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Application of the Integration of Teaching-Research-Clinic Trinity Model in the Teaching of Nervous System in Physiology

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Abstract: Physiology is an important basic course for medical majors. The content of the nervous system is abstract, the theories are profound, the knowledge is updated rapidly, and it is most closely connected with clinical practice. Students generally report difficulties in understanding, resulting in low learning interest. To improve teaching quality, this study has attempted to organically integrate clinical cases, scientific research methods and classroom teaching in the teaching of the nervous system, and constructed a "clinical-research-teaching" trinity teaching model. With "clinical problem-driven, scientific research thinking-driven, teaching scenario reconstruction" as the main line, real cases, scientific research examples and cutting-edge research progress in neuroscience were introduced to stimulate students' learning interest and cultivate their scientific thinking and clinical application abilities. Practice has shown that this model can effectively improve teaching effectiveness and students' comprehensive quality. Compared with the traditional teaching model, this teaching model significantly improved students' final exam scores ($p < 0.01$), scores of the Critical Thinking Disposition Inventory ($p < 0.01$), and the number of approved college students' innovation and entrepreneurship projects. It is proved that the "trinity" teaching model can stimulate learning interest, cultivate integrated medical talents, and is an effective way to achieve in-depth connection between basic medicine and clinical practice.

Keywords: Physiology; Nervous system; Teaching reform; Trinity

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1. Introduction

Physiology is a bridging course connecting basic medicine and clinical practice in medical education. As the most important part of this discipline, the nervous system involves the structure, function and regulatory mechanisms of the nervous system. The content of neurophysiology is microscopic and abstract, and closely linked to clinical practice. The theoretical knowledge of the nervous system is profound and difficult to understand, and students generally reflect that it is "hard to understand, hard to remember, and hard to apply", which puts forward higher requirements for teachers' comprehensive quality and integration ability. How to synchronously improve "knowledge—ability—literacy" is an urgent problem to be solved in physiology teaching. The traditional teaching model often focuses on theoretical teaching, making it difficult for students to combine abstract knowledge with clinical practice, leading to insufficient learning motivation and insufficient depth of understanding [1]. Therefore, this study adhere to the "student-centered" concept, rely on the Brain Science and Mental Health Laboratory of the college, organically integrate clinical cases, ongoing research projects and published papers with classroom teaching, and implement the "clinical-research-teaching" trinity teaching model in the nervous system. Guided by clinical problems, supported by scientific research technologies and methods, and taking classroom teaching as the carrier, the three are organically integrated to effectively stimulate students' learning interest and desire for knowledge, and realize the dual tasks of theoretical knowledge teaching and clinical literacy training.

2. Specific implementation of the trinity teaching model

2.1. Taking clinical cases as the entry point to stimulate learning interest

Neurophysiological knowledge, such as action potentials, synaptic transmission, and neurotransmitters, is relatively abstract and tends to be dull for students, with related content being particularly difficult to understand. In our teaching, this study has introduced typical clinical cases, such as Parkinson's disease, Alzheimer's disease, and epilepsy, and guide students to explore the underlying physiological mechanisms through case discussions.

Taking the teaching of Alzheimer's disease as an example, a complete teaching design is as follows: First, case presentation: A short clinical scenario video was played or an anonymous medical record summary was displayed, which mainly described a 70-year-old retired teacher who has experienced progressive memory loss over the past two years, accompanied by disorientation and personality changes. No focal signs were found in the neurological examination, and the score of the Mini-Mental State Examination (MMSE) decreased significantly [2]. Then, questions were raised to guide students' thinking and discussion. Clinical questions: Based on the above manifestations, what is the most likely diagnosis? Which diseases (such as vascular dementia and frontotemporal dementia) need to be differentiated from it? Followed by physiology-related theoretical questions: Which brain regions (with emphasis on the "hippocampus") and neural activities (such as synaptic transmission and synaptic plasticity like LTP) are involved in memory formation? What changes may have occurred in these physiological functions of the patient in this case? Further, research questions are proposed: If we want to explore the causes of this disease, from which aspects should we start the research? Real clinical cases quickly capture students' attention, connect abstract neural functions with specific clinical symptoms, stimulate their curiosity, and naturally introduce relevant neurophysiological content.

Next, while systematically explaining theoretical knowledge, some research-related content was integrated into knowledge modules

(1) Explaining the classic pathological mechanisms of AD [3]

(2) Integrating research

Displaying comparative images of brain tissue sections (silver-stained or immunohistochemically stained) from AD patients and normal individuals, allowing students to intuitively perceive pathological changes, which also promotes their learning of clinical diagnostics

(3) Introducing key biological technologies

Using techniques such as ELISA and Western Blotting to detect Aβ and Tau protein levels in cerebrospinal fluid, and explaining their applications in AD biomarker research and value in clinical auxiliary diagnosis [4].

Such a teaching design combines tedious pathological mechanisms with vivid scientific research technologies and cutting-edge progress, making knowledge "come alive". It helps students understand how textbook theories were verified, applied, and continuously developed through scientific research. This study also incorporated current hot topics, such as "the application of brain-computer interface technology in neural rehabilitation" and "early biomarkers of neurodegenerative diseases", to guide students to pay attention to the application value of physiological knowledge in cutting-edge medical technologies, thereby enhanced their sense of reality and mission in learning [5].

2.2. Integrating scientific research into classroom teaching

To help students understand the research methods of neuroscience electrophysiology, this study has integrated experimental designs, technical routes, and phased results from published papers into teaching. In this part of the teaching, the experimental technology and protocol of patch clamp, an electrophysiological technique were presented to students in the form of videos, enabling them to gain a deeper understanding of the process of neuron activation and action potential transmission. By deeply integrating patch clamp technology to demonstrate research methods and cutting-edge progress in neuroscience, teaching is no longer limited to tedious theoretical deduction. Instead, students intuitively learnt about this advanced technology known as the "window to ion channels." Vivid animations were used to show its core technical principle: forming a gigaohm high-resistance seal between a glass microelectrode and the cell membrane, thereby recording picoampere-level tiny currents generated by individual ion channels. This allowed students to intuitively understand the dialectical relationship between recording macroscopic currents in the "whole-cell mode" and revealing microscopic events in the "single-channel mode," transforming abstract ion channel kinetics into visual current traces. Furthermore, by linking to cutting-edge neuroscience, this study explained how patch clamp technology is used to screen specific channel blockers derived from scorpion venom or seaweed toxins, and revealing their potential in the development of new analgesics or insecticides.

This study also introduced the combined technology of optogenetics and patch clamp expressing light-sensitive channels in specific neurons to achieve "light-controlled" neuron firing while synchronously recording their electrophysiological responses, thereby accurately analyzing neural circuit functions. This not only enables students to master core knowledge but also helps them deeply recognize the driving role of technological breakthroughs in scientific research and the great value of basic research in promoting scientific innovation and drug development. Through the introduction of scientific research examples, students not only deepen their understanding of theoretical knowledge but also initially grasp the basic logic and technical paths of neuroscience research, laying a foundation for their subsequent participation in research projects or graduation design.

2.3. Constructing a mutually promoting "clinical-research-teaching" cyclic teaching model

In the teaching process, this study has emphasized the cyclic promotion of the three components: clinical problems initiate research projects, research achievements feed back into teaching content, and teaching in turn provides feedback to guide the adjustment of clinical and research directions. In the teaching of depression, "clinical practice, scientific research, and teaching" form a dynamic, cyclic, and mutually promoting organic whole [6]. This cycle starts with clinical practice. Faced with practical dilemmas such as "slow onset of drug effect" and "treatment ineffectiveness in some patients", clinicians refine key scientific questions, which directly spawn cutting-edge research directions in rapid antidepressant therapy, such as the role of ketamine in neural circuit plasticity and neuromodulation technologies including transcranial magnetic stimulation [TMS]) [7]. These research achievements then feedback into teaching content, expanded the classroom from the traditional "monoamine neurotransmitter hypothesis" to the "neural circuit dysfunction" model [8]. In the teaching of Integrated Basic Medical Experiments, this study allowed students to personally experience the process of establishing depression models, followed by animal behavioral experiments to detect depression-like behaviors. This enables students to intuitively understand the external manifestations of depression. More importantly, feedback from the teaching process can serve as an important driving force for adjusting clinical and research directions. Questions raised by students after learning the latest theories, such as "How does psychotherapy reshape brain circuits?", often inspire new research ideas. Meanwhile, this cutting-edge-integrated teaching cultivates students' critical and innovative thinking, enabling them to observe and propose clinical problems more acutely in the future, thereby initiating a new cycle of "clinical practice guiding scientific research" [9].

In summary, clinical practice is the source of fundamental questions; scientific research is the engine of exploration, delving into mechanisms and creating new knowledge and technologies; classroom teaching is the hub and amplifier for integration and dissemination, systematically integrating and disseminating new knowledge while stimulating new inspirations through teaching interactions and cultivating talents who can drive future innovations.

3. Evaluation of teaching effects

3.1. Academic performance and aptitude assessment

A comparative analysis was conducted before and after the teaching reform. A total of 248 five-year clinical medicine students from the 2023 cohort served as the control group (traditional teaching group), and 256 students from the 2024 cohort as the experimental group (trinity teaching group). The final written test score of the experimental group (82.6 ± 7.4) was significantly higher than that of the control group (75.3 ± 8.1) ($t = 6.42$, $p < 0.01$); the score of the Critical Thinking Disposition Inventory increased by 11.7%; and the score of the OSCE station "neuroreflex examination + mechanism explanation" increased by 15.3%.

3.2. Research participation and output

In recent years, the proportion of students participating in teachers' research projects has increased significantly. Many student-initiated "College Students' Innovation and Entrepreneurship Training Program" projects have been approved at the national or provincial level, and some results have been published in academic conferences or journals. Students in the experimental group presided over 4 national-level and 6 provincial-level innovation and entrepreneurship projects, and published 3 SCI papers as co-authors (second author or above); the corresponding numbers in the control group were 1, 2, and 1, respectively. The proportion of students in the 2023 cohort choosing neuroscience-related directions for postgraduate studies increased from 12.4% to 27.6%.

3.3. Affective attitudes and values

Analysis of post-class reflection reports before and after the reform showed that the co-occurrence frequency of "knowledge-clinic-research" increased from 12% to 41%; the coverage rate of the "learning interest" node rose from 34% to 68%. Anonymous questionnaires indicated that 92.4% of students believed the "trinity" teaching helped “establish a knowledge network”, and as high as 88.1% of students expressed willingness to participate in teachers’ research projects [10].

4. Discussion and reflection

4.1. The “trinity” teaching model breaks the isolation of the “three-stage” separation of basic medicine, clinical practice, and scientific research

Traditional teaching often arranges basic courses, clinical courses, and research training linearly by semester, resulting in delayed knowledge transfer for students. This teaching practice places “clinical problems” at the forefront, embeds “mechanism learning” into the “diagnostic and treatment pathway”, and extends the depth of learning through “scientific research verification”. It conforms to the four elements of constructivism” situation, collaboration, conversation, and meaning construction” and effectively improves students’ long-term memory and far-transfer abilities.

4.2. Higher requirements for teachers and teaching team building

Teachers were required to be competent in three roles simultaneously: “physician, scholar, and instructional designer”. The teaching and research section has established a “3 × 3” cross lesson-preparation system: 3 basic medicine teachers + 3 clinicians + 3 postdoctoral researchers, holding monthly teaching seminars themed on “cases, mechanisms, and cutting-edge progress”.

4.3. Directions for continuous improvement

(1) Further expand the case library toward “rare diseases + interdisciplinary diseases”, introducing new disease types such as inherited metabolic diseases, neuroimmune diseases, and diabetes-related neurological diseases

(2) Utilize AI generative models to develop a real-time dialogue system with “intelligent patients”, increasing the intensity of clinical thinking training

(3) Construct a digital platform for the “trinity” teaching evaluation, realizing a multi-dimensional visualized evaluation system covering learning trajectories, research participation, and clinical competencies

5. Conclusion

The “clinical-research-teaching” trinity teaching model is not a simple superposition of three elements, but a systematic reconstruction centered on students, anchored in real clinical problems, driven by the latest scientific evidence, and oriented toward higher-order teaching goals, an organic integration focusing on students’ competency development. Practice has shown that this model effectively stimulates students’ learning initiative and creativity, significantly improves teaching quality as well as students’ academic performance, research literacy, and professional identity, and provides a replicable and promotable paradigm for the teaching reform of basic medical courses. In the future, study should further optimize the teaching content and methods to promote physiology teaching toward deeper levels and broader scopes.

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Disclosure statement

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