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The exploration and implementation of the problem-based learning (PBL) teaching model in pathology within a digital environment

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Abstract: *Pathology, as a crucial fundamental discipline in rehabilitation medicine education, not only possesses profound theoretical depth but is also closely linked to clinical practice, serving as a bridge between basic medical science and clinical medicine. In the wave of digital transformation in education, the reform of pathology coursework is pivotal for cultivating rehabilitation medicine talents with solid theoretical foundations and practical skills. Problem-based learning (PBL) is a student-centered teaching model that emphasizes autonomous learning and problem-solving abilities. By establishing specific problem scenarios, PBL stimulates students' interest and motivation in learning, and fosters their teamwork and critical thinking skills. Introducing the PBL teaching philosophy into pathology education can better ignite students' enthusiasm for learning, facilitate the integration and application of knowledge, and enhance students' learning outcomes and clinical practice abilities. This article, based on the actual situation of our university, proposes an overall construction framework for the PBL teaching model of pathology coursework in the digital context, covering four aspects: teaching environment, teaching form, teaching method, and course assessment. The implementation of this model will provide new ideas and practical experiences for the reform of pathology teaching, thereby promoting continuous innovation in educational content and methods.*

Keywords: *Pathology; PBL Teaching Mode; digital background; exploration and practice*

1. Introduction

With the rapid development of information technology, the field of education is undergoing unprecedented changes. The widespread application of digital technology has brought both new challenges and opportunities to traditional teaching modes. Pathology, as a bridge discipline connecting basic medical science and clinical medicine, holds a pivotal position in medical education. However, traditional pathology teaching modes often focus on instructor-led lectures and passive student reception, which to some extent limits the cultivation of students' active learning and problem-solving abilities. Therefore, exploring and practicing new pathology teaching modes in the digital context is particularly significant.

In recent years, the PBL teaching mode has received widespread attention and application globally. The PBL teaching mode emphasizes a student-centered approach, stimulating students' learning interest through real-life problem scenarios and cultivating their autonomous learning abilities and critical thinking[1]. It is probable that medical students, through Problem-Based Learning (PBL), will not only gain knowledge but also develop various competencies essential for medical professionalism[2]. Introducing the PBL mode into pathology teaching can not only enhance students' learning initiative and problem-solving abilities but also help them better understand and master pathology knowledge, laying a solid foundation for future clinical practice.

Since the emergence of the COVID-19 pandemic in 2019, there has been a significant acceleration in the adoption and development of digital education and teaching practices[3]. The rapid development of digital technology provides powerful support for the application of the PBL teaching mode in pathology teaching. Through digital platforms, instructors can easily design and publish problems, guiding students to engage in autonomous learning and discussion. Students can utilize online resources for information searching, online communication, and collaboration, thereby more efficiently completing learning tasks.

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Additionally, digital technology can provide rich multimedia resources and simulated experimental environments for pathology teaching, further enhancing students' learning experience and effectiveness.

This study aims to explore effective implementation strategies for the PBL teaching mode in pathology under the digital background and analyze its impact on improving students' learning outcomes and teaching quality. At the same time, this study will also focus on the applications and challenges of digital technology in the PBL teaching mode, providing beneficial enlightenment for future teaching practices.

2. Core Values of PBL Teaching Mode in Pathology Education

The core values of the PBL teaching mode in pathology education lie in stimulating students' active learning, cultivating problem-solving skills, fostering teamwork and communication, and nurturing critical thinking[4]. The PBL teaching mode emphasizes active learning on the part of students, rather than the traditional passive reception of knowledge. In the teaching of sports rehabilitation pathology, this mode encourages students to engage in the learning process, take the initiative to search for information, analyze problems, propose solutions, and engage in discussions and exchanges with classmates more actively. This learning approach helps deepen students' understanding of professional knowledge and enhances their interest and motivation in learning.

The core of the PBL teaching mode revolves around problems. By setting practical, meaningful, and highly inspiring problem scenarios, students are guided to apply their learned knowledge to solve real-world problems. In sports rehabilitation pathology education, students need to confront various complex cases and pathological issues. The PBL mode cultivates their ability to solve practical problems, enabling them to better cope with future clinical practices.

PBL teaching often takes place in group settings, encouraging teamwork and communication among students. In sports rehabilitation pathology education, students need to analyze problems and discuss solutions with their peers, learning from and inspiring each other in the process. This learning approach helps cultivate students' teamwork spirit and communication skills, laying a solid foundation for their future career development.

The PBL teaching mode not only focuses on the transmission of knowledge but also emphasizes the cultivation of students' critical thinking. In sports rehabilitation pathology education, students need to constantly question, analyze, and evaluate various information to form their own judgments and solutions. This learning approach helps cultivate students' independent thinking abilities and critical thinking, enabling them to better navigate complex and ever-changing clinical environments. These core values not only contribute to students' personal growth and development but also lay a solid foundation for their future career paths.

3. The necessity of pathology PBL teaching model reform under the digital background

With its advantages of abundant resources, strong interactivity, and flexible learning forms, digital education has gradually become the mainstream trend in modern education. As an important discipline in medical education, the teaching mode of pathology should also adapt to the development of the digital era by introducing innovative teaching modes such as PBL, fully utilizing digital resources and tools, and enhancing teaching quality and efficiency. Traditional pathology teaching modes often center on teachers, with students passively receiving knowledge, which is difficult to stimulate their learning interest and initiative. While the introduction of digital tools (such as online learning) has improved some issues, it still needs to be combined with the PBL teaching mode. By using real cases to drive students to actively explore pathological mechanisms and clinical connections, this approach addresses the pain points of "fragmented knowledge" and "disconnection from practice."

Pathology content is complex, and a single teaching form can easily make students feel bored and uninterested. The PBL teaching mode emphasizes students' active exploration, discovery, and resolution of problems in practical situations, which helps cultivate their problem-solving skills and teamwork abilities. By introducing the PBL teaching mode, the difficulties of traditional pathology teaching can be overcome, students' learning interest and motivation can be stimulated, and teaching effectiveness can be improved.

Therefore, the reform of the PBL teaching mode in pathology in the digital context is aimed at adapting to the trend of digital education, addressing the issues of traditional pathology teaching,

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enhancing the effectiveness of pathology teaching, promoting the reform and innovation of pathology teaching, and cultivating comprehensive talents who can adapt to the future development of rehabilitation medicine.

4. Construction of digital pathology teaching model based on PBL

The traditional "teacher-centered" indoctrination teaching mode makes it difficult to meet the teaching needs of the information age. In the context of educational digitization, the blended teaching mode represents the development direction of the curriculum and teaching reform[5]. Blended teaching shifts the focus to a "student-centered" teaching philosophy, actively guiding and encouraging students to engage in all facets of curriculum teaching. It fosters an environment where students take ownership of their learning, cultivating their autonomous learning abilities and encouraging critical thinking.

In response to the educational transformation necessitated by the digital age, this course innovatively constructs a Problem-Based Learning (PBL) teaching mode specifically tailored for pathology education. This mode not only aligns with the principles of blended teaching but also proposes a comprehensive and holistic design approach encompassing four pivotal aspects: teaching environment, teaching form, teaching method, and teaching assessment. Each of these aspects is meticulously considered to ensure that the PBL teaching mode not only enhances students' engagement and understanding of pathology but also equips them with the skills necessary to navigate and thrive in the digital era. The detailed design concept is shown in Figure 1.

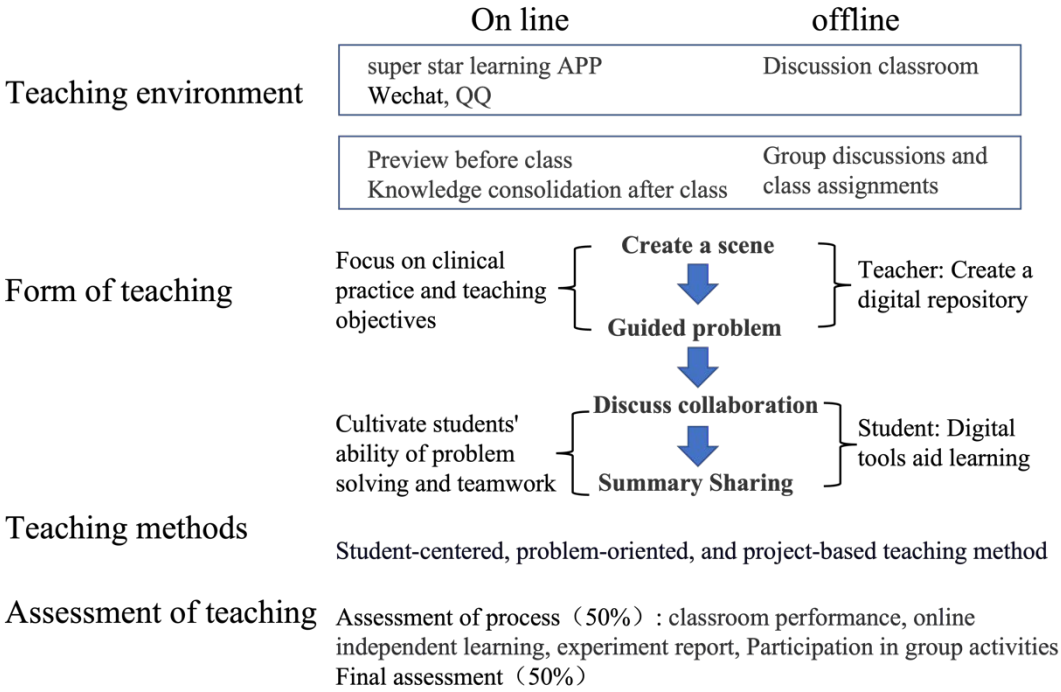

Figure 1: Construction of digital teaching model based on PBL

4.1. Teaching environment design: Build an interactive learning scene with virtual and real integration

The configuration of smart classrooms in schools has laid a solid foundation for the integrated virtual-real learning scenario. The multi-screen interactive equipment not only achieves seamless information flow, but also plays a pivotal role during group discussions. Students can sit together in a circle, jointly observing and analyzing case data displayed synchronously, which encompasses high-precision imaging images, detailed pathology reports, and other materials, providing students with intuitive and comprehensive learning resources. Teachers can utilize the real-time annotation function to directly mark key information on the screen and push it to each student's personal device with a single click, ensuring instant information sharing and deep understanding.

The abundance and convenience of digital resources have greatly broadened the boundaries of

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learning. We have selected pathology slices relevant to teaching needs from China's digital pathology cloud slice library (such as http://qp.91360.com) for teaching activities. These high-quality resources not only enhance the intuitiveness of teaching but also greatly facilitate students' cognition and memory of complex pathological structures. Furthermore, we have extensively collected and organized a large number of authentic pathology cases, establishing a case library that is comprehensive and appropriately in-depth. For each case, we have designed thought-provoking and hierarchically structured questions, forming a question bank. These questions are intended to guide students to think deeply and integrate abstract theoretical knowledge with specific clinical situations.

The establishment of the case library and question bank has provided fertile soil for the implementation of PBL (Problem-Based Learning) teaching. In this mode, students are no longer passive recipients of knowledge but become active explorers and problem-solvers. They are encouraged to engage in group discussions around cases, apply their learned knowledge to analyze conditions, propose hypotheses, design diagnostic plans, and gradually deepen their understanding under the guidance of teachers. By simulating real-world medical decision-making processes, students can not only deepen their mastery of pathology knowledge but also practice critical thinking, team collaboration, and communication skills in practice, laying a solid foundation for future work in sports rehabilitation.

4.2. Teaching form design: Problem-centered

Centered around "clinical problems" as the core driver, the process revolves around five key stages: problem introduction and scenario simulation, student autonomous learning and collaborative inquiry, classroom discussion and question-answering, knowledge consolidation and expansion, and teaching evaluation and feedback. During the problem introduction and scenario simulation stage, teachers design open-ended, authentic, and hierarchical questions based on the pathology syllabus and clinical practice. These questions are intended to spark students' curiosity and desire to explore, guiding them to gradually delve deeper into the study of pathology. Through scenario enactment, students are immersed in the practical applications of pathology, enhancing their sense of engagement and experience in learning.

Students engage in autonomous learning and initial exploration based on the questions posed by the teacher and the digital resources provided (such as multimedia courseware, online databases, academic forums, etc.), forming preliminary understandings and hypotheses about the problems. In classroom instruction, students are divided into small groups where they share their learning outcomes and initial hypotheses, engaging in discussions and collaborative inquiry to reach consensus or raise new questions. Within each group, clear divisions of labor and cooperation mechanisms should be established to ensure that every student actively participates and contributes.

Finally, the teacher organizes a classroom discussion for all students to share the learning outcomes and collaborative inquiry results of each group. Students are encouraged to present their own insights and questions, engaging in thorough exchanges and debates. Throughout this process, teachers should focus on guiding students to discover, analyze, and solve problems independently, cultivating their autonomous learning abilities. At the same time, teachers provide comments and feedback on students' learning outcomes to help them consolidate their knowledge. Teachers can also provide relevant expansion resources and suggestions to guide students in in-depth learning and research.

A diversified evaluation system is established, including student self-evaluation, peer evaluation among group members, and teacher evaluation. Students' mastery and application of pathology knowledge are assessed through exams, assignments, learning reports, and other methods. Through the design and implementation of these stages, students' interest and enthusiasm in learning can be stimulated, their abilities to learn autonomously and solve problems can be cultivated, and the teaching effectiveness and quality of pathology can be improved. Examples in actual teaching are shown in Table 1.

Table 1: Example of teaching design of coronary heart disease pathology

Teaching Objectives	a) Knowledge Objectives: Master the pathological mechanisms of coronary heart disease (coronary atherosclerosis), including plaque formation, ischemic injury, and myocardial remodeling, as well as their relationship with motor function. b) Skill Objectives: Be able to design individualized exercise prescriptions based on pathological staging, and master methods for assessing and monitoring exercise risk. c) Thinking Objectives: Establish a clinical reasoning logic of "pathological mechanism → functional limitation → rehabilitation intervention".
Teaching Preparations	a) Virtual Heart 3D Model (for displaying coronary artery anatomy and plaque distribution)

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	b) Dynamic Pathological Slice Library (microscopic images of plaque staging in atherosclerosis) c) Literature data on exercise and coronary heart disease risk d) Case Study: A 65-year-old male patient who presented with chest pain after activity. An electrocardiogram showed myocardial ischemia, and coronary angiography revealed a 70% stenosis in the left anterior descending branch.
PBL Design	Phase 1: Problem Introduction and Pathological Mechanism Analysis Task 1: Pathological Mechanism Exploration Problem Chain Design: a) What are the main causes of coronary heart disease? b) How does plaque affect coronary blood flow? c) What are the consequences of coronary heart disease? Group Output: Draw a "Coronary Heart Disease Pathological Mechanism Mind Map" Phase 2: Exercise Risk Assessment and Functional Assessment Task 2: Cardiovascular System Response to Exercise Problem Chain: a) How do heart rate, blood pressure, cardiac output, and lung ventilation change as exercise intensity increases? b) What are the mechanisms by which exercise benefits the cardiovascular system? c) How to assess the exercise risk of coronary heart disease patients? Group Output: Consult literature and guidelines to obtain relevant knowledge and answer corresponding questions. Phase 3: Group Task Presentation and Discussion Phase 4: Teacher Evaluation and Summary
Teaching Evaluation System	Process Evaluation: a) The scientific nature of the mind map (completeness of the pathological mechanism chain) b) Completeness and accuracy of problem answers c) Participation in group tasks

4.3. Teaching method innovation: Deep interaction of digital empowerment

In the process of educational digitization, utilizing multimedia teaching tools to enrich the presentation of teaching content is a key strategy for innovating teaching methods and enhancing classroom effectiveness. In the teaching practice of this course, we have thoroughly implemented a student-centered educational philosophy, enhancing students' teamwork abilities, problem-solving skills, and innovative thinking through the implementation of a group-based learning model. Specifically, students were divided into several well-balanced groups, and each group was assigned a challenging problem or case study that was closely related to rehabilitation practice. These cases often integrated knowledge from multiple disciplines, including anatomy, physiology, pathology, and rehabilitation medicine, aiming to comprehensively assess students' ability to apply knowledge and clinical thinking.

Upon receiving their tasks, group members immediately immersed themselves in intensive research. They extensively gathered literature related to the cases through libraries, the internet, and other resources to ensure comprehensive and accurate information. Following this, group members engaged in regular offline or online meetings to deeply discuss the pathological mechanisms, clinical manifestations, diagnostic criteria, and rehabilitation plans for the cases. In this process, students not only learned how to efficiently retrieve and utilize information but also gained important skills in effective communication, teamwork, and collaborative problem-solving.

Considering the complexity of pathology as an interdisciplinary field, we particularly encouraged students to utilize advanced generative AI tools, such as DeepSeek and ChatGPT[6-7], to aid in their learning and research. These tools, based on vast amounts of data and algorithms, can quickly generate knowledge points and explanations related to the cases, providing students with timely and accurate information support. Additionally, we guided students to use AIGC technology to create mind maps, systematizing and structuring scattered knowledge points to help them better understand and remember the content.

Online collaboration tools like Tencent Docs played a significant role in the teamwork process. These

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tools support multiple users editing and viewing documents simultaneously, enabling group members to share resources, discuss progress, and significantly improve work efficiency in real-time. Furthermore, through online collaboration, students were better able to record and organize key information discussed, laying a solid foundation for subsequent research and presentations.

To assist students in presenting their research findings more effectively, we recommended online PPT creation tools such as Qingzhu PPT and Kimi. These tools utilize intelligent algorithms to quickly generate PPT outlines and various stylish, well-designed PPT templates based on users' brief instructions. Students only need to select appropriate templates and add corresponding content based on their research content and presentation needs to easily create high-quality PPTs. This not only improved students' PPT creation abilities but also allowed them to focus more time and energy on deepening and expanding their research content.

As teachers, we played a crucial guiding and supporting role in this process. We not only provided necessary academic guidance and technical support to students but also encouraged them to actively express their views and opinions, cultivating their critical thinking and innovation abilities. Through regular feedback and evaluations, we helped students continuously improve their research proposals, enhancing their abilities in pathological analysis and rehabilitation program design. Simultaneously, we focused on cultivating students' autonomous learning abilities and teamwork spirits, laying a solid foundation for their future career development.

4.4. Diversified evaluation setting

In the process of educational digitization, designing diversified assessment question types to comprehensively evaluate learning outcomes is a crucial aspect of improving the functionality of online assessment systems and facilitating the assessment of learning effectiveness. This course has introduced a formative assessment and evaluation mechanism that deeply integrates the concept of digital empowerment, ensuring the comprehensiveness, fairness, and dynamism of evaluations. The assessment system is comprised of two parts: final assessments and formative assessments, each accounting for 50% of the overall weight.

The formative assessment leverages digital platforms to establish a diversified evaluation system that encompasses various aspects such as offline classroom performance, online autonomous learning, experimental reports, multiple online theoretical quizzes, and experimental assessments. The online autonomous learning component utilizes digital systems to monitor students' learning progress and effectiveness, enabling teachers to dynamically track students' learning status and promptly obtain data analysis of their learning behaviors. This approach allows teachers to accurately identify students' learning difficulties and weak areas, providing a solid basis for subsequent teaching adjustments.

By incorporating a range of assessment methods, the course aims to capture a holistic view of students' learning experiences and achievements. The offline classroom performance evaluations assess students' engagement, participation, and understanding during face-to-face sessions. Online autonomous learning, monitored through digital platforms, provides insights into students' self-directed learning habits, progress, and comprehension. Experimental reports evaluate students' practical skills, data analysis abilities, and scientific writing. Multiple online theoretical quizzes, offered at various stages of the course, help gauge students' mastery of theoretical concepts and their ability to apply knowledge in different contexts. Lastly, experimental assessments test students' hands-on skills and experimental design capabilities.

The integration of these diverse assessment methods ensures that students are evaluated not just on their final performance but also on their ongoing progress and development throughout the course. This comprehensive approach fosters a more equitable and dynamic learning environment, where students can receive timely feedback, identify areas for improvement, and adjust their learning strategies accordingly. By leveraging digital technologies, the course aims to enhance the accuracy and efficiency of assessment processes, ultimately contributing to better learning outcomes and student success.

5. Analysis of Teaching Implementation Effectiveness

After adopting the PBL teaching model, students' academic performance has seen a notable improvement. Through discussing and solving practical cases, students can gain a deeper understanding of pathology knowledge and enhance their learning effectiveness. Additionally, the application of digital resources has diversified students' learning methods, aiding them in better mastering and applying

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knowledge. The PBL teaching model emphasizes students' autonomous learning and active exploration, as well as the importance of group cooperative learning and discussion. In the digital context, students can utilize abundant digital resources for autonomous learning, improving their problem-solving abilities and laying a foundation for their future studies and career development. Furthermore, students can engage in real-time communication and collaboration through online platforms, enhancing their teamwork and communication skills, and thereby strengthening their social adaptability.

Despite the remarkable implementation effects of the PBL teaching model in pathology education within the digital context, there are still some issues, such as low utilization of digital resources by some students and a lack of autonomous learning ability among others. To address these problems, we can adopt a series of improvement measures. On one hand, we should continuously enrich and optimize digital resources, enhancing their practicality and appeal by designing more vivid and interactive learning content to guide students in better utilizing these resources for autonomous learning. On the other hand, for students who lack autonomous learning ability, teachers can provide more learning guidance and support, such as regular learning plans, personalized learning suggestions, and timely feedback and encouragement, to help them gradually cultivate autonomous learning skills and adapt to and benefit from the PBL teaching model. Through these efforts, we can further leverage the advantages of the PBL teaching model and promote the sustainable development and innovation of pathology education.

6. Conclusions

The digitization of education has set higher requirements for higher education. It is the focal point for fulfilling the fundamental task of cultivating talent through moral education, implementing the development concept of education in the new era, and accelerating the high-quality development of higher education. Courses, as the key to educating people, should continuously explore ways to enhance their educational effectiveness and further promote the digital transformation of specialized courses. In the future, pathology will continue to develop in the directions of deepening technology integration, optimizing teaching modes, innovating evaluation systems, and sharing teaching resources. This will provide more efficient, convenient, and personalized learning pathways for pathology education, laying a solid foundation for cultivating outstanding talent in sports rehabilitation.

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