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Analysis of the Application of Virtual Simulation Technology Based on the BOPPPS Teaching Model in the Teaching of "Medical Imaging Examination Technology"

Xuecheng Liu[1*], Lei Feng[1], Qi Wu[2#]

[1]Department of Radiology, The First Affiliated Hospital of Wannan Medical College, Wuhu, China
[2]Department of Obstetrics, The First Affiliated Hospital of Wannan Medical College, Wuhu, China
Email: 1135028790@qq.com, #tian371279611@sina.com

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Abstract

This study aims to explore the application path and practical effect of the deep integration of the BOPPPS teaching model and virtual simulation technology in the teaching of "Medical Imaging Examination Technology". In response to the long-standing core pain points in the teaching of this course, such as expensive equipment, scarce practical opportunities, high risks, and the disconnection between theory and practice, a new teaching system is constructed with the BOPPPS six-stage teaching model as the framework and a high-fidelity virtual simulation system as the carrier. Through a quasi-experimental research method, medical imaging technology students are divided into an experimental group and a control group, and the teaching effects are systematically compared. The results show that the virtual simulation teaching based on BOPPPS can significantly improve students' theoretical knowledge mastery, standardized operation skills, clinical problem-solving abilities, and learning satisfaction. This model, through a closed-loop design of "introduction-objectives-pre-test-participatory learning-post-test-summary", effectively guides students to achieve in-depth learning from cognitive understanding to skill internalization in a risk-free, repeatable immersive environment, providing a replicable and scalable systematic solution for the practical teaching reform of the medical imaging technology major.

Subject Areas

Educational Technology, Medical Education

*First author.
#Corresponding author.

Keywords

BOPPPS Teaching Model, Virtual Simulation, Medical Imaging Examination Technology, Teaching Reform

1. Introduction

With the rapid development of medical imaging technology, high-end equipment such as CT, MRI, and DSA has become the core pillar of modern clinical diagnosis. This requires medical imaging technology professionals to not only have a solid theoretical foundation but also possess excellent equipment operation, parameter optimization, and image quality control skills. "Medical Imaging Examination Technology" as a core course for cultivating such talents, its teaching effect directly relates to students' professional competence [1].

However, the traditional teaching model is facing severe challenges: 1. Economic and safety barriers: High-end imaging equipment is expensive, and schools find it difficult to provide a large number of devices for students to practice; and direct operation training on patients poses unacceptable safety and ethical risks [2]; 2. Time and space limitations of teaching: Limited class hours and equipment resources result in insufficient average practical time for each student, making it difficult to internalize skills [3]; 3. The gap between theory and practice: The traditional "classroom theory first, then laboratory practice" fragmented model makes it difficult for students to directly associate abstract physical parameters, scanning protocols, and final image quality [4]; 4. Single evaluation method: Traditional written tests are difficult to effectively assess students' dynamic operation process standardization, on-the-spot adaptability, and image optimization decision-making processes [5].

At the same time, the maturity and popularization of virtual simulation technology bring historic opportunities to solve these problems. This technology can build a highly realistic (defined as being able to realistically simulate the operation interface of the equipment, human anatomy, physical imaging process and image generation effect) three-dimensional operation environment, simulating the entire process from patient registration, body position placement, equipment operation, parameter adjustment to image post-processing, allowing students to train their skills under "zero-risk, low-cost, and unlimited repetition" conditions [6] [7]. However, the introduction of this technology without the guidance of scientific teaching methods is prone to becoming a "technology for the sake of technology" electronic game or merely a simple embellishment of traditional teaching, unable to deeply empower teaching goals.

In this context, this study introduces the BOPPPS teaching model as the top-level design framework. BOPPPS is a closed-loop teaching model that emphasizes student participation and immediate feedback, with its six stages (introduction, objectives, pre-test, participatory learning, post-test, summary) forming a clear goal, rigorous structure, and highly interactive teaching unit. Integrating virtual simulation technology organically into each stage of the BOPPPS model aims to achieve student-centered, deeply participatory learning, converting technological advantages into tangible improvements in teaching effectiveness, and exploring an innovative path that conforms to the laws of modern medical education and efficiently cultivates applied imaging technology talents. This research protocol has been submitted to the Ethics Review Committee of Wannan Medical College for review and was approved for exemption. Before the start of the study, all participants were informed of the research purpose, data usage methods, and confidentiality measures, and signed a written informed consent form. All data were de-identified, strictly confidential, and used only for the academic purposes of this study.

2. Core Concepts and Theoretical Framework

2.1. The Connotation and Advantages of the BOPPPS Teaching Model

The BOPPPS teaching model originated from the Canadian teacher training system, with its core concept being to ensure the effective achievement of teaching goals through precise instructional design [8]. This model consists of six closely linked stages: Introduction, which aims to attract students' attention, stimulate their interest in learning, connect with their existing knowledge, and clarify the value of learning; Objectives, which require clear, specific, and measurable statements of learning outcomes; Pre-assessment, used to detect students' prior knowledge levels to adjust the teaching starting point and focus; Participatory Learning, as the core of teaching, guiding students to actively construct knowledge through diverse interactive strategies such as discussion, hands-on practice, and collaboration; Post-assessment, used to measure the achievement of the teaching objectives for this class and provide immediate evidence of teaching effectiveness; and Summary, which consolidates learning outcomes through the summary of key points, the elevation of the theme, and the connection with future learning. The BOPPPS model has prominent advantages such as strong goal orientation, high student participation, timely and effective feedback, and good structural universality, ensuring that all teaching activities serve clear goals, breaking the "teacher-centered" approach, and achieving dynamic adjustment and verification of the teaching process.

2.2. The Functional Positioning of Virtual Simulation Technology in Medical Education

In the field of medical education, virtual simulation has developed into an innovative teaching environment and method [9]. Its core functions include: immersive scenario simulation, which can create realistic clinical environments and enhance professional immersion; a safe training platform for high-risk skills, allowing students to repeatedly practice operations with extremely low error tolerance in a risk-free environment; process visualization and immediate feedback, which can visually present invisible physical principles and operation consequences and provide immediate feedback on the correctness of operations; and personalized and adaptive learning paths, where the system can intelligently push training tasks of different difficulties based on students' pre-assessment performance, achieving individualized teaching. These functions collectively provide a safe, efficient, and replicable advanced solution for medical skills teaching.

2.3. Theoretical Integration: BOPPPS as the Body, Virtual Simulation as the Use

The combination of BOPPPS and virtual simulation is a deep integration of "educational concepts" and "technical tools". BOPPPS provides a scientific design blueprint and the soul of teaching methods for the application of virtual simulation in teaching, ensuring that the use of technology has clear teaching purpose and structure. Virtual simulation, on the other hand, provides a powerful and ideal technical implementation means and interactive carrier for BOPPPS, especially its core "participatory learning" stage, making it possible to achieve deep interaction, independent exploration, and immediate feedback that are difficult to achieve in traditional classrooms. The two complement each other, jointly constructing a highly consistent "goal-activity-assessment" efficient skills teaching model.

3. Design and Implementation of Virtual Simulation Teaching System Based on BOPPPS

This study takes the "Chest CT Scanning Technology" module in "Medical Imaging Examination Technology" as an example to elaborate on the integrated design and implementation process.

3.1. Teaching Analysis

The teaching content covers the complete process of chest CT examination, including its indications, pre-examination preparations, position design and positioning, determination of scanning baseline, planning of scanning range, setting principles of basic scanning parameters (kV, mA, pitch, slice thickness), application of contrast agents, and image post-processing. The teaching target is the second-year students majoring in medical imaging technology. They have already acquired the basic knowledge of medical imaging physics and human anatomy, but they are relatively unfamiliar with the overall operation process of CT equipment, especially lacking the intuitive understanding and practical experience of influencing image quality by adjusting scanning parameters. Therefore, the teaching focus of this module is set as: mastering the standardized patient positioning process, accurately defining the scanning range, and understanding and setting basic scanning parameters; while the teaching difficulty lies in: how to personalize the adjustment of scanning parameters based on the individual conditions of patients and specific clinical needs to obtain images that meet diagnostic requirements (defined as images that meet clinical diagnostic needs, have no major technical defects, and have controllable artifacts, hereinafter referred to as "qualified diagnostic images"), and being able to identify and correctly handle common artifacts (referring to identifying the type of artifact and taking the correct measures to reduce or eliminate its impact).

3.2. Six-Step Integrated Teaching Design

3.2.1. Introduction

The teacher creates a highly immersive clinical scenario through virtual simulation technology to stimulate cognitive conflict and introduce the teaching topic: the main interface of the system plays a short video of a clinical case in the emergency room, showing a patient with breathing difficulties and suspected pulmonary embolism being rushed into the hospital, and the clinical requirement is to immediately complete a chest CT pulmonary angiography (CTPA); after the video ends, the screen freezes on the anxious doctor and the complex CT operation console interface. Then, the teacher leads the discussion with a guiding question—"If you were operating at this moment, could you quickly, accurately, and safely complete this life-saving examination? Any mistake in any step could lead to the failure of the examination and delay in diagnosis and treatment. Today, we will use the virtual simulation system to transform into a CT technician and jointly tackle the key task of 'standardized and personalized scanning of chest CT'." This step uses the realistic and urgent scene created by virtual simulation to quickly capture students' attention and stimulate their intrinsic learning motivation and professional responsibility.

3.2.2. Objectives

At the beginning of the course, the teacher clearly states the learning outcomes in a clear, specific, and measurable way: by the end of this class, students will be able to, at the cognitive level, recite the standard operation process steps of chest CT scanning; At the skill level, independently complete the full process of a plain chest CT scan on a standard patient (defined as a standard adult male body type preset in the system, without any special anatomical variations) in a virtual simulation system, and achieve a score of 90 or above in the operation standardization assessment.at the higher-order thinking level, for a virtual case of an "obese patient", be able to adjust the scanning parameters to obtain images that meet diagnostic requirements and verbally explain the logic of the parameter adjustments. The design intention is to precisely describe the learning goals at different levels using action verbs such as "recite", "complete", "adjust", and "explain", allowing students to clearly understand the expected learning outcomes.

3.2.3. Pre-Assessment

Students enter the pre-assessment module on their personal terminals and complete a set of interactive multiple-choice and short-answer questions covering key knowledge within 5 minutes, such as "What is the purpose of respiratory training for patients before CT scanning?", "Which anatomical landmark is commonly used as the scanning positioning line for chest CT?", "Which aspect of image characteristics is mainly affected by the kV value?" etc. The teacher's end can receive and view the real-time statistical analysis report of all students' pre-assessment data, thereby quickly identifying the common knowledge blind spots of students. The design intention of this step is to efficiently diagnose students' prior knowledge level and make the arrangement of teaching content more focused and targeted.

3.2.4. Participatory Learning

Participatory learning is the core of this model and is divided into four progressive stages:

1. Guided exploration and imitation practice: The teacher demonstrates the standard operation process step by step at a slow pace through the virtual simulation system on the main control end, and explains the technical essentials and clinical significance of the parameters. 1. Students follow the teacher's demonstration on their individual virtual terminals, performing "mirror imitation" operations. The system provides step-by-step visual and voice prompts.

2. Autonomous practice and process reinforcement: Students need to independently complete 2 to 3 full-process operations on standard patients without step-by-step prompts. The system automatically records each operation and makes intelligent judgments on its standardization. The teacher patrols, observing in real-time through the monitoring terminal and providing individualized guidance, while collecting common errors.

3. Inquiry-based learning and parameter optimization: The system pushes special clinical cases (such as obese patients), presenting initial images of poor quality after scanning with standard parameters. Students work in groups to collaboratively explore, attempting to adjust scanning parameters to optimize image quality. The system generates new images in real-time for observation. The teacher organizes group sharing and discussion, deepening students' understanding of the principle of parameter adjustment and clinical trade-offs through guiding questions.

4. Contextual problem-solving: The virtual simulation system simulates clinical emergencies (such as patient movement causing artifacts, suspected allergic reactions), cultivating students' emergency response and clinical decision-making abilities. Students need to promptly identify problems and take standardized measures to deal with them, with the system providing immediate feedback. These four stages form a progressive learning path of "imitation-proficiency-inquiry-adaptability".

3.2.5. Post-Assessment

Students enter an independent "assessment mode", with the system randomly assigning a comprehensive case. Students need to independently complete the full process from patient assessment to obtaining a qualified diagnostic image without any operation prompts. The system automatically generates a multi-dimensional objective assessment report, covering total operation time, completeness and correctness of operation steps, rationality of key parameter settings, and quality score of the final reconstructed image. This stage directly corresponds to and forms a closed-loop test with the "teaching objectives", providing a reliable formative evaluation basis for teaching effectiveness.

3.2.6. Summary

Based on the system analysis report generated from the post-assessment stage, the teacher reviews the overall performance of the class, summarizes key points and common problems, and uses the system's "operation replay" function to visually display typical errors and their consequences. At the same time, outstanding students are invited to share their operation ideas. All students complete written reflections, summarizing key points and raising questions. Additionally, post-class extension tasks are assigned, requiring students to attempt to design personalized scanning plans for specific cases in the virtual system's "open exploration library". This stage aims to consolidate knowledge, correct errors, elevate skill experience to a professional knowledge structure, and promote the internalization and transfer of knowledge after class through system feedback, peer sharing, and personal reflection.

3.3. Teaching Conditions of the Control Group

To ensure fairness and repeatability of the comparison, the control group received traditional teaching methods, with the same 8-hour teaching duration and the same instructor. The teaching mode for the control group was "theoretical instruction (4 hours) + observation of laboratory equipment and teacher demonstration (2 hours) + group-based practical operation practice on physical equipment (2 hours)". The theoretical learning content was exactly the same as that of the experimental group. Laboratory observation was limited to the instructor operating a CT teaching machine for demonstration, with students observing closely. During the practical operation practice on physical equipment, each group (10 people) shared one teaching CT machine, and each student's actual operation time was less than 15 minutes. The practice content was limited to the positioning of standard chest positions and basic parameter settings, without the opportunity for complete process practice or exploration of personalized parameter optimization.

4. Teaching Effectiveness Analysis

In the quantitative analysis of teaching effectiveness, this study made comparisons from three dimensions. In terms of knowledge acquisition, the average score of the theoretical examination of the experimental group (87.6 ± 5.2) was significantly higher than that of the control group (79.3 ± 7.1), with a statistically significant difference ($P < 0.001$), especially in application-type questions. Regarding operational skills, the results of the physical operation assessment showed that the experimental group scored significantly higher than the control group in the three dimensions of operation process standardization (36.5 ± 2.8 vs 30.1 ± 4.3), parameter setting rationality (35.8 ± 3.1 vs 29.5 ± 4.9), and image quality evaluation (17.2 ± 1.5 vs 15.0 ± 2.1) (all $P < 0.001$). Additionally, the post-test scores of the virtual simulation of the experimental group (92.4 ± 4.7) were significantly positively correlated with the total scores of the physical operation assessment ($r = 0.51$, $P < 0.001$). In terms of learning experience, the results of the questionnaire survey indicated that the experimental group scored significantly higher than the control group in four items: classroom attention (4.3 ± 0.6 vs 3.5 ± 0.8), learning interest (4.4 ± 0.5 vs 3.6 ± 0.7), skill confidence (4.2 ± 0.7 vs 3.3 ± 0.9), and recognition of the professional relevance of the teaching method (4.5 ± 0.5 vs 3.7 ± 0.8) (all $P < 0.001$). The qualitative interview results further confirmed that students in the experimental group gained stronger learning autonomy and a sense of achievement, while students in the control group generally expressed anxiety over insufficient practical opportunities. Therefore, virtual simulation teaching based on the BOPPPS model can comprehensively and effectively enhance the teaching quality and learning outcomes of the "Medical Imaging Examination Technology" course.

5. Discussion

This study confirms the effectiveness of the "Virtual Simulation Teaching under the BOPPPS Framework" model. The key to its success can be summarized as follows: structured design ensures the goal-oriented nature and efficiency of teaching activities; the "learning by doing" environment created by virtual simulation, combined with the participatory design of BOPPPS, enables the deep internalization of knowledge; the immediate closed-loop feedback system drives the continuous optimization of teaching and learning; and the safety features of the virtual environment significantly reduce students' anxiety during skill training.

However, this model also faces challenges in practice. The high initial construction cost and the high requirements for teachers' capabilities are the main obstacles, which can be addressed through school-enterprise cooperation, phased construction, and systematic teacher training. A balance needs to be struck between the degree of simulation and teaching objectives, adhering to the principle of "teaching applicability". At the same time, excessive human-computer interaction leading to teaching isolation should be prevented, and social interaction can be promoted by embedding group discussions, sharing, and comments in the teaching design.

Looking to the future, this model has broad prospects. The integration of virtual simulation systems with artificial intelligence can achieve personalized path recommendations based on learning data; the introduction of mixed reality technology can create a more immersive transitional training environment. Additionally, the process data recorded by the system can be used to improve the formative assessment system and further evolve towards a competency-based medical education model.

6. Limitations of the Study

This research focused on the short-term teaching effect evaluation of a single teaching module (chest CT), and the transferability of its results to other course contents or more complex skills requires further verification. Meanwhile, the long-term retention effect of skills (such as the proficiency in operation several months later) has not been examined. Future studies can more comprehensively assess the long-term benefits and transfer effects of this model by including more teaching modules, conducting delayed post-tests after the course ends (e.g., three months later), and tracking and evaluating students' performance in subsequent clinical internships.

7. Conclusion

In conclusion, the BOPPPS and virtual simulation deeply integrated solution constructed and verified in this study represents a systematic teaching innovation guided by scientific teaching methods. Through a clearly defined structured design, a safe and immersive participatory environment, and an immediate data-driven feedback loop, it effectively addresses the bottlenecks in traditional teaching, significantly enhancing students' ability to apply theoretical knowledge, practical operation skills, and clinical thinking. This model provides a reform paradigm with both theoretical support and practical effects for medical imaging technology and the entire medical practice education field, and has significant practical significance for cultivating high-quality applied talents that meet the needs of the era of smart healthcare.

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Conflicts of Interest

The authors declare no conflicts of interest.

References

[1] Yuan, H., Wang, L., Wang, X.X., *et al.* (2023) Reform and Practice of "Medical Imaging Examination Technology" Course Based on Job Competency. *Science and Technology Wind*, No. 32, 133-135.

[2] Lu, Y.B., Cai, C.L. and Wang, X.J. (2025) Research on the Teaching Reform of "X-Ray Examination Technology" Course Based on Virtual Simulation Technology. *Journal of Science and Education*, No. 33, 4-6.

[3] Qi, Y.W., Sun, B., Liu, T.L., *et al.* (2025) Preliminary Exploration and Reflection on the Application of Virtual Simulation Laboratory in Practical Teaching of Medical

Imaging Technology. *Journal of Qiqihar Medical University*, **46**, 1874-1879.

[4] Cui, C.X., Zhang, J. and Liu, J.R. (2025) Research on the Innovation of Teaching Mode of Medical Imaging Technology under Virtual Simulation Technology. *Campus*, **18**, 61-63.

[5] Wei, K. and Wang, Y. (2025) Practice of Teaching Reform of "Medical Imaging Technology" Virtual Simulation Training Based on PBL Model. *Journal of Science and Education*, No. 10, 101-103.

[6] Li, W.J., Lyu, F.J., Yu, R.Q., *et al.* (2024) Research on Virtual Simulation Experiment Skills Competition in Practical Teaching of Undergraduate Students in Medical Imaging Technology. *General Practice Clinical and Education*, **22**, 814-816.

[7] Li, G., Li, Y.X. and Xin, J. (2023) Construction of Medical Imaging Technology Laboratory Based on Virtual Simulation Teaching Platform. *Journal of Huanghe Science and Technology University*, **25**, 91-95.

[8] Zhong, J.L., Hao, P., Peng, R.C., *et al.* (2025) Innovative Practice of BOPPPS Teaching Mode in MRI Internship Teaching of Medical Imaging Technology. *Journal of Health Vocational Education*, **43**, 67-70.

[9] Li, J., Lyu, X.L., Ping, X.J., *et al.* (2023) Application of Virtual Simulation DR Operation Intelligent Training System in the Innovation and Education Reform of Medical Imaging. *Chinese Journal of Continuing Medical Education*, **15**, 1-5.