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Teaching Research and Practice of "Medical Microbiology" Experimental Courses with the Aid of Virtual Simulation Technology

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Abstract: Microbiology itself is an important basic discipline, and it is even more necessary to attach great importance to the cultivation of medical students, highlighting the application and practicality of the course to lay a solid foundation for students' future clinical practice. Focusing on the "Medical Microbiology" experimental course, it is crucial to understand the course characteristics, such as scattered knowledge and large information volume, and adopt appropriate teaching methods to regulate them to promote students' knowledge absorption, comprehensive understanding, and practical application. For example, virtual simulation teaching can leverage technological advantages to enable experimental practice to be carried out anytime and anywhere, allowing more students to expand their practice around one class period, one unit, or one project, achieving twice the educational effect with half the effort. Therefore, this paper discusses the teaching strategies of "Medical Microbiology" experimental courses assisted by virtual simulation technology, hoping to provide more references for frontline educators.

Keywords: Virtual simulation technology; Medical microbiology; Experimental course; Teaching strategy

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1. Virtual simulation technology and its educational value

Virtual simulation technology uses computer systems to simulate real-world objects or existing phenomena, real-timely reflecting changes, interactions, and other dynamics of the objects. This enables users to intuitively predict and deduce how corresponding operations would behave or impact in real environments. With its high interactivity and immersive experience, the technology allows users to operate within a computer-generated environment as if they were in the real world. Currently, this technology has been widely applied in various fields such as education and training, military drills, architectural design, and medical simulation, providing a safe environment and systematic operation framework to enhance users' capabilities and competencies in multiple aspects [1]. In the future, with the further development of science and technology, virtual simulation experiments will be promoted across all sectors, demonstrating greater value by enabling the prediction and optimization of

complex scenarios before real resource investment.

The application of virtual simulation technology in education is often manifested through virtual simulation experiments, which have been actively promoted in various types of experiments due to their high convenience and safety [2–4]. For instance, some relatively dangerous chemical experiments require a high level of proficiency from operators. Since most students are beginners, they can practice first on virtual simulation platforms. This allows them to familiarize themselves with experimental content, operations, and procedures while ensuring personal and property safety. Similarly, large-scale projects such as bridge construction or aviation are impractical for students to undertake in reality, but virtual environment training can still cultivate their professional qualities, accumulate vocational experience, and lay a solid foundation for their long-term career development. Evidently, the integration of virtual simulation technology in education transcends disciplinary and spatio-temporal constraints, offering students a more flexible approach to learning and practice—a truly multifaceted advantage.

2. Analysis of the characteristics of "Medical Microbiology" experimental courses

2.1. Microscopic and complex nature of experimental content

As the name suggests, experiments in Medical Microbiology fall under the category of "microbiology," involving countless bacteria, viruses, fungi, etc. Accessing this microscopic world requires sophisticated instruments [5]. The first step in experimental learning is mastering the operation and application of these tools to build a solid foundation. For example, observing bacterial morphology involves complex procedures like Gram staining to distinguish between Gram-positive and negative bacteria under a microscope. Additionally, microorganisms exhibit diverse culture requirements and metabolic pathways. Anaerobic bacteria, for instance, demand specialized anaerobic environments distinct from aerobic culture methods. Such complexities necessitate students to possess foundational knowledge, memorize microbial characteristics, and apply appropriate experimental techniques—a duality that underscores the microscopic and intricate nature of the discipline.

2.2. Rigorous standardization of experimental operations

The accuracy of experimental results in this course is directly tied to the precision of laboratory procedures. Given the direct implications for future healthcare practice and public health, strict adherence to protocols and a rigorous academic ethos are imperative. For instance, improper specimen collection, such as contaminating a blood sample during pathogen detection, can yield false results, misleading clinical decisions [6,7]. Every step in microbiological procedures, from inoculation to identification, follows explicit guidelines: flaming inoculation loops, maintaining sterile technique, and controlling agar thickness during plating. Even minor errors can compromise microbial growth or cause cross-contamination. Moreover, handling pathogenic microorganisms demands biosafety compliance to prevent laboratory-acquired infections. Thus, standardized operations are emphasized throughout the curriculum to instill habits critical for both academic success and patient safety.

2.3. Close association between experiment and clinic

The ultimate goal of medical microbiology experiments is to serve clinical medical practice. Contents involved in experiments, such as pathogenic bacteria detection and drug sensitivity tests, directly provide critical evidence for clinical diagnosis and treatment. For example, through microbial culture and identification of a patient's sputum sample, the type of pathogenic bacteria causing pulmonary infection can be determined. Combined with the results of drug sensitivity tests, doctors can accurately select effective antibiotics for treatment, thereby improving

the cure rate. Obviously, such experiments require students to master laboratory operation skills, understand the significance of experimental results in clinical diagnosis and treatment, and cultivate the ability to think from a clinical perspective, laying a solid foundation for their future medical careers.

2.4. Special experiments pose significant risks

Due to the involvement of large quantities of pathogenic microorganisms, such as highly infectious pathogens like the hepatitis B virus and Mycobacterium tuberculosis, medical microbiology experiments carry substantial safety risks. Once a laboratory infection occurs, the consequences could be catastrophic. Therefore, experimental safety is of utmost importance. The curriculum includes dedicated safety training sessions to teach students how to properly use protective equipment (e.g., protective clothing, masks, goggles), master methods for handling laboratory waste, and learn emergency response measures for accidents [8–10]. During experiments, strict adherence to safety protocols is required, such as standardizing the placement of experimental materials and restricting personnel movement in experimental areas, to ensure a safe laboratory environment and protect the physical health and life safety of teachers and students.

3. Strategies for virtual simulation technology to boost the reform of medical microbiology experimental teaching

3.1. Constructing virtual simulation experiment centers and platforms

The construction of virtual simulation experiment centers and platforms serves as the foundation for the effective application of virtual simulation technology in medical microbiology experimental teaching. First, schools and relevant educational institutions should increase capital investment to build virtual simulation experiment centers with complete hardware facilities. This includes equipping high-performance computer devices to ensure smooth operation of complex virtual simulation software and meet the needs of multiple students conducting experimental operations simultaneously. In particular, the spatial layout of the center should be reasonably planned to create an environment similar to a real laboratory, allowing students to better immerse themselves in virtual experimental scenarios through immersive experiences. In terms of software platform construction, collaboration with professional educational software developers is essential to customize virtual simulation platforms specifically for medical microbiology experimental teaching. These platforms should cover rich experimental resources, including morphological and structural displays of various microorganisms, simulations of growth and reproduction processes, dynamic demonstrations of infection mechanisms of different microorganisms, etc. The interface design of the platform should be simple and intuitive, facilitating students' operation and navigation [11]. It is necessary to set up clear experimental project classification menus so that students can quickly locate corresponding experimental contents according to their learning progress and needs. Additionally, the platform should have interactive communication functions, enabling students to promptly communicate with classmates and teachers through online discussion areas to share experimental insights and experiences when encountering problems during experiments. The teacher terminal can monitor students' experimental operations in real time, record their operation steps and data, and provide subsequent evaluation and guidance on students' experimental performance [12]. It is believed that one day, medical microbiology experiments will be equipped with fully functional virtual simulation experiment centers and platforms, providing strong technical support for experimental teaching reform and technology-enabled education, and laying a solid foundation for the growth and development of medical students.

3.2. Adding new experimental projects in Medical Microbiology

Traditional experimental projects in medical microbiology are often restricted by experimental conditions, safety factors, etc., making it difficult for students to fully and deeply engage with various microbial experimental scenarios. With the help of virtual simulation technology, a series of novel and challenging experimental projects can be boldly added. First, high-pathogenicity microorganism experimental projects. In real-world experiments, students rarely have the opportunity to operate with highly pathogenic microorganisms due to their significant biosafety risks [13]. However, through virtual simulation technology, students can simulate experimental procedures such as the isolation and identification of highly pathogenic microorganisms in a virtual environment. For example, simulating the laboratory detection process of Ebola virus, SARS virus, etc., allows students to deeply understand the characteristics of these viruses and corresponding detection methods, cultivating their professional literacy and emergency response capabilities in the face of major public health incidents. Second, comprehensive experimental projects. Integrating microbiology experiments with knowledge from related disciplines such as immunology and pathology to design comprehensive virtual experiments. For instance, simulating the entire process of a patient's journey from microbial infection to immune response and pathological changes. In this process, students need to use microbiology knowledge for pathogen detection, immunology knowledge to analyze the body's immune response, and pathology knowledge to explain the mechanisms of lesions, thereby cultivating the ability to comprehensively apply multidisciplinary knowledge to solve practical problems. Third, exploratory experimental projects. On the virtual simulation platform, open experimental topics are provided for students to independently design experimental schemes and conduct explorations. For example, by providing basic information about some unknown microorganisms, students can attempt different identification methods and experimental conditions through virtual operations to explore the types and characteristics of these microorganisms. Evidently, the diversified experimental projects in medical microbiology enrich the experimental teaching content and resources, and expand students' knowledge base.

3.3. Leveraging the auxiliary role of virtual simulation experimental teaching

In microbiology, many experimental phenomena are difficult to intuitively capture through physical operations. Virtual simulation technology, however, can present these microscopic processes to students in an intuitive and clear manner through animations, 3D models, and other forms. Students can watch these visualizations repeatedly to deeply understand the changing patterns of microorganisms under different conditions, which is of great significance for enhancing their comprehension and memory of knowledge. Moreover, virtual simulation experiments are not restricted by time or space—students can log into the system at any time after class to repeatedly practice weak links in their classroom learning, consolidate knowledge, and truly achieve personalized learning [14]. Specifically, in the teaching of pathogenic microbiology, displaying the morphology, growth, and reproduction methods of pathogens can help students more clearly understand the characteristics and impacts of pathogens, thereby better comprehending prevention and control measures. In teaching immunology-related content, multimedia devices can be used to demonstrate the structure and function of the immune system, accompanied by animations and demonstrations, enabling students to deeply understand and remember relevant knowledge points. After class, collecting multimedia materials related to pathogenic microbiology and immunology for students to study independently can expand their knowledge base and depth of thinking, while effectively enhancing their autonomous learning ability and comprehensive analytical skills.

3.4. Note that virtual simulation experiments cannot replace physical experiments

Despite the many advantages of virtual simulation experiments, they can never fully replace physical experiments. The real sense of experience brought by physical experiments is something that virtual simulation cannot replicate. Students can truly feel the touch of experimental equipment, smell the unique odors generated during microbial culture, and it is also conducive to mastering detailed experimental content and operations, laying a solid foundation for future clinical practice. A series of hands-on operations in various types of experiments, such as smearing, fixing, staining, and rinsing, accumulates experience that virtual simulation cannot copy [15]. Therefore, a model that combines virtual simulation experiments with physical experiments is what we should strive to build, and it is beneficial to students' development, medical education, and medical careers. The author has always believed that in medical-related experiments, various unexpected situations are inevitable, and students need to use their learned knowledge to solve problems through actual troubleshooting and operational adjustments. The ability developed in real-life scenarios is equally crucial for students' future entry into clinical work or research fields. In addition, team collaboration in physical experiments is beyond the reach of virtual simulation, making it key to coordinate simulation experiments with physical ones.

4. Conclusion

In summary, virtual simulation technology is an emerging technology that, when applied in the education sector, presents knowledge in a more intuitive manner, facilitating students' absorption of key and difficult knowledge points while being more efficient, energy-saving, safe, and convenient compared to traditional experimental teaching methods. Of course, through a series of attempts at application, we have proposed several improvement strategies combined with medical biology experimental teaching. It is hoped that future virtual simulation experiment platforms can develop mobile application interfaces, enrich diverse functions, provide team collaboration modes, control experimental operation time, etc., to support students' experimental exploration. Additionally, how to cultivate students' professional attitudes and spirit, as well as digital literacy and information literacy, through medical microbiology experimental courses will also be an important part of future teaching work, worthy of in-depth exploration and practice.

Disclosure statement

The author declares no conflict of interest.

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