of pharmaceutical regulation in social stability [11]. In lectures on adverse drug reactions, cases of new drug recalls due to adverse reactions can be used to examine lessons learned from regulatory oversights. This deepens understanding of the development of the drug safety evaluation system, with an emphasis on the professional ethical responsibilities of healthcare workers.

In case design dimension, it is necessary to focus on the interdisciplinary integration of professional knowledge and social issues. For instance, clinical vignettes detailing metoprolol-induced acute decompensation in heart failure are instrumental in cardiovascular pharmacotherapy instruction, supporting students' progression from comprehensive medication history interpretation to the formulation of individualized therapeutic regimens. Concurrently, through the analysis of the sociological characteristics of patient populations, students can analyze the role of pharmacoeconomics in the allocation of medical resources and develop their ability to understand social pharmacy from a public health perspective.

Teaching on psychoactive drugs should be based on hospital statistics related to inappropriate benzodiazepine use. This allows for in-depth discussion of issues of drug dependence, an analysis of the responsibilities of medical staff in performing their risk assessment roles in prescribing practices, and guides students to consider the balance between managing patients' acute symptoms and minimizing long-term medication dependence risks.

3.2.2 Designing problem-oriented teaching scenarios for ideological and political education

Problem-based learning can provide a dynamic teaching model for integrating curriculum-based ideological and political education. Core problems with ideological and political educational significance are designed to place students in medical contexts, guiding them in solving practical problems to fully recognize the profound connections between pharmacology and social responsibility and professional ethics. The optimized design must accentuate the multidimensional stratification and social pertinence of problems, ensuring that during the analytical processes, students transcend technical focus to initiate critical deliberation through the dual lenses of bioethical considerations and healthcare governance paradigms.

In the unit on rational antimicrobial use, using "cephalosporin antibiotic misuse in community hospitals" as a scenario, students are required to analyze the causes and propose countermeasures from multiple dimensions: pharmacoeconomics, prevention and control of AMR, and prescription management. By analyzing these problems, students understand the threat posed by misuse of antimicrobials to public health and the significance of rational medication use. Meanwhile, by integrating national AMR surveillance data to illustrate global collaborative responsibility in antimicrobial stewardship, students are guided to develop the insight that pharmaceutical practice influences the ecosystem of human society and to nurture their global health perspective and sense of responsibility [12, 13].

In the pharmacotherapeutics chapter, by focusing on "pricing controversies for novel rare-disease drugs", students are guided in comprehensively weighing R&D costs, patient affordability, and medical insurance fund pressures to explore mechanisms for balancing innovation incentives and social equity. Through the analysis of a medical insurance negotiation, students appreciate the complexity of balancing multiple stakeholders' interests in policy formulation. This enhances the awareness of humanistic care in professional decision-making [14]. Teachers can create a problem scenario in which students confront an ethical issue in drug development, such as "severe adverse events in clinical trials of new anti-tumor drugs", and are asked to design an improvement plan from the perspectives of developers, regulators, and patients. Students can thus develop a systematic understanding of the scientific integrity and ethical responsibilities of pharmaceutical professionals while mastering safety evaluation procedures [15].

3.3 Optimizing pharmacology teaching resources and support system based on curriculum-based ideological and political education requirements

3.3.1 Establishing a repository of pharmacology cases integrated with ideological and political elements

Finally, to address the areas of drug R&D, clinical application, and social impacts, a case repository with ideological and polit-

Table 1. Examples of ideological and political education resources in curriculum development

Ideological and political content module	Key ideological and political education points	Corresponding drugs/cases	Background information and teaching focus
Scientific spirit and innovative exploration	Sharp observational skills and scientific exploration spirit	Penicillin	Fleming's R&D process in overcoming technical obstacles, combined with its life-saving significance during World War II, is used to discuss the scientific exploration spirit and the responsibility of building a shared future for humanity
	Rigor and innovation in scientific research	Beta-blockers	Analyzing the precise discovery process of drug targets and demonstrating the rigor and innovative thinking in scientific research through the clinical application history
	Persistent pursuit in scientific research	Trimebutine	Case study of an R&D team overcoming structural optimization challenges, highlighting the relentless innovative scientific spirit of researchers
Professional ethics and responsibility	Patient safety first	Thalidomide	Analyzing the teratogenicity incident to expose deficiencies in drug safety evaluation, and discussing the ethics of respecting patient safety and regulatory responsibility
	Ethical responsibility in personalized medication	Warfarin	Designing personalized medication regimens based on genetic polymorphisms, combined with hospital blood concentration monitoring cases, to strengthen professional responsibility for safety in decision-making
	Professional integrity in adverse reaction prevention	Statins	Case analysis of rhabdomyolysis, integrating medication risk assessment and patient education, to cultivate ethical awareness in adverse reaction prevention
Social responsibility and public health impact	Public health responsibility in antibiotic misuse	Cephalosporins	Using 2023 national antibiotic resistance surveillance data to reveal community misuse issues, with designed discussions on prescription management strategies to address public health responsibilities
	Professional commitment in prescription risk assessment	Benzodiazepines	Using statistical data on irrational use in tertiary hospitals to explore ethical decision-making by medical workers in balancing acute treatment needs and drug dependence risks
	Role of drug regulation in social stability	Fentanyl	Analyzing provincial control regulations on social harm caused by drug abuse, combined with global control measures, to understand the role of regulatory systems in maintaining stability
Social equity and ethical decision-making	Balancing fairness in access to innovative drugs	PD-1 inhibitors	Conducting a lifecycle analysis from patent protection to generic drug market entry to discuss the balance between innovation incentives and patient access fairness through domestic medical insurance negotiation cases
	Ethical value in medical resource allocation	Imatinib	Analyzing the negotiation process from R&D to inclusion in the National Reimbursement Drug List, to guide students to reflect on the ethical value of pricing policies in medical resource allocation
	Humanistic care in high-value therapy decision-making	CAR-T therapy	Facilitating a scenario-based discussion on pricing controversies considering R&D costs and medical insurance fund pressures, to explore the significance of humanistic care in institutional innovation for fair resource allocation

Note: R&D, research and development.

ical elements will be constructed within the Pharmacology curriculum. This repository will prioritize the collection of key events in drug R&D history, real-world cases on the impact of classic drugs on society, the public health impact of drug abuse, and discussions on fairness in pharmacoeconomics. These will then be systematically organized and categorized into case resources that are directly usable for course teaching.

Case design should focus on fostering the scientific spirit, professional ethics, and social responsibility, guiding students to deeply understand, through case analysis, the intrinsic connections between pharmacological science and these values. This will provide substantive material support for classroom teaching. Such a case repository must be designed to cover multi-level content ranging from basic research and clinical translation to social impact. This repository is expected to guide students to deepen their understanding of social responsibility within pharmacological science through case analysis, thus providing systematic material support for classroom teaching that integrates both professional depth and value-based depth [16].

The following section lists some representative cases suitable for inclusion in the pharmacology case repository and their inherent ideological and political elements, which are detailed in **Table 1** [17, 18].

3.3.2 Developing diversified supplementary teaching resources for course-based ideological education

A series of supplementary teaching resources has been developed to meet the practical needs of ideological education in pharmacology teaching, including micro-lesson videos, graphic materials, case interpretation manuals, experimental teaching guidance materials, and more [19]. The newly prepared teaching resources should focus on drug knowledge and also reflect ideological elements, with key content areas such as scientific exploration in drug research, ethical issues in drug use, and policy practice in pharmaceutical social governance. In this way, the development of such supplementary teaching resources can broaden classroom teaching formats and support students in multiple dimensions to enhance their understanding and internalization of the course's ideological elements both in and out of class. In the chapter on pharmacokinetics, a specialized lesson plan titled "Monitoring of drug blood concentration" has been designed. Through the analysis of blood concentration monitoring data for vancomycin in a tertiary hospital, this lesson highlights the professional responsibility of clinical pharmacists in formulating individualized drug administration regimens. In the teaching unit on adverse drug reactions, a guidance manual entitled "Analysis of an atorvastatin-induced rhabdomyolysis case" has been compiled. Combining aspects such as adverse reaction monitoring, medication risk assessment, and patient education on medication use, the manual helps students foster a sense of responsibility in drug safety. Through the development of teaching guidance with ideological depth, systematic teaching references can be provided for instructors to ensure the effective implementation of ideological education in the teaching process.

4 CONCLUSION AND OUTLOOK

This paper has established a pedagogical reform framework for pharmacology based on curriculum-based ideological and political education. Through systematically restructuring instructional content, methodologically innovating pedagogical approaches, and strategically optimizing resource systems, the framework addresses core deficiencies—including the lack of value orientation, methodological singularity, and insufficient resource support—inherent in conventional pedagogy. At the content level, the framework deeply explores the scientific spirit in the history of drug research, innovative thinking in teaching drug mechanisms, and ethical responsibility in drug safety evaluation, achieving the organic integration of professional knowledge and ideological elements. At the method level, it adopts clinical case teaching and problem-oriented teaching to construct practical scenarios for understanding social responsibility. At the resource level, it builds a case library for ideological education covering core areas of pharmacology and develops corresponding supplementary tools to provide systematic support for value guidance.

Looking to the future, further reforms can be carried out in the following areas: establishing a multi-dimensional evaluation system for the effectiveness of ideological and political education, integrating tools such as student behavior observation, case analysis reports, and career values questionnaires, and tracking graduates' professional behaviors—such as prescription decisions—through school-enterprise cooperation platforms, to form a quantifiable evaluation mechanism. Furthermore, promoting technology-driven pedagogical innovation necessitates the application of virtual reality to simulate scenarios such as the social consequences of substance abuse, thereby enhancing instructional responsiveness to contemporary demands [20]. In summary, continuous attention must be paid to the evolving requirements of medical technology innovation and changing social demands for ideological and political education in the course. Through systematic iterative optimization, pharmacology teaching can become a model field for implementing the fundamental task of fostering virtue and cultivating talents.

DECLARATIONS

Author contributions

Jiaxi Zhang collected and analyzed the cases and drafted the manuscript. Panpan Hu provided teaching cases for the theoretical courses. Tianying Xu conceptualized and designed the study, provided critical revisions to the manuscript, and approved the final version for submission. Haiyan Wang guided the writing of the manuscript and provided the analytical cases.

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Competing interests

The authors declare that they have no competing interests.

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