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A study on the construction and application of PBL teaching model of pathology driven by metacognitive strategies

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ABSTRACT

This study innovatively constructed a metacognitive strategy-driven PBL hybrid teaching model (metacognitive-PBL three-stage method) to address the problems of knowledge fragmentation and insufficient clinical transfer ability in pathology teaching. Through the three-stage closed-loop design of pre-course metacognitive knowledge padding, in-course case analysis and monitoring and reflection, and post-course knowledge transfer and reconstruction, metacognitive theory and problem-oriented learning were deeply integrated. Taking Cirrhosis of the Liver as a practical case study, we adopt the methods of group collaboration, progressive problem-guidance and multimodal evidence cross-validation to promote students to form a systematic cognitive framework of "etiology-pathology-clinical". This model not only strengthens the connection between pathology and clinical practice, but also fosters students' structured knowledge integration and lifelong learning ability through the metacognitive cycle of "planning-monitoring-reflectin", which provides a practical paradigm for medical education reform.

KEY WORDS: Metacognitive strategies; Problem-Based Learning (PBL); Pathology education

Introduction

Pathology plays a crucial role in the basic curriculum of clinical medicine, which is not only a bridge connecting basic medicine and clinical medicine, but also provides a solid foundation for students' subsequent clinical courses and the cultivation of clinical thinking ability. Under the background of continuous reform of classroom teaching in colleges and universities, various teaching methods and educational models have emerged. These models have shown positive development in the process of implementation and final results. However, each teaching model has its specific advantages and limitations when adapted to different courses and student groups. In this context, this study aims to explore the practical exploration of applying Problem-Based Learning (PBL) guided by metacognition to a clinical medical pathology course.

1. Metacognitive Theory

Metacognitive theory was first proposed by American psychologist J.H. Flavell [1] in the 1970s by the book Cognitive Development, and has been one of the focal points of cognitive psychology research.In the early 1990s, metacognitive theory also attracted extensive attention from our educational community. Flavell defines metacognition as an individual's knowledge of his or her own cognitive processes and their results, as well as the ability to actively monitor, continuously regulate, and coordinate cognitive processes according to the cognitive object in order to achieve a specific goal

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or task. Metacognition consists of three elements: metacognitive knowledge, metacognitive experience, and metacognitive monitoring [2]. Metacognitive knowledge involves the individual's understanding of cognitive tasks and strategies; metacognitive experience involves the cognitive and emotional experiences arising from cognitive activities; and metacognitive monitoring is the continuous monitoring of one's own cognitive activities during the cognitive process and regulating them accordingly to achieve the best cognitive effect. Metacognition plays a central role in cognitive activities and is particularly important for professional education in clinical medicine. Metacognitive knowledge can influence, assess, and monitor teaching and learning activities; metacognitive experience involves the perception of context, emotions, and feelings at the time of knowledge acquisition; and metacognitive monitoring continuously evaluates the teaching and learning process, adjusts the teaching and learning programme in due course, and selects appropriate paths and methods to complete teaching and learning tasks [3].

Metacognitive ability, which refers to the monitoring and regulation of cognitive processes, is an advanced cognitive skill that emphasises the ability of students to be actively motivated to learn and to choose appropriate learning methods and strategies to increase efficiency and improve outcomes, with interest in problems and a desire to solve them being the underlying motivation for learning [4]. Teachers should capitalise on students' curiosity by guiding them towards self-directed exploration and learning while enhancing relevant knowledge. In this process, both students and teachers are required to reflect on the learning activities. The self-directed learning process should involve active motivation of the learner, self-monitoring, scrutiny and evaluation, as well as learning adjustments and encouragement based on feedback. The core of metacognitive skills lies in self-monitoring, i.e. the learner's awareness of his/her own mental and behavioural awareness, which is a process of real-time evaluation and regulation of learning. The involvement of metacognition is crucial throughout the whole process of independent learning, throughout the act of metacognitive monitoring, which is a key aspect of independent learning [5].

2. Metacognition and PBL Instruction

Problem-Based Learning (PBL) is not only a teaching method innovation in pathology teaching, but also a core carrier of clinical thinking training. Its core value lies in the reconstruction of the dilemma of "morphological memory-clinical connection fragmentation" in traditional pathology teaching through the reduction of real cases and the design of multi-dimensional problem chain. To stimulate students' interest in learning and desire for investigation, students need to analyse the problem in depth and apply the medical knowledge they have learned to solve the problem. Under the guidance of teachers, students study medical-related knowledge in depth to achieve in-depth integration of knowledge, improve independent learning ability, and make students become the dominant players in the acquisition of medical knowledge and skills. In the practice of pathology, PBL is usually carried out with the logic of "clinical case-pathological characteristics-diagnostic and therapeutic decisions" as the main line. For example, in the teaching of liver cirrhosis, the teacher provides complete data of a patient with a history of hepatitis B (including liver function indexes, ultrasound images, and liver biopsy biopsies), and asks students to start from the identification of pseudo lobe morphology, and then gradually deduce the pathological mechanism of portal hypertension and explain the clinical manifestations. In this process, students need to integrate anatomical, pathophysiological and pharmacological knowledge across disciplines, and at the same time observe the digital pathological slides through the virtual microscope platform, so as to realise the two-way validation of "macroscopic clinical manifestations and microscopic pathological changes".

While traditional PBL models often stop at problem solving, the intervention of metacognitive theory elevates the learning process from task completion to cognitive optimisation. In PBL learning that incorporates metacognition, students not only focus on the content of learning, but also reflect on and cognise their own learning process. This reflection takes the learning process itself as the object of cognition and requires students to implement metacognitive monitoring of their own learning activities based on certain metacognitive knowledge. Such monitoring activities are an embodiment of the application of metacognitive theory in practice and are a key component of the independent learning process [6].

In metacognitively oriented PBL, teachers need to systematically design "cognitive scaffolding": firstly, metacognitive knowledge guidance is embedded in the pre-study stage, for example, students are required to mark "known - to-be-known - error-prone points" in cirrhosis learning through the mind-mapping tool. Secondly, metacognitive monitoring strategies are embedded in the case discussion, such as setting up a "diagnostic decision checklist", forcing students to check the key indicators sequentially when analysing the pathological slides, and recording their self-questioning in real time; lastly, the metacognitive experience is strengthened in the summarising section through the "error case comparison method". Finally, in the concluding session, the metacognitive experience is strengthened through the "error case comparison method", which allows students to observe the differences between their own diagnostic pathways and those of experts, for example, comparing the diagnostic reports of the student group and the head of the Department of Pathology on the same liver biopsy section, and analysing the cognitive root causes of the thinking bias. This PBL model, which deeply integrates metacognition, is reshaping the paradigm of pathology education - from "knowledge transfer" to "cognitive ability incubation", so that medical students can really grow into This will enable medical students to grow into a new generation of clinical decision makers with critical thinking and adaptive learning abilities.

3. Pathways of PBL pedagogy to promote the development of metacognitive skills in teaching pathology

Metacognition consists of three core elements: metacognitive knowledge, metacognitive experience, and metacognitive monitoring, and although there are variations in the extent and basis of students' mastery of these competencies, these elements constitute the basic competencies of learners. In the realm of metacognitive learning, the key lies in fostering learners' metacognitive skills and strategies [7]. In this practicum, we conducted a preliminary survey of students involved in the Problem-Based Learning (PBL) instructional model. The findings showed that, on the one hand, students were able to apply some metacognitive strategies in the learning process, such as making a study plan, seeking help from teachers and peers in learning, and using online resources to learn about the subject. However, students were relatively unfamiliar with the concept of "metacognition", and they failed to understand the positive impact of metacognitive skills and strategies in enhancing

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learning outcomes at a theoretical level. On the other hand, students lacked the knowledge of how to use metacognitive strategies effectively and how to improve their metacognitive abilities.

Understanding metacognitive knowledge is the basis for implementing metacognitive strategies, and teachers need to assist students in acquiring the necessary metacognitive knowledge and learning strategies. Classroom teaching should start from teaching metacognitive knowledge, covering its definition, ability development methods and other aspects, which not only helps students to build up their metacognitive self-knowledge, but also stimulates their interest in actively adopting metacognitive strategies, and lays a solid foundation for the continuous and repeated application of metacognitive strategies. The cultivation of metacognitive ability needs to be gradually formed in learning activities and deepened through the cycle of "practice-reflection-adjustment-practice again". The exercise of metacognitive strategies is closely related to the teaching content, and the PBL teaching mode, with its context-based project learning, provides a suitable platform for the training of metacognitive strategies.

4. Examples of PBL practice in pathology guided by metacognitive strategies

Based on the metacognitive strategy, we constructed a metacognitive-PBL pathology teaching three-stage method, and took the chapter of Cirrhosis as an example of practical case illustration. Firstly, according to the requirements of PBL, the 30 students in the class were randomly divided into 6 groups of 5 students each, who took turns to be the group leader, secretary and team members. The task assignment of the group is specific to the individual, guaranteeing that each student can participate in the PBL teaching throughout the whole process.

4.1 Metacognitive knowledge bedding (pre-course preparation)

The first step was to clarify individual metacognitive knowledge. A pre-study task was assigned online, asking students to review the normal histological structure of the liver and the basic pathological features of cirrhosis. Secondly, learning objectives were clarified and tasks were broken down, and self-assessment questionnaires were administered, e.g., "Do you understand the main causes of cirrhosis (viral hepatitis, alcoholic liver disease, etc.)?" "Can you distinguish the structural differences between pseudolobules and normal liver lobules?" . The aim was to conduct metacognitive knowledge guidance and learning behaviour diagnosis to help students establish a clear perception of their knowledge base, cognitive abilities and learning needs, thus providing targeted preparation for subsequent PBL learning activities.

4.2 PBL case implementation

During the implementation of the case, a three-stage metacognitive-PBL pathology teaching method of "case introduction - group collaboration and metacognitive monitoring - reflection and correction" was constructed. The first step was to introduce a real clinical case and give basic information about the case, such as history of hepatitis B, imaging data, pathological diagnosis, etc. Next, progressive problems were designed. Next, progressive questions were designed to guide students to work in groups, from the identification of pseudolobule morphology to the analysis of portal hypertension mechanism to the diagnosis and treatment of complications. Each group focused on pathological section observation, interpretation of liver function indexes and clinical treatment strategies, respectively. Metacognitive strategies, such as intra-group questioning, "Did you miss any key indicators?" and peer assessment of "Is the diagnosis based on sufficient evidence?" Real-time monitoring and adjustments were made. Afterwards, we will report to each other and discuss the error cases to strengthen the understanding of the confusing points such as the structure of the pseudolobule and the abnormalities of copper metabolism. Reflection and improvement were carried out during the lesson, and a systematic cognitive framework integrating pathological features, etiology and clinical management was eventually formed. The whole process is centred on metacognitive monitoring, which promotes students to shift from passive acceptance of knowledge to active construction of clinical thinking.

4.3 Summary and transfer of knowledge

In the PBL summary and migration session, metacognitive ability is strengthened in depth through the three-dimensional path of knowledge integration, clinical migration and reflection and reconstruction. Students first take the pseudolobular morphology in pathological sections as the core, and link the scattered knowledge points such as portal hypertension and liver function abnormalities into a logical chain of "etiology→pathological changes→clinical manifestations→complications" to form a migratory framework for analysing the disease; and then, through the cross validation of the multimodal evidence, they learn to migrate the diagnostic paradigm of liver cirrhosis to a new diagnostic paradigm of cirrhosis through the three-dimensional pathway of "pathology-clinical imaging". Subsequently, through the cross validation of "pathology-clinical-imaging" multimodal evidence, we can learn to migrate the diagnostic paradigm of cirrhosis to the differentiation of similar diseases, such as alcoholic liver disease and cholestatic liver disease; finally, we can look back on the learning process, understand the cognitive blind spot, and take the initiative to amend the diagnostic strategy by using the "Comparison Table of Mistake Cases" to form the "Identification of Mistake→Correction" framework. Finally, the learning process was retraced to understand the cognitive blind spots, and the diagnostic strategy was actively revised by using the "error case comparison table", forming a dynamic cycle of "identifying misconceptions→correcting the path→establishing a new cognitive pattern". This process not only consolidates the pathological features of cirrhosis, but also develops students' ability to transform metacognitive monitoring (e.g., "Did I miss key evidence in my analysis?") into a lifelong learning tool. This process not only consolidates the pathological features of liver cirrhosis, but also develops students' ability to transform metacognitive monitoring (e.g., "Did I miss any key evidence in my analysis?") into a lifelong learning tool, so that they can consciously invoke the metacognitive model of "structured knowledge extraction-multidimensional evidence integration-dynamic strategy adjustment" in the face of complex clinical problems, and realise a leap forward from solving a single case to mastering the same kind of problems.

5. Application effectiveness

In 2024, the application of PBL-metacognition teaching mode was carried out in 60 students of clinical medicine in the class of 2022 in our university, and the students reflected better. Firstly, it was reflected in the significant improvement of knowledge mastery, compared with the performance of students in the class of 2021, the slice identification accuracy in the traditional teaching group averaged 68%, while the metacognitive-PBL group improved to 82% ($p<0.05$); in the 3-month follow-up test after the class, the students' retention of the integrated memory of the etiology-pathology-clinical correlation of cirrhosis was increased by 35%.

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There was a 120 per cent increase in the length of pre-course study sessions (from an average of 15 minutes/session to 33 minutes/session), and the percentage of "self-questioning" and "strategy adjustment" entries in the learning log increased from 21 per cent to 67 per cent;

53 per cent of students took the initiative to review the latest guidelines or literature on cirrhosis of the liver after the lesson (compared to only 19 per cent in the traditional group). Metacognitive skills also developed significantly, with 91% of the students mentioning that they "paid more attention to knowledge gaps rather than just right or wrong answers" in their post-lesson reflections. The metacognitive strategy, through the closed loop of "plan-monitor-reflect", significantly improved students' knowledge integration, clinical decision-making efficiency, and lifelong learning awareness. The effect is not only reflected in the short-term performance improvement, but also through the transfer of metacognitive skills, providing students with sustainable thinking tools to deal with complex clinical problems.

6. Summary

Based on the metacognitive theoretical framework, this study innovatively constructed a hybrid teaching model of "metacognition-PBL three-stage method", which realises the dual enhancement of knowledge construction and ability cultivation in pathology teaching through the three-phase closed-loop design of pre-course knowledge advancement, in-course monitoring and reflection, and post-course transfer and reconstruction. Practice shows that this model effectively solves the problems of knowledge fragmentation and insufficient clinical migration ability in traditional medical education through the organic integration of metacognitive strategies and PBL 8teaching. The dynamic learning path of "case analysis - metacognitive monitoring - reflection and correction" was constructed, which significantly improved the accuracy of students' section identification; the clinical thinking mode of "structured knowledge extraction - multidimensional evidence integration" was formed, which increased the retention rate of knowledge by 35% after the class; and the metacognitive cyclic mechanism of "plan-monitor-reflect" was established, which prompted 83% of students to form active learning behaviours. This teaching model not only strengthens the connection between basic pathology and clinical practice, but more importantly, through the cultivation of metacognitive ability, the learners acquire sustainable lifelong learning ability. This study not only provides an innovative path for medical education reform, but also provides a practical paradigm for how to integrate higher-order thinking development in blended teaching. In the future, the sample can be further expanded and the potential of the model for transferable application in multidisciplinary teaching can be explored.

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