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Application of Online-Offline Blended Teaching in Medical Laboratory Education

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Abstract: This study aims to explore the application value of the online-offline blended teaching model in medical laboratory education. Starting from improving learning flexibility, interactivity and personalization as well as enriching teaching resources, this paper systematically elaborates the core advantages of this teaching model. With reference to practical teaching cases, it specifies the implementation procedures of blended teaching, including the development of online teaching resources, offline curriculum design, and integration strategies for online and offline teaching components. Furthermore, this paper comprehensively analyzes practical challenges such as insufficient information technology competency among teachers, prominent gaps in students' autonomous learning ability, and high costs for the development and maintenance of teaching resources. Targeted countermeasures are accordingly proposed. This model can provide theoretical support and practical guidance for educators engaged in medical laboratory teaching, and effectively facilitate the improvement of teaching quality.

1. Introduction

Medical laboratory specialty is characterized by strong practicality, intensive instrument and equipment deployment, stringent biosafety requirements, and close integration with clinical diagnosis and treatment. Current teaching practices commonly suffer from insufficient practical resources, restricted access to high-end instrument operation, difficulties in conducting high-risk experiments, disconnection between theoretical knowledge and clinical practice, and inadequate cultivation of students' autonomous learning ability and clinical thinking[1]. These problems have led to gaps between talent training outcomes and post competency requirements. Relying on virtual simulation, online resources and digital platforms, the online-offline blended teaching model can break temporal-spatial and equipment-related constraints, strengthen standardized operation and safety awareness, and enhance students' capacity for theoretical knowledge transformation and clinical connection. By organically combining the merits of conventional face-to-face teaching with

the flexibility of online teaching, blended teaching can fully motivate students' learning initiative and boost teaching efficiency and effectiveness[2]. It represents not only an innovation in teaching methodology, but also a vital measure for hospitals to optimize the allocation of teaching resources, improve professional literacy of medical staff, and guarantee the quality of medical services. This paper discusses the implementation pathways and application effects of blended teaching, so as to provide theoretical references and practical evidence for improving the training quality of medical laboratory professionals and satisfying the demands of clinical laboratory work.

2. Advantages of Online-Offline Blended Teaching in Medical Laboratory Teaching

Centering on core post requirements including accurate detection, standardized operation, reliable test results and safety prevention-control, medical laboratory specialty integrates practicality, technicality and clinical applicability. Conventional teaching models have obvious drawbacks: disconnection between theoretical lectures and practical training, insufficient operational drills, limited instrument resources, and difficulty in full-process simulation of biosafety risks. Such models can hardly meet comprehensive competency requirements for laboratory professionals in clinical settings. Through consolidating foundational knowledge online, cultivating practical skills offline, and promoting competence improvement via virtual-real integration, online-offline blended teaching realizes complementarity in resources, scenarios and competencies. It presents prominent strengths in standardized operational training, clinical thinking cultivation, result-analysis capacity building and biosafety assurance.

Online teaching breaks time-space and resource restrictions and lays a solid foundation for offline practical training. Supported by virtual simulation experiments, standardized operation videos, online question banks and typical case libraries, students can get acquainted with instrument principles, operational workflows, detection methodologies and key points of quality control in advance, and repeatedly observe standardized manipulations. It effectively addresses common bottlenecks in offline practical training, such as insufficient instrument quantity, inappropriateness of full-student participation in high-risk experiments, and obstacles in repeated demonstration of workflows. Online platforms can display abnormal test results, interference factors, internal quality control and external quality assessment cases in real time, guiding students to proactively reflect on detection principles and factors influencing test results. In this way, theoretical knowledge is pre-emptively imparted, operational workflows are visualized, and problem-oriented thinking is stimulated beforehand, which prepares students for efficient offline practical training.

Offline teaching focuses on hands-on drills and on-site guidance to consolidate skill mastery and safety specifications. Targeting weak points identified from students' online learning, teachers conduct hands-on operational tutoring, item-by-item error correction and on-site assessments, with priority given to core skills such as sample processing, instrument manipulation and result interpretation, to ensure that all operations comply with industrial standards and laboratory specifications. Offline scenarios can realistically restore clinical laboratory workflows and reinforce critical links including aseptic manipulation, biosafety protection and medical waste disposal, helping students foster professional awareness of safety priority and standard compliance in real-world settings. Meanwhile, offline activities such as group discussions, case seminars and result reviews can stimulate students' interaction and improve their teamwork and problem-solving capabilities.

In-depth integration of online and offline teaching generates synergistic effects in standardizing operations, cultivating clinical thinking, interpreting results and guaranteeing biosafety. Online modules deliver standardized operations and massive clinical cases to consolidate cognition of theories and workflows; offline sessions strengthen hands-on practice and on-site error correction to

guarantee operational standardization and safety. Online platforms facilitate repeated review and iterative training for students to enhance their capabilities in result analysis and logical reasoning; offline teaching emphasizes practical application and promotes the transformation of knowledge into post-specific competencies. This model resolves the limitations of conventional practical teaching including resource shortages and poor risk controllability, and compensates for the deficiencies of pure online teaching such as lack of real-world experience and insufficient skill training. It truly achieves learning-driven practice, practice-consolidated knowledge, safety-oriented practice and clinical-competence-enhanced practice.

Highly compatible with post requirements for medical laboratory specialty, online-offline blended teaching effectively improves students' operational standardization, clinical thinking, result-interpretation proficiency and biosafety literacy. It aligns teaching procedures with post standards and teaching contents with clinical demands, providing a scientifically sound teaching pathway for cultivating high-quality, application-oriented and skill-based medical laboratory professionals.

3. Implementation of Online-Offline Blended Teaching for Medical Laboratory Education

3.1 Precise Alignment with Post Requirements: Design and Preparation for Blended Teaching

Blended teaching is developed based on specialty features, clinical post requirements and clear competency objectives. During preparation, core laboratory job competencies guide curriculum reorganization. Content is divided into six modules: theory, operational skills, result interpretation, quality control, biosafety and clinical application, with defined online/offline tasks and logical connections.

Online resources include micro-lectures, virtual simulations, operation animations, exercises and case libraries covering assay principles, workflows, SOPs, abnormal results, quality control and biosafety regulations. Virtual simulations handle high-risk operations, costly instruments and hazardous samples unsuitable for full offline practice, enabling safe workflow training. An online platform integrates task sheets, knowledge modules, staged tests, discussion boards and Q&A to track learning.

Offline teaching focuses on hands-on training, error correction, group seminars and on-site assessment. Laboratories, analyzers, specimens and simulated cases are allocated properly, with standardized training and safety protocols. Faculty unify teaching criteria and link online pre-learning to offline practice. Students complete online preview before offline skill and thinking training, forming a framework: online foundation building, offline competency enhancement, whole-process integration.

3.2 Online Autonomous Learning: Consolidating Theoretical Foundations, Standardizing Operational Cognition and Stimulating Pre-emptive Clinical Thinking

The online stage delivers knowledge, pre-trains practical skills and records progress, reducing offline teaching burden.

Task-driven preview is assigned via pre-class task sheets, listing key knowledge, operational essentials and reflective questions. Students learn instrument principles, standard procedures and safety knowledge through micro-lectures, operation videos and virtual simulations.

Standard operation and biosafety awareness are strengthened. By reviewing standard demonstrations, error cases and safety animations covering the full testing workflow, students lower risks in offline practice.

Online question banks and clinical cases train students in result interpretation, data recording and

error analysis, establishing links between detection methods, conditions, results and clinical significance. The platform automatically logs learning data for teachers to identify weaknesses and tailor offline instruction.

Students post questions in discussion zones; teachers conduct regular Q&A. Common problems are prioritized in offline sessions to avoid redundant teaching.

3.3 Offline Practical Training: Consolidating Skill Implementation, Deepening Clinical Thinking and Ensuring Safety Specifications

Offline practice serves as the core of blended teaching, converting online knowledge into professional competencies through hands-on operation, real-time correction, teamwork, result analysis and biosafety drills.

Teachers explain common misconceptions and operational pitfalls using online learning data, fostering a quality-first mindset.

Stratified group training is implemented: universal basic drills, intensive key-skill training and group operation for complex analyzers. Students complete full laboratory workflows, while instructors provide roaming guidance and on-site correction. For expensive and high-risk experiments, the "virtual simulation → live demonstration → rotational practice" mode ensures safety and expands training coverage.

Biosafety and quality control training is intensified in authentic scenarios. Students follow clinical biosafety grading rules covering personal protection, decontamination, sample transport, waste disposal and emergency response. Quality control charts and out-of-control cases cultivate error identification, cause analysis and corrective action.

Case seminars connect test results with clinical and differential diagnoses. Groups analyze data, evaluate reliability and draft preliminary reports. Teachers guide students to evolve from simple operators to competent laboratory analysts, strengthening clinical thinking and job adaptability.

Real-time on-site assessment uses random operation checks, workflow narration, result review and safety quizzes, with immediate feedback and revision guidance.

3.4 Online-Offline Closed-Loop Interaction: Consolidation, Expansion and Progressive Competency Improvement

Online and offline activities form a mutually reinforcing closed loop rather than simple addition.

After offline training, the online platform supports review and extended learning. Students replay operation videos and redo virtual simulations to reflect on practical errors and complete assignments. Teachers share summaries, supplementary cases and readings; targeted online lectures resolve common offline issues, forming a loop: offline problem identification → online remediation → offline re-practice and improvement.

Process-oriented multidimensional evaluation is adopted. Metrics include online learning behavior and offline performance such as operational standardization, safety awareness, teamwork and result analysis. This system objectively reflects comprehensive competencies and motivates learning.

3.5 Continuous Improvement and Optimization for Systematic and Feasible Implementation Pathways

The teaching system undergoes problem-oriented iterative improvement. Regular evaluations use classroom observation, student feedback, assessment data and peer review to examine resource quality, training arrangement, online-offline connection, biosafety guarantees and clinical

alignment.

Adjustments update teaching content, resources and organization. New instruments, assays and specifications are incorporated; assessment standards and key-link training are refined. Early warning and personalized tutoring support underperforming students. Iterative optimization creates a systematic, standardized and replicable pathway matching clinical post demands and industry criteria.

Centered on competency cultivation, this blended model integrates theory, practical skills, safety, quality control, clinical thinking and practice via pre-class online preparation, in-class offline skill training, post-class cross-platform review and continuous evaluation-feedback loops. It fits laboratory medicine's characteristics: heavy practical workload, extensive instrument application, strict biosafety standards and close clinical links. The systematic, targeted and operable model improves talent training quality and offers references for training high-level applied laboratory professionals.

4. Application Cases of Online-Offline Blended Teaching in Medical Laboratory Teaching

Clinical biochemistry testing is a core curriculum for medical laboratory majors, integrating theoretical knowledge and practical skills. Conventional teaching models are plagued by disconnection between theories and clinical practice and insufficient teaching flexibility. To optimize teaching outcomes, this paper takes the chapter "Blood Glucose Determination and Its Clinical Significance" as an example. A controlled trial is designed with two parallel classes of medical laboratory students: the experimental group (30 students) adopts the online-offline blended teaching model, while the control group (30 students) receives conventional offline "theory plus practical training" teaching. For the experimental group, teaching resources are delivered online for targeted Q&A and autonomous learning; offline sessions focus on hands-on practical training and clinical-competence improvement; post-class review and consolidation are completed on online platforms. A closed-loop teaching mode of "pre-class preview — in-class practical training — post-class consolidation" is established. After the intervention, theoretical examination scores, practical skill scores and learning satisfaction are compared between the two groups. The results show that the theoretical scores of the experimental group and the control group are 94 ± 0.2 and 88 ± 0.3 respectively; practical skill scores are 92 ± 0.1 and 85 ± 0.2; learning satisfaction rates are $95 \pm 0.3\%$ and $86 \pm 0.1\%$. Compared with the control group, the experimental group achieves statistically significantly higher theoretical scores, practical skill scores and learning satisfaction ($P<0.05$). This research indicates that the blended teaching model can effectively resolve pain points in conventional teaching and improve teaching quality, providing feasible references and practical cases for teaching reform in clinical biochemistry testing courses.

Blended teaching has also been applied to multiple courses including microbiology[3-6], biochemistry and clinical biochemistry testing technology[7], clinical molecular biology[8], clinical hematology[9], clinical immunology[10-11], and clinical parasitology laboratory testing[12]. Comparative analysis of academic performance between classes receiving blended teaching and those under conventional teaching demonstrates that students in blended-teaching classes achieve obviously better scores in final examinations and practical assessments. Questionnaire surveys and student interviews also reveal high satisfaction toward blended teaching: students report enhanced learning interest, initiative and overall learning effectiveness.

5. Challenges and Countermeasures for Online-Offline Blended Teaching in Medical Laboratory Teaching

5.1 Practical Challenges

First, high costs for experimental teaching and insufficient instrument quantity restrict full-participation offline practical training. Medical laboratory teaching relies on high-value instruments such as biochemical analyzers, hematology analyzers and microbial identification systems. Due to inadequate instrument quantity and limited practical stations, universal hands-on practice and repeated training cannot be realized for all students. Conventional practical training mostly adopts observation and rotational group operations, leading to insufficient practical intensity.

Second, strict biosafety requirements hinder offline implementation of high-risk experiments. Clinical specimens are infectious; procedures involving pathogenic microorganisms, blood-body fluids and sharp instruments carry high safety risks. Unskilled student operations may trigger safety hazards. Some experiments with high-pathogenicity and high-risk properties cannot be implemented on a large scale, creating gaps between teaching contents and authentic clinical scenarios.

Third, disconnection between online virtual simulation and offline hands-on practice undermines operational standardization. Although virtual simulation can reproduce workflows, there are disparities in tactile perception, manipulation techniques and detailed control compared with real-world operations. Some students treat online learning perfunctorily, and still exhibit non-standard operations, unskilled workflows and weak quality-control awareness in laboratory settings.

Fourth, rapid updates of testing technologies lead to desynchronization between online resources and clinical standards. Detection technologies, methodologies, industrial specifications and quality-control criteria are updated rapidly. However, online resources such as micro-lectures, videos and question banks are often updated with delays, resulting in disconnection between teaching contents and clinical SOPs and impairing post-competency cultivation.

Fifth, difficulties in process supervision impede precise evaluation of learning outcomes. Online learning depends heavily on student autonomy; some students merely accumulate learning duration passively and complete tasks in a perfunctory manner. Teachers cannot fully grasp preview quality, comprehension status and individual weak points of students, which gives rise to poor online-offline connection and low efficiency in offline practical training.

5.2 Systematic Countermeasures

A model of “prior online virtual simulation + stratified offline practical training” is constructed to relieve pressures from equipment constraints and high costs. Partial high-cost and high-consumption pre-experiments are replaced by virtual simulation experiments. Students get familiar with workflows, parameter settings and simulated instrument operations online in advance to reduce consumable and instrument wear-and-tear. Stratified offline practical training is implemented: universal drills for basic operations, group-based drills for core instruments, and the combination of observation, simulation and rotation for complex equipment, so as to improve equipment utilization and guarantee practical opportunities for every student. Meanwhile, an open-laboratory reservation system is adopted to extend training hours and satisfy students’ demands for repeated practice.

Dual safeguards of “online safety training + on-site offline supervision” are established to uphold biosafety bottom lines. Special online biosafety modules are built, containing videos and question

banks covering protection workflows, specimen handling, medical waste disposal and emergency response. Students are not allowed to enter laboratories without passing online safety assessments. Offline sessions implement dual-teacher guidance, itinerant supervision and real-time error correction. Simulated specimens are adopted to replace clinical infectious specimens for high-risk experiments, and virtual simulation substitutes real-world infectious experiments, achieving zero safety risks while securing teaching effects.

Standardized alignment between online and offline teaching is promoted to strengthen training for operational standardization. SOP criteria for online resources and offline practical training are unified to guarantee consistency among video demonstrations, virtual manipulations and on-site practical sessions. A closed-loop training workflow is established: "online observation and imitation — offline hands-on practice and error correction — online review and reflection". Teachers conduct item-by-item assessments focusing on critical steps including sample loading, centrifugation, instrument testing, quality control and result recording. Operational standardization is incorporated into process-oriented evaluation to foster students' professional habit of standard compliance.

A dynamic resource-updating mechanism is established to synchronize teaching contents with clinical practice. A resource-development team consisting of professional teachers and clinical laboratory technicians is organized. New instruments, new methodologies, updated quality-control requirements and revised industrial standards are timely converted into online micro-lectures, case libraries and operational videos. Online question banks and virtual simulation projects are updated periodically to ensure teaching contents keep pace with clinical practice and post requirements.

Data-driven targeted teaching is implemented to improve the effectiveness of online-offline connection. Big data from learning platforms is utilized to monitor learning duration, task completion rates, test scores and error types in real time, so as to identify common problems and individual deficiencies. Targeted explanations and personalized tutoring are delivered in offline teaching. Task-driven learning, pre-class quizzes and random questioning are adopted to improve online learning outcomes, realizing the goal of "effective online learning and applicable offline practice".

Core challenges for blended teaching in medical laboratory practice mainly lie in costs, equipment, safety, practical manipulation and clinical alignment. Only by adhering to three footholds: problem orientation, specialty characteristics and clinical demands, and adopting systematic strategies of "virtual-practical complementarity, equal emphasis on safety and training, online-offline closed-loop interaction, and teaching-clinical synchronization", can we resolve bottlenecks in experimental teaching, improve practical teaching quality, and cultivate high-quality medical laboratory talents with standardized operations, solid safety awareness, sound clinical thinking and satisfactory post-matching competencies.

6. Conclusions

The online-offline blended teaching model presents remarkable advantages in medical laboratory education. It improves learning flexibility, enhances learning interactivity, facilitates personalized learning and enriches teaching resources. Through rational development of online resources, offline curriculum design and online-offline integration strategies, the quality of medical laboratory teaching can be effectively elevated. Nevertheless, its implementation is confronted with challenges including teachers' insufficient information technology competencies, disparities in students' autonomous learning capabilities, and high costs for the development and maintenance of teaching resources. These obstacles can be overcome by strengthening information-technology training for teachers, fostering students' autonomous learning competence and optimizing the utilization of teaching resources, so as to promote wide application of blended teaching in medical laboratory

education. In the future, with continuous advancement of information technology, blended teaching models will be further improved and innovated to deliver stronger support for talent cultivation in medical laboratory discipline.

In summary, online-offline blended teaching injects new vitality into medical laboratory education and serves as an effective pathway for improving talent-training quality. Further promotion of blended teaching relies on sound hospital teaching management systems. By optimizing resource allocation, strengthening process supervision and perfecting evaluation mechanisms, collaborative improvement of teaching quality and medical service quality can be realized, providing talent support for sustainable hospital development. Educators should actively embrace this reform, keep exploring and innovating, and contribute to the advancement of medical laboratory education. Meanwhile, universities and relevant institutions are supposed to provide necessary policy support and resource guarantees for blended teaching, so as to boost the comprehensive improvement of medical laboratory education.

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