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Discussion on the Construction Plan and Implementation Scheme of the "Four-in-one" Smart Functional Experiment Center at Hubei University of Medicine

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Abstract [**Objectives**] Based on the existing resources of the Functional Experiment Center at Hubei University of Medicine, this study explores the integration, planning, design, and construction of a "four-in-one" smart laboratory. [**Methods**] The necessity of constructing a smart laboratory is elucidated from the national, university, and college levels, with specific requirements proposed for its development. First, construction objectives are defined; subsequently, existing resources are integrated, planned, and designed to ultimately overcome technical challenges, resulting in a smart laboratory tailored to the university's needs. [**Results**] Through comprehensive research and demonstration, the construction plan and implementation scheme for the smart laboratory are presented in both graphical and textual formats. [**Conclusions**] Following multiple expert seminars, it is concluded that this scheme aligns with the development trend of "Internet + Education", facilitating the deep integration of education and information technology, thereby enhancing the level of informatization construction and application at the university.

Key words Functional laboratory, Integration, planning & design, Construction plan and objectives, Implementation scheme, Four-in-one smart laboratory

0 Introduction

As a base for biomedical teaching, the functional laboratory naturally serves as a cradle for the research, development, validation, and incubation of high-tech innovations in basic medicine[1]. With the rapid advancement of high technologies such as the Internet of Things (IoT), big data, and artificial intelligence, achieving efficient, low-carbon, intelligent, and safe laboratory operations to realize laboratory smartification has become a current hot topic[2]. Based on this, leveraging the opportunity provided by the Medical Education Research Project (Experimental Teaching Special) of the Chinese Society of Pathophysiology, this study addresses the current status of our university's functional laboratory regarding site environment, operators, equipment usage, experimental methods, safety protection, and emergency measures. By combining the current state of smart technology application in domestic laboratories, existing problems, and our university's specific needs, we have summarized a construction plan and implementation scheme for a "four-in-one" smart functional experiment center that fits our teaching characteristics and requirements.

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1 Necessities of constructing a smart laboratory

1.1 Teaching needs Functional experimental science is a multi-disciplinary integrative experimental science based on the theoretical foundations of pharmacology, physiology, and pathophysiology, focusing on phenomena and laws of life activities, pathophysiological changes, and the interaction between drugs and the organism[3]. Transforming the Functional Experiment Center of Hubei University of Medicine into a "four-in-one" smart functional experiment center aligns with the university's commitment to actively promoting "Internet + Education" and enhancing the overall level of teaching and management.

1.2 Upgrading the experimental platform To adapt to the demands of informatized teaching in the new era, upgrading the laboratory is essential. The Experimental Center of the School of Basic Medical Sciences is a Demonstration Center for Experimental Teaching in Hubei Province; upgrading it to build a national first-class basic medical experimental teaching center contributes to the construction of a "Double First-Class" university. The smart functional experiment center represents a solution for the overall construction of the next phase of the functional experiment center, built upon the summary of previous reform ideas.

1.3 Conducive to unified management The construction of a smart platform facilitates efficient laboratory management and helps prevent laboratory safety accidents.

2 Construction objectives

2.1 Introducing advanced concepts (i) Student-centered approach: Being student-centered is a teaching objective explicitly proposed by the Ministry of Education, aiming to fully mobilize enthusiasm for integrating learning with thinking, and innovation with practice. (ii) Early Integration of Basic and Clinical Sciences: The early integration of basic and clinical sciences is an effective teaching model that assists students in combining theory with practice, fostering the concept of applying knowledge to practical use, and laying a solid foundation for becoming excellent doctors or researchers. (iii) Combination of virtual and real: Adhering to the principle of "virtual-real complementarity and prioritizing reality where possible," this approach utilizes virtual simulation technology to complete experimental parts that are difficult or impossible to perform in the laboratory, while reinforcing understanding of knowledge difficulties through forms such as animated demonstrations, effectively improving experimental teaching outcomes.

2.2 Standardized teaching management Unified information management assists laboratory instructors in utilizing modern information technology to improve laboratory management levels. The informatized auxiliary teaching system provides various existing experiment-related resource contents, including experimental teaching courseware, videos, PPTs, e-books, exercises, and extended knowledge materials. The system also provides an E-learning platform for teacher instruction and student learning management, enabling teachers to perform tasks such as: creating proprietary courses (including syllabi, schedules, content, lesson plans, courseware, teaching videos, virtual experiments, assignments, *etc.*), lesson preparation, answering queries, online examinations, and teaching effectiveness analysis. Students can communicate with teachers, learn, submit assignments, and take examinations online.

2.3 Introducing intelligent technology Intelligent technological means not only alleviate the burden on teachers but also enhance laboratory management levels and teaching quality, contributing to establishing a good image for the school, thus killing three birds with one stone. For instance, introducing an intelligent laboratory power management system allows for the automated management and statistics of experimental equipment usage, generating statistical reports on equipment. Similarly, leveraging automatic judgment technology for experimental operations and result accuracy assists teachers in objectively evaluating students' completion of each experiment, fully realizing the role of formative assessment.

2.4 Perfecting the teaching process A perfected teaching process achieves reinforced learning through continuous repetition before, during, and after class, ultimately helping students master knowledge. For example, before the experiment, students utilize online virtual experiments for previewing to grasp basic knowledge and operational steps; during the experiment, they first watch the micro-lecture for the session to preview key points again, followed by watching operational videos to further enhance their perceptual understanding of the experiment.

2.5 Constructing a "four-in-one" experimental teaching method Perfect experimental teaching methods and means can stimulate students' strong exploration drive and learning interest, promoting student learning from various aspects, and ultimately achieving the goal of educating people. Through "four-in-one" smart functional experimental teaching means, organically integrating various experimental methods (such as virtual simulation experiments, *in vivo* and *ex vivo* animal experiments, human functional experiments, *etc.*) with diverse teaching resources and advanced technologies constructs a truly effective teaching system, realizing ideal teaching outcomes.

2.6 Strengthening the construction of the laboratory informatization platform By constructing a perfect laboratory informatization system, teachers can complete the following tasks: creating proprietary courses (including syllabi, schedules, content, lesson plans, courseware, teaching videos, virtual experiments, assignments, *etc.*), lesson preparation, answering queries, online examinations, and teaching effectiveness analysis.

Students can communicate with teachers, learn, submit assignments, and take examinations online.

3 Integration, planning, and design

3.1 Building an integrated and informatized animal experiment platform Integrating our university's functional experimental equipment (including the BL-422i informatized signal acquisition and processing system, BL-422 functional experiment system accessory kit, HW-200S constant temperature smooth muscle bath, BL-30 surgical instrument accessory kit, and HF-12 movable functional experiment platform) into an informatized animal experiment platform enables the completion of all traditional classic functional experiments and facilitates innovative and research-oriented physiological experiments.

3.2 Networked system (formative assessment system) Conducting formative assessment via real-time video recording of the experimental process significantly enhances students' experimental interest and teaching effectiveness. The formative assessment system of the smart laboratory, based on whole-process data collection and analysis, realizes multi-dimensional dynamic evaluation of students' experimental learning progress.

3.3 Building a virtual-real fusion human physiology experiment platform The HPS-103 Human Physiology Experiment System is a new-generation system launched based on concepts such as integration, virtual-real combination, virtual-real linkage, and the combination of basic and clinical sciences. Compared with traditional experimental systems, the core advantages of this system lie in its innovative virtual-real linkage mechanism, AI intelligent acquisition, and VR immersive experience. Its graphical display and sensory stimulation methods can greatly stimulate medical students' interest in human functional science, enhance their clinical thinking abilities, and effectively achieve the teaching goals of "early clinical exposure, strong practice, and emphasis on thinking".

3.4 Constructing a virtual medical experiment platform (VMC-100) The VMC-100 2.0 virtual simulation teaching software employs a combined online and offline model, playing a positive role in stimulating students to explore problems, solve problems, and think independently.

3.5 Constructing an intelligent management system (ILS-100) The ILS-100 smart laboratory system can connect multiple sets of different laboratory equipment, thereby forming a comprehensive laboratory solution with configurability and scalability. This smart laboratory system realizes the smartification of personnel management, course teaching, equipment management, experimental evaluation, environmental monitoring, and information management.

4 Conclusions

The implementation of smart functional experiments has brought significant multi-dimensional results to modern medical education. Relying on a highly integrated and automated system, it optimizes the experimental teaching process in all aspects, improving teaching efficiency and quality. Meanwhile, leveraging functions such as intelligent formative assessment, it achieves multi-dimensional automatic analysis and feedback on students' operational skills and experimental results, significantly enhancing the objectivity of the teaching process and the pertinence of guidance.

Furthermore, smart functional experimental teaching enhances the standardized collection and in-depth analysis capabilities of experimental data, improves the scientific nature and reliability of experimental results, and achieves intelligent scheduling and management of laboratory resources, effectively reducing operating costs.

In comparison, the traditional functional experimental model typically relies on non-integrated equipment and manual operations; due to scattered equipment and complicated steps, it often leads to low operational efficiency. In terms of teaching evaluation, it lacks a systematic automatic assessment mechanism, relying mostly on teachers' subjective experience, making it difficult to conduct comprehensive and objective formative assessments. Simultaneously, there are obvious defects in data integration and resource management, thus facing significant challenges in adapting to the needs of informatization and refined development in modern medical education.

In summary, this project is closely linked to the construction of smart functional experiments at our university. After rigorous research, the relevant schemes were submitted to the college and university levels. During this period, experts were organized multiple times for discussion and demonstration, ultimately forming the Construction Plan and Implementation Scheme for the "Four-in-one" Smart Functional Experimental Teaching Center of Hubei University of Medicine. This scheme conforms to the development trend of "Internet + Education", helps promote the deep integration of information technology with education and teaching, and has a significant driving effect on improving the level of informatization construction and application at our university.

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