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Exploration and Application of the "Dual-Line Integration Mode" in Systematic Anatomy Experimental Teaching

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Abstract: *Objective:* To explore the application effect of the "dual-line integration teaching mode" in the experimental teaching of systematic anatomy. *Methods:* A total of 120 students majoring in clinical medicine (Grade 2022) from Hunan University of Medicine were selected and randomly divided into a control group (traditional offline teaching mode) and an experimental group (dual-line integration teaching mode), with 60 students in each group. The control group adopted the traditional teaching mode, where teachers gave explanations and students observed specimens; the experimental group implemented online-offline blended teaching based on the 3D human anatomy specimen teaching system, specimen demonstration videos, and a case-based learning case bank. The teaching effect was evaluated through questionnaire surveys and final comprehensive scores (including theoretical scores, experimental skill assessment scores, and daily performance scores). *Results:* Compared with the control group, the students in the experimental group showed significant improvements in knowledge mastery ability, hands-on operation ability, teamwork ability, and communication and expression ability ($P < 0.05$); the final theoretical scores (44.4 ± 3.4 points vs. 40.8 ± 5.3 points) and experimental skill assessment scores (17.4 ± 2.3 points vs. 14.2 ± 3.9 points) of the experimental group were significantly higher than those of the control group, with statistically significant differences ($P < 0.05$). *Conclusion:* The "dual-line integration teaching mode" can effectively improve the quality of experimental teaching in systematic anatomy, promote the comprehensive development of students' learning abilities, and provide new ideas for medical experimental teaching.

Keywords: Anatomy; Online-offline integration; Informatization; Teaching mode; Operational competence

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1. Introduction

Systematic Anatomy is a fundamental medical course that emphasizes experiments and specimen observation in teaching [1], with experimental classes occupying a pivotal position [2]. Although online theoretical teaching has achieved favorable outcomes in certain domains [3], how to enhance the quality of experimental teaching remains a pressing issue. The online-offline blended teaching model, as an inevitable trend in contemporary educational development [4], often suffers from the limitation of separation and fragmentation in its dual-line teaching approach [5]. Achieving the integration and symbiotic development of dual-line teaching has become a significant opportunity and challenge in the reform of medical higher education, as well as a core issue that urgently needs to be addressed in teaching practices of the new era [6]. This study aims to explore new teaching approaches that can respond to unexpected situations and improve the quality of Systematic Anatomy experimental courses. This is achieved by constructing information-based resources for the experimental curriculum, breaking the limitations of online experimental teaching, and tightly integrating online and offline instruction to realize the "blended integration of dual-line teaching."

2. Materials and methods

2.1. Subjects

A total of 120 clinical medicine majors of Grade 2022 from Hunan University of Medicine were selected as the research subjects and randomly divided into an experimental group and a control group, with 60 students in each group. There were no statistically significant differences in gender, age, physical condition, and learning ability between the two groups ($P > 0.05$).

2.2. Teaching methods

All students used the same textbooks, teaching syllabuses, teaching schedules, and assessment methods. The teaching mode of theoretical courses was also consistent, with the traditional teaching method adopted for all. Teachers first delivered lectures and demonstrated operations, after which students observed physical specimens and models in groups. Meanwhile, teachers patrolled to provide guidance and answer questions, and finally made a summary.

Control group: Adopted the traditional offline experimental teaching model, without access to online resources such as the 3D human anatomy specimen teaching system and specimen demonstration videos. Experimental group: Implemented the "dual-line integration" teaching model, combining online resources with offline practice, with the same teaching duration as the control group.

2.2.1. Instructional design pre-class

The experimental group was divided into 10 subgroups. The learning objectives and online resources for the experimental course were pushed in advance via the Superstar Learning Platform, the online 3D human anatomy specimen teaching system was made available, and case-based learning (CBL) tasks were assigned. The students were required to conduct collaborative learning and summarize the content for presentation.

In-class: Randomly selected team members present their pre-class assignments, while other teams pose questions, with the teacher providing guidance and supplementary information. The teacher then summarizes key and difficult points, analyzing structural morphology, location, and function in conjunction with clinical cases. Students are encouraged to use mind maps, drawings, and other methods to consolidate their understanding. Online teaching was carried out in the form of live-stream interaction by integrating cloud classrooms, the Superstar Platform, and the 3D anatomy specimen system; offline teaching was conducted with virtual-real interactive activities by utilizing the 3D specimen system, physical specimens, and models in the laboratory.

Post-class: Online, review exercises such as labeling tasks and case analyses are assigned through the 3D anatomy specimen system, allowing teachers to monitor completion in real time and provide targeted Q&A support. Extracurricular activities, including anatomy drawing and specimen creation, are organized to further reinforce learning outcomes.

2.2.2. Informatization resource construction enhancement of the 3D human anatomy specimen teaching system

In collaboration with Shandong Digital Human Technology Co., Ltd., 3D scanning technology has been utilized to process and annotate laboratory specimens, thereby constructing an online 3D anatomy specimen teaching system. Students can independently label anatomical structures as needed to strengthen their memory.

Production of anatomical specimen demonstration videos and establishment of a CBL case database: Demonstration videos of anatomical specimens are recorded based on key knowledge points and, after editing, are uploaded to the experimental course resource library for students' pre-class self-study and post-class review. Simultaneously, typical clinical cases are collected, integrated, and modified in alignment with students' theoretical knowledge to establish a CBL case database.

2.3. Observation indicators and assessment evaluation

Upon completion of the teaching program, a comprehensive assessment is conducted. The overall grade is composed of the final theoretical examination (60%), practical skills assessment (20%), and regular performance (20%). Theoretical examination: The examination is uniformly designed by the teaching department in a closed-book format. It includes terminology explanations (10 points), fill-in-the-blank questions (20 points), single-choice questions (30 points), and essay questions (40 points), totaling 100 points. The focus is on assessing knowledge mastery and clinical application abilities. Papers are graded collectively and strictly according to standardized scoring criteria. Practical skills assessment: Conducted in the form of physical specimen identification, the assessment consists of 10 structures (7 from osteology, 3 from myology), each worth 10 points, totaling 100 points. It must be completed within 3 minutes, with a focus on testing structural recognition ability. Regular performance: It is marked out of 100 points, covering attendance, in-class performance, the viewing of audio and video materials on the Superstar Learning Platform, and the completion of chapter quizzes. It assesses students' learning attitudes and participation levels. Questionnaire survey on teaching effectiveness: A self-designed questionnaire was distributed to the experimental group, focusing on 7 indicators, including knowledge mastery and practical operation, and a three-level evaluation criterion was adopted to quantify the impact on comprehensive abilities. The questionnaire recovery rate was 100%. The test results showed that the reliability coefficient (Cronbach's α) was 0.83, indicating good reliability and validity.

2.4. Statistical methods

Data analysis was performed using SPSS 27.0 software. Measurement data were expressed as mean ± standard deviation (SD), and comparisons between groups were conducted using the independent-samples *t*-test. Enumeration data were expressed as frequencies, and comparisons between groups were made using the chi-square test. A P value < 0.05 was considered statistically significant.

3. Results

3.1. Results of the questionnaire survey

The results of the questionnaire survey showed that most students recognized that the dual-line integration teaching model had effectively improved their relevant learning abilities (**Table 1**).

Table 1. Results of the questionnaire survey on the ability improvement of students in the experimental group [*n* (%)]

Effect	Comprehensive improvement	Partial improvement	No improvement
Knowledge mastery ability	57 (95.0%)	2 (3.3%)	1 (1.7%)
Practical operation ability	54 (90.0%)	4 (6.7%)	2 (3.3%)
Team collaboration ability	56 (93.3%)	3 (5.0%)	1 (1.7%)
Communication and expression ability	55 (91.7%)	3 (5.0%)	2 (3.3%)
Ability to interpret and distinguish anatomical charts	57 (95.0%)	3 (5.0%)	0 (0%)
Literature retrieval ability	51 (85.0%)	7 (11.7%)	2 (3.3%)
Comprehensive analysis ability	56 (93.3%)	3 (5.0%)	1 (1.7%)

3.2. Analysis of comprehensive scores

This study compared the final comprehensive scores of the experimental group and the control group. The results showed that the experimental group had significantly higher scores than the control group in terms of final theoretical scores, experimental skill scores, and comprehensive scores ($P < 0.05$). Although the regular performance of the experimental group showed an upward trend, the difference was not statistically significant (**Table 2**).

Table 2. Comparison of final comprehensive scores between the experimental group and the control group

Group	Theoretical score	Experimental score	Regular score	Comprehensive score
Control	40.8 ± 5.3	14.2 ± 3.9	18.3 ± 1.5	74.8 ± 8.6
Experimental	44.4 ± 3.4*	17.4 ± 2.3*	18.8 ± 1.9	81.2 ± 7.8*
t-value	4.432	5.472	1.603	4.271
P-value	< 0.001	< 0.001	0.111	< 0.001

*$P < 0.05$ vs control group

4. Discussion

In recent years, the deep integration of digital resources in the field of education has provided solid technical support for the reform of anatomical experiment teaching, promoting the gradual transformation of anatomical experiment teaching from traditional physical dependence to the integration of virtual and real approaches [7]. Currently, in the digitization of anatomy education, virtual digital human resources—leveraging 3D modeling technology—can clearly delineate the hierarchical structures of the human body, serving as a crucial supplementary tool for offline laboratory teaching [8]. However, constrained by the technical characteristic of massive data volume across multiple modules [9], its data transmission and online interaction efficiency are relatively low, making it difficult to meet the convenience requirements of online teaching scenarios. This results in an obvious disconnect between online and offline digital resources. From 2020 to 2022, the online experimental courses in Systematic Anatomy conducted by our teaching department, consistent with most related studies, utilized two-dimensional resources such as images and instructional videos for teaching [10].

However, practical feedback has shown that these flat resources are inadequate in helping students establish three-dimensional spatial cognition, particularly revealing significant limitations in understanding complex structures like the cranial base and mediastinum. In addition, although the commonly used 3Dbody software can provide a three-dimensional viewing angle, it has a texture difference between the virtual model and the real specimen, lacks the physical observation experience required for clinical practice, and thus fails to achieve an effective connection between anatomical knowledge and clinical application.

To address the current pain points in anatomical experiment teaching, such as the difficulty in online application of virtual digital human resources and the lack of three-dimensional cognition with planar resources, this study collaborated with Shandong Digital Human Technology Co., Ltd. to innovatively construct a 3D Human Anatomical Specimen Teaching System. The system performs 3D scanning, precise annotation, and database integration of physical specimens in the laboratory. It not only retains the morphological details and realistic texture of physical specimens to solve the problem of virtual digital humans being divorced from clinical practice, but also supports online multi-angle observation and independent annotation to compensate for the lack of spatial cognition in planar resources, thus achieving the goal of online preview ability and offline operability. On this basis, the study further refined the digital resource system: establishing a specimen demonstration video library for pre-class self-learning and post-class review, constructing a CBL case library to support the teaching that connects anatomical knowledge with clinical scenarios, and building an experimental examination question bank based on the 3D digital specimen library to break through the bottlenecks of traditional examinations and achieve the standardization of assessments. The resource development approach achieves the digital integration of teaching materials, learning resources, and specimen preservation through the collaboration of multidimensional resources. It strengthens students' ability to understand and apply knowledge via a closed-loop design consisting of independent preview, clinical correlation, and standardized assessment, which is consistent with the conclusion that the rational application of various digital resources can simultaneously improve students' academic performance and teachers' teaching effectiveness [11].

From the perspective of teaching model optimization, the traditional online LBL model for systematic anatomy involved in this study can ensure the continuity of teaching under special scenarios such as public health emergencies [12]. However, this mode of one-way knowledge transmission fails to meet the core requirements of medical education for interactive experience and clinical thinking cultivation. Medical students majoring in clinical medicine need to understand the inherent correlations between structure, function, and disease on the basis of mastering anatomical structures, yet the LBL model lacks a mechanism to guide students' active exploration, making it difficult to achieve this training goal. The CBL teaching method is driven by clinical cases. It guides students to think actively through heuristic questioning, which is more suitable for medical freshmen who have a weak foundation and are in large numbers. Moreover, it is easier to exert the advantages of teacher-student interaction and ideological collision in small-sized experimental classes [13]. Based on this, this study takes CBL as the link in the online-offline integrated teaching mode and constructs a closed-loop teaching process covering pre-class, in-class, and post-class stages. This design not only makes up for the deficiency of the LBL model that emphasizes memorization over application [14], but also cultivates students' abilities of teamwork and communication through group collaboration and presentation. The questionnaire results indicate that the experimental group of students achieved comprehensive improvement rates exceeding 85% across seven indicators, including knowledge mastery ability (comprehensive improvement rate 95.0%) and hands-on operation ability (comprehensive improvement rate 90.0%). This aligns with the significantly higher experimental skill assessment scores of the experimental group compared to the control group (17.4 ± 2.3

vs 14.2 ± 3.9, $P < 0.001$), demonstrating the effectiveness of this model in cultivating practical skills.

Aiming at the experimental teaching of systematic anatomy, this study constructs an online-offline integrated experimental teaching mode. Online, relying on digital resources such as the 3D Human Anatomical Specimen Teaching System and the specimen demonstration video library, it breaks the constraints of time and space, supports students to carry out independent learning at their own pace, and gives full play to their subjective initiative [15,16]. Offline, it focuses on practical operation and interaction. Teachers guide students to carry out experimental operation training through physical specimen demonstration, on-site discussion, and Q&A, cultivate their abilities of specimen identification and skill operation, and make up for the lack of practical experience in online learning. This mode is the implementation of the concept of student-centered and teacher-led teaching. Practical data show that the theoretical scores (44.4 ± 3.4 points), experimental skill scores (17.4 ± 2.3 points), and comprehensive scores (81.2 ± 7.8 points) of the experimental group are significantly higher than those of the control group, providing effective support for the experimental teaching of systematic anatomy. However, this study still has certain limitations. First of all, the sample size is relatively small, and the sources are single, which may affect the generalizability of the research results. Secondly, no follow-up evaluation has been conducted on the knowledge retention rate of students in the long-term learning process and the continuous development of their clinical thinking ability.

5. Conclusion

To sum up, the application of the online-offline integrated mode in the experimental teaching of systematic anatomy has significant advantages, which can effectively improve the teaching quality and students' comprehensive abilities. Future research can expand the sample scope, include students from different colleges and universities as well as different majors to conduct multicenter studies, so as to enhance the generalizability of the results. Meanwhile, it can extend the observation period, conduct follow-up evaluations on students' long-term learning effects, continuously optimize and improve the online-offline integrated mode, and provide a more solid theoretical and practical basis for the reform and development of medical experimental teaching.

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Disclosure statement

The authors declare no conflict of interest.

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