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Effects of a Digital Intelligence-Empowered Blended Teaching Model in a Medical Reproductive System Course

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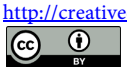

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Abstract

Objective: To investigate the efficacy of an integrated online and offline teaching model empowered by digital intelligence in the course on reproductive system diseases. **Methods:** A total of 192 first-semester clinical medicine students from September 2023 to July 2024 were assigned to the control group, receiving traditional instruction. Meanwhile, 172 second-semester students formed the observation group, where a blended teaching approach incorporating digital medicine was implemented. Post-semester evaluations compared the teaching quality and learning outcomes between the two groups. **Results:** The observation group exhibited lower usual scores but significantly higher final exam and overall scores compared to the control group ($P < 0.05$). Additionally, the observation group demonstrated significant improvements in content comprehension, learning interest, self-directed learning skills, team communication and collaboration, scientific research thinking, and teacher-student interaction ($P < 0.05$). No significant differences were observed in medical humanistic care, professional mission, or social responsibility between the groups ($P > 0.05$). Overall satisfaction was notably higher in the observation group ($P < 0.05$). These findings suggest that the blended teaching model supported by digital intelligence can effectively enhance teaching outcomes and students' understanding and application of complex knowledge. **Conclusion:** The implementation of a digital intelligence-enabled blended teaching model in reproductive system disease courses significantly improves academic performance and practical skills, with high student satisfaction. This approach holds potential for enhancing teaching quality and fostering comprehensive student development.

Keywords

Digital Intelligence Technology, Mixed Teaching, Reproductive System Course, Medical Education, Teaching Reform

1. Introduction

The report of the 20th National Congress of the Communist Party of China explicitly proposed the requirement to "promote educational digitization", aiming to cultivate future builders of socialism who are developed morally, intellectually, physically, and aesthetically. In the rapidly developing era, as an important part of higher education, clinical medical teaching must keep pace with the times, actively explore methods for educational digitization, and contribute to the cultivation of high-quality talents with both moral integrity and professional competence. The "Guiding Opinions of the General Office of the State Council on Accelerating the Innovative Development of Medical Education", released in September 2020, also pointed out the direction for medical education reform, emphasizing the improvement of talent cultivation quality, accelerating the training of high-level interdisciplinary medical talents, and promoting the "Medicine + X" multidisciplinary integrations (Wang et al., 2023). In the context, digital intelligence empowerment is gradually penetrating and profoundly influencing the transformation of traditional teaching models such as medical education. Its impact is particularly significant in the teaching of reproductive system diseases (Gao et al., 2024). Although traditional learning modes for professional knowledge hold a foundational position, issues such as the static nature of information transmission, lack of teacher-student interactions, the highly abstract professional knowledge, and the disconnections between theory and practice severely restrict the improvement of student learning efficiency and the cultivation of clinical thinking and skills. In recent years, the blended teaching model, with its unique advantage of integrating the flexibility of online teaching with the intuitive interactive experience of offline teaching, has become a forefront trend in higher education reform and innovation. The vigorous development of digital intelligence empowerment, especially the application of advanced technologies such as augmented reality, virtual reality, 3D simulation, and interactive learning platforms, provides innovative solutions to these traditional teaching challenges (Magalhães & Cruz-Correia, 2024; Gan et al., 2023). Therefore, this study innovatively introduced the combination of digital intelligence empowerment and the online-offline blended teaching model in the reproductive course, fully leveraging the advantages of both to provide students with a more flexible, vivid, and highly interactive learning experience.

2. Data and Methods

2.1. General Data

The total course consists of 93 credit hours, including 57 theoretical hours, 21

probation hours, and 15 laboratory hours. The control group received traditional teaching methods: 1) Teachers created PPTs based on the syllabus and delivered lectures in the classroom; 2) Probation classes involved watching videos, case analysis, and using teaching aids, encouraging students to participate actively to deepen understanding of reproductive system diseases through interaction with actual cases and models; 3) Laboratory classes primarily involved reproductive system anatomy, histology, and embryology, mainly conducted through viewing human gross specimens, pathological specimens, and pathological pictures to visually reinforce anatomical and pathological knowledge. The control group used traditional teaching methods, focusing on teacher lecturing, videos, and specimen viewing, emphasizing both coverage of knowledge and, to some extent, stimulating students' participation.

2.2. Methods

The observation group adopted a digital medicine-based blended teaching model, integrating it comprehensively into all aspects of student learning. The specific implementation methods were: 1) In theoretical courses, the application of digital technologies provided diverse teaching methods. For example, online live teaching utilized the advantages of the internet (images, animations, sound, videos) to make abstract and difficult medical knowledge more concrete and vivid, enhancing student's interest and enthusiasm. Recorded lectures, a common online teaching method, ensured smooth teaching during the COVID-19 pandemic. They allowed flexible arrangement of teaching locations and time for both teachers and students, free from specific spatial and temporal constraints. Coupled with their stability, low cost, and the ability to review, they effectively improved teaching outcomes and expanded the teaching scope. With the widespread application of information and network technologies in education, teaching methods like MOOCs and micro-lectures promptly update and expand frontier knowledge, compensating for the slow update of traditional textbooks. Simultaneously, pictures, animations and refined instructional videos were used to increase student's interest, effectively improve teaching effectiveness, and provide autonomous learning-oriented personalized teaching. Furthermore, micro-lectures can explain a single knowledge point in a short time, suitable for personalized and deep learning needs. 2) In probation practice, students applied knowledge and consulted relevant digital resources to creatively produce online popular science micro-lecture videos, deepening their understanding of female reproductive health and diseases. In offline clinical scenario simulations, students reproduced the entire clinical process from consultation to treatment plan formulation, enhancing their flexibility. Meanwhile, surgical operation practice was conducted using virtual anatomy tools (e.g., a laparoscopic instrument skills center) to improve practical skills. For the mechanism of obstetric delivery, magnetic resonance imaging (MRI) 3D reconstruction technology was used to display pelvic structure, combined with animation demonstrations, helping students understand the delivery process and the pathogenesis of pelvic floor disorders more intuitively. This multi-

angle, multi-level teaching strengthened theory and cultivated comprehensive clinical thinking. 3) In laboratory teaching, 3D animation technology was used in reproductive system anatomy courses. Dynamic displays of the structure and function of the reproductive system helped students establish more intuitive and clear cognition. For example, using 3D exploration tools like Visible Body Suite, students could comprehensively learn human anatomy, A & P (Anatomy and Physiology), and related biology knowledge online, enhancing self-directed learning ability.

The control group was evaluated using traditional teaching methods, with assessment comprising 30% for class attendance, 20% for classroom performance and participation, and 50% for homework completion. In contrast, the observation group adopted a blended learning model incorporating more diverse assessment dimensions. While maintaining the 30% weighting for attendance and homework, it added: 1) 20% for online learning behaviors (e.g., platform login frequency and study duration), 2) 30% for online quizzes and task completion, 3) 20% for group collaboration and discussion participation. This formed a more comprehensive system for evaluating regular coursework performance.

2.3. Observation Indicators

In the teaching evaluation of this course, we adopted diversified evaluation indicators to comprehensively measure students' learning outcomes and the implementation effects of teaching activities. The specific evaluation indicators were: 1) Process-based assessment were based on class attendance, class assignments, online tests, online discussion participation, and class performance, using a percentage system. 2) Summative assessment: After the end of the entire course, students underwent a final assessment, including a final written exam and a satisfaction questionnaire. The final written exam had a total score of 100 points, covering key knowledge points such as male and female reproductive system anatomy, pregnancy physiology, common gynecological diseases, pregnancy complications, normal and abnormal delivery, breast diseases, and female pelvic floor dysfunction disorders etc. 3) Score calculation: The final overall score was calculated by summing the usual score and the final written exam score in a 3:7 ratio. 4) Teaching satisfaction survey: to learn about students' feedback of different teaching methods, an online questionnaire was developed specifically for this study. Evaluation indicators included understanding of teaching content, learning interest, self-directed learning ability, team communication and collaboration ability, scientific research thinking ability, teacher-student interactions and sense of participation, humanistic care in medical practice, professional mission and social responsibility, and overall satisfaction.

2.4. Statistical Methods

Data analysis was performed using SPSS 23.0. Enumeration Data were expressed as mean ± standard deviation ($\bar{x} \pm s$) and analyzed using t-tests. Count data were

expressed as (n, %) and analyzed using χ^2 tests. $P < 0.05$ was considered statistically significant.

3. Results

3.1. Comparison of Usual Performance, Final Exam Scores, and Final Overall Scores between the Two Groups

Our study compared the usual scores, final exam scores, and final overall scores between the observation group and the control group to evaluate the teaching effectiveness of the digitally integrated blended teaching model in the reproductive system course. Statistical analysis results showed that although the usual scores of the observation group were slightly lower than those of the control group, the observation group demonstrated significantly higher final exam scores and final overall scores compared to the control group ($P < 0.05$), seen in Table 1. The results indicate that although the new teaching model might have initially posed some challenges to students' daily learning routines, its advantages in promoting knowledge mastery and comprehensive ability improvement were fully reflected in the final assessment.

Table 1. Comparison of usual performance, final exam scores, and overall final evaluation scores between two groups of students (scores, $\bar{x} \pm s$).

Group	Number of Participants	Usual Performance	Final Exam Scores	Overall Final Evaluation Score
Control Group	192	98.23 ± 1.10	62.64 ± 9.30	73.36 ± 6.54
Observation Group	172	93.34 ± 1.44	80.45 ± 9.25	84.38 ± 6.59
t-value	-	36.68	18.29	15.99
P-value	-	<0.0001	<0.0001	<0.0001

3.2. Questionnaire Results of the Two Groups

To gain an in-depth understanding of students' acceptance and feedback on different teaching models, this study designed and distributed a questionnaire of multi-dimensional evaluation items. A total of 364 questionnaires were distributed, and 364 valid questionnaires were recovered, achieving a 100% questionnaire recovery rate. Students in the observation group generally believed that the new method combining digital medicine and the blended teaching model significantly enhanced their understanding of the teaching content in the reproductive system course and greatly stimulated their learning interest ($P < 0.05$). This suggests that the new teaching model effectively enhanced students' learning motivation and cognitive depth through diverse teaching resources and interactive methods. The new teaching model also significantly improved the self-directed learning ability of the observation group students and enhanced their team communication and collaboration skills ($P < 0.05$). This reflects that the combination of digital medical tools and the blended learning environment provided students

with more opportunities for independent exploration and cooperative learning, promoting the development of these key skills. In terms of scientific research thinking ability and teacher-student interactions, the observation group also showed significant advantages ($P < 0.05$). This indicates that the new teaching model not only helps cultivate students' critical thinking and problem-solving abilities but also enhances the sense of participation and effectiveness of the teaching process by increasing the frequency and quality of interaction between teachers and students. It is worth noting that no significant differences were observed between the two groups of students in terms of humanistic care in medical practice, professional mission, and social responsibility ($P > 0.05$). This result suggests that although the new teaching model is highly effective in imparting knowledge and skills, cultivating medical ethics and professional spirit may still require combined efforts with traditional teaching models. Finally, the overall satisfaction survey results regarding the teaching method showed that the satisfaction of the observation group students was significantly higher than that of the control group ($P < 0.05$), seen in Table 2.

Table 2. Comparison of questionnaire evaluation between two groups of students (n, %).

Group	Number of Participants	Understanding of Teaching Content	Learning Interests	Self-Directed Learning Ability	Team Communication and Collaboration	Research Thinking Ability	Teacher-Student Interaction and Sense of Participation	Humanistic Care in Medical Practice	Sense of Professional Mission and Social Responsibility	Overall Satisfaction
Control Group	192	171	160	170	160	168	175	178	165	170
Observation Group	172	168	162	165	163	167	169	166	158	167
χ^2-value	/	10.52	10.47	6.76	11.87	11.39	8.83	2.53	3.18	9.66
P-value	/	0.005	0.005	0.034	0.003	0.003	0.012	0.282	0.203	0.008

4. Discussion

Since the National Education Conference in 2018, we comply with the important speech spirit of President Xi Jinping, adhering to the fundamental task of fostering virtue through education, continuously deepening education reforms, and are committed to cultivating a new generation of people who can shoulder the great responsibility of national rejuvenation (Zhang et al., 2021). In this background, building a modern medical education system that complies with the Healthy China strategy has become a crucial task for clinical educator. With the advent of the digital era, numerical intelligence empowerment has gradually become a key

force driving educational reform and innovation. The field of medical education is at the forefront of this transformation, it can not only enrich teaching methods but also improve the flexibility and interactivity of teaching, and as a result, students' learning experiences are optimized. In this context, the teaching of reproductive system courses, must actively rely on digital intelligence empowerment, utilizing simulation technology, digital intelligence tools to infuse new vitality into higher medical education, thereby improving teaching quality, enhancing students' comprehensive quality, and cultivating more compound talents who can meet the future medical needs (Wang et al., 2024).

The rapid development of numerical intelligence empowerment including virtual simulation, 3D animation, and artificial intelligence technology, has brought about unprecedented and profound changes to medical education. In the traditional medical teaching methods, students mainly relied on lectures, texts, and limited practical opportunities, which greatly restricted the efficiency of their learning. However, the introduction of digital intelligence empowerment has completely broken those limitations, making medical education more flexible, vivid, and individualized. Students can practice clinical operations with virtual simulation technology in a highly realistic virtual environment. This teaching method not only accurately simulates real clinical scenarios but also dynamically adjusts the difficulty based on students' learning progress and performance, thereby greatly enhancing their clinical skills and ability to handle emergencies (Li et al., 2022). Meanwhile, the application of 3D animation enables students to observe human anatomies and their changes in three-dimensional perspective, making complex anatomies and physiology understandable. The perfect combination of virtual simulation and 3D animation has freed medical education from the constraints of text and static images, making it interactive, intuitive, and vivid, thus significantly improving students' learning experience (Liu et al., 2023). Additionally, digital intelligence empowerment provides a wealth of online learning resources, greatly enhancing the flexibility of learning. Students are no longer passive recipients of knowledge but can freely choose learning content based on their own needs and learning pace. Whether through online courses, simulation cases, or interactive online quizzes, students can practice multiple times in a risk-free environment, deepening their understanding and mastery of knowledge (Li & Qin, 2023). The diversity of online learning resources not only enables students to apply what they have learned in different scenarios but also provides them with opportunities for repeated practice and self-feedback, helping them to promptly identify and correct mistakes and improve learning efficiency. Besides, digital intelligence empowerment offers students the opportunity for self-directed learning, stimulating their enthusiasm and initiative for learning. With the assistance of artificial intelligence, students can make personalized learning plans based on their own learning needs and receive targeted feedback and guidance during the learning process. This self-directed learning model not only boosts students' learning motivation but also cultivates their self-study ability and awareness of

lifelong learning (Pucchio, Eisenhauer, & Moraes, 2021).

On this basis, the integration of digital intelligence further strengthens the advantages of the blended teaching model in medical education (Zhang & Zhang, 2023). The blended teaching model creatively combines traditional face-to-face teaching with modern digital intelligence, providing students with a more comprehensive and three-dimensional learning experience. In practical subjects such as reproductive system courses, the blended teaching model supported by digital intelligence particularly demonstrates its unique advantages. Reproductive system courses not only require students to master solid theoretical knowledge but also emphasize the cultivation of practical operation skills. Digital intelligence provides rich learning resources through online platforms, enabling students to preview relevant content before class and be well-prepared for learning. After class, students can also use online quizzes, case analyses, and other methods to consolidate and deepen their knowledge. At the same time, in-depth discussions and practical operation sessions in the classroom further enhance students' understanding and application of knowledge. Specifically, interactive discussions in the classroom help students deepen their understanding of complex concepts, while practical operations allow students to transform theoretical knowledge into practical skills, which happens to be a process of knowledge internalization. With the support of digital intelligence, the blended teaching model plays a more important role in reproductive system courses. For example, 3D animations are used to display the anatomical structure of the reproductive system, allowing students to visually and intuitively grasp the spatial relationships and functions of each organ, which is difficult to achieve through traditional lecturing or static images. In addition, online resources also provide dynamic simulations of the embryonic development process, helping students deeply understand complex physiological changes, which are difficult to explain clearly through lectures or pictures in traditional teaching. This kind of online resource support provided by digital intelligence not only enriches teaching methods but also enhances students' learning interest and practical ability. Students can better apply what they have learned in practice, thereby more deeply understanding and mastering the essence of reproductive system courses.

In this study, the students in the observation group initially had lower regular academic performance than those in the control group. This phenomenon may derive from the transition period required to adapt to the new teaching model. The new teaching model deeply integrates digital medicine with a blended learning approach (combining online and offline methods), enabling students to access a wealth of digital resources and engage in independent learning activities such as virtual simulations and 3D animations. This requires higher demands on students' ability to manage their learning and adapt to the technical tools. The teaching model for the observation group further emphasizes students' independent learning capabilities—for example, through activities like creating micro-lectures independently and participating in situational simulations to deepen their under-

standing of knowledge. For some students, this highly proactive learning style may not be easily adaptable. They may encounter difficulties in arranging their time independently, planning learning tasks, or integrating information, which ultimately leads to poor regular performance. Secondly, the observation group employs teaching and assessment methods distinct from traditional approaches, placing greater emphasis on the depth of thinking and innovative abilities students demonstrate during the learning process rather than solely focusing on task completion. As students encounter a diverse assessment system for the first time, they need to adapt to platform operations, learning pacing, and interactive methods. Consequently, their regular grades may be relatively lower during the first half of the semester. This adjustment in assessment methods may result in differences from traditional teaching in scoring details, making the regular performance of the observation group appear slightly lower. However, this does not indicate that the overall performance of the observation group was poor. An analysis of the final exam scores and overall final assessment showed that the performance of the observation group were significantly better than those of the control group. This reflects that students in the observation group received in-depth training in a more challenging environment. Although the new digital and intelligent-enabled teaching model affected regular performance in the short term, it was effective in enhancing students' long-term comprehensive abilities. Furthermore, the results of a follow-up questionnaire survey revealed that the overall satisfaction of students in the observation group with the new teaching method was significantly higher than that of the control group. This demonstrates that the new teaching model has significant advantages in several aspects: strengthening understanding of teaching content, stimulating learning interest, improving independent learning abilities, enhancing team communication and collaboration skills, boosting research thinking capabilities, and promoting teacher-student interaction and sense of engagement. There were no significant differences between the two groups in terms of humanistic care, professional mission, and social responsibility. This suggests that the teaching methods of the control group also played a fundamental role in cultivating these qualities, covering the basic content of medical literacy and humanistic education. The findings of this study are consistent with the results of recent relevant studies (Yu et al., 2022; Li et al., 2021; Chen et al., 2023).

In the background of the integration of digital-intelligent empowerment and blended teaching models, medical education is undergoing a profound transformation. This shift brings new challenges and opportunities for instructors (Bian et al., 2024; Zhang, 2025; Li & Wang, 2025). Teachers must continuously update their teaching content, methods, and approaches to keep pace with the rapid development of digital-intelligent education. As artificial intelligence technologies become increasingly integrated into the educational field, instructors need to adjust their teaching strategies and flexibly utilize digital technologies to achieve personalized and precision teaching, thereby meeting the demands of cultivating fu-

ture medical professionals. For instance, artificial intelligence can assist teachers in designing correspondent learning methods for students at different stages to precisely enhance learning outcomes. In this process, the digital literacy, data analysis capabilities, and innovative skills of instructors are particularly critical, which are the foundation of digital-intelligent transformation and educational technology reform.

Digital-intelligent empowerment not only alters teaching methods but also imposes higher requirements on teachers' professional skills. Educators should not only impart medical knowledge but also possess the ability to make use of new technologies to enhance teaching. The implementation of individualized teaching poses a significant challenge. The aim of digital-intelligent empowerment in education is to enable tailored instruction through technological support, encouraging personalized, diverse, and efficient learning development among students rather than to replace teachers with intelligent technologies.

It represents that in class, teachers need to monitor the overall learning progress of all students, at the same time, to provide differentiated teaching plans based on individual characteristics and learning paces to enhance learning efficiency. However, personalized teaching relies heavily on teachers' deep understanding and flexible application of digital technology, which requires for their high adaptability. Teachers need to reflect on how to use technological tools without losing the core of education, ensuring that every student receives a learning experience tailored to their needs while stimulating their ability for independent thinking and active learning.

Medical education is gradually shifting from a teacher-centered traditional model to a student-centered autonomous learning model, requiring instructors to think about the design and presentation of teaching content (Liu et al., 2024). This transformation involves comprehensive innovation in teaching forms, content, and methods. For example, teachers need to utilize interactive resources such as simulated exercises and case studies on digital platforms to help students practice clinical operations in virtual scenarios.

This student-centered model not only enhances the learning experience but also enables students to better grasp and internalize medical knowledge, laying a solid foundation for their future careers. In this model, teachers should be regarded as learning facilitators or supporters rather than mere transmitters of knowledge. Therefore, educators must develop the ability to design and guide students' autonomous learning.

However, there are some limitations in our study. Firstly, our study includes the first-semester students for the control group and second-semester students for the observation group. The different academic experience of the two group could be a confounding factor that influence the results. Secondly, no significant differences were observed in medical humanistic care, professional mission, or social responsibility between the two groups, it indicates we need to explore how to infuse those into digital-intelligent empowerment and blended teaching models in

the future. For example, we can design specific situations associated with medical humanistic care and social responsibility to enhance students' abilities. And for improving professional mission, we can add typical and difficult clinical cases in the online digital-intelligent platform to cultivate their clinical thinking.

5. Conclusion and Outlook

In the context of current educational reforms, this study successfully integrates digital-intelligent technologies with the medical education of reproductive system diseases courses. It indicated that the online-offline integrated blended teaching model, combined with digital medicine, shows significant advantages in enhancing students' academic performance and practical abilities when compared with traditional teaching methods. This teaching model not only enriches instructional methods but also stimulates students' interest and initiative in learning, providing them with a better learning experience and outcomes. At the same time, the model has received higher satisfaction from students, highlighting its potential and value in medical education.

In the future, we will continue to implement the application of digital-intelligent technologies in medical education and further explore the possibilities and advantages of the online-offline integrated blended teaching model. We will continuously optimize teaching design and implementation strategies, enhance teachers' instructional capabilities and digital literacy, and better adapt to and meet the developmental needs of medical education. Additionally, to improve teaching quality and foster innovative abilities, we will adjust and refine the teaching model to provide solid support according to the students' feedback and learning needs. We believe that the integration of digital-intelligent empowerment and blended teaching models will offer medical students broader learning and development opportunities, helping them realize greater potential and value in their future medical careers.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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