

Article

Design and Construction of a Virtual-Simulation Training Platform for Basic Nursing Techniques

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Abstract: Against the backdrop of digital transformation in education, traditional nursing practical training is plagued by excessive consumable waste, high training costs, substantial operational risks, spatial-temporal constraints, and subjective assessment practices. These drawbacks hinder the cultivation of high-competency nursing professionals required in the modern era. To address these long-standing challenges, this study develops a Virtual-Simulation Training Platform for Basic Nursing Techniques. Built upon virtual-simulation technology and aligned with nursing education standards and clinical workplace requirements, the platform integrates theoretical learning, hands-on virtual practice, intelligent assessment, and data-driven evaluation. It adopts a four-tier hierarchical architecture guided by core design principles: authenticity, standardization, safety, and scalability. Modular systems for curriculum delivery, skill training, comprehensive simulation exercises, and intelligent evaluation jointly enable a closed-loop teaching workflow of learn-practice-assess-evaluate. Practical deployment demonstrates that the platform mitigates key limitations of conventional hands-on training. It standardizes nursing workflows for students, strengthens clinical reasoning and workplace readiness, and cuts training-related costs and safety hazards. This work offers practical references and evidence to support digital teaching reform within nursing education.

Keywords: virtual simulation; training platform; teaching reform; Basic Nursing Techniques

1. Research Background and Significance

1.1. Research Background

Basic Nursing Techniques constitutes a core course for nursing majors. Its practical-training modules cover aseptic techniques, vital-sign monitoring, medication administration, and fundamental emergency care. The discipline demands strict procedural standards, precise maneuvers, and allows little margin for error. Consistent technical proficiency serves as the cornerstone for safe, high-quality clinical nursing care. Conventional offline training depends heavily on physical supplies and fixed laboratory spaces. It suffers from high consumable turnover, considerable instructional expenses, limited opportunities to rehearse high-risk invasive procedures, and inflexible scheduling. These constraints fail to satisfy students' need for regular, individualized skill reinforcement. Amid nationwide educational digitalization initiatives, the Ministry of Education of China has released official guidelines for virtual-simulation teaching development. The documents explicitly advocate leveraging information technology to offset gaps in traditional practical training and promote blended virtual-physical instructional models [1-2]. Accordingly, developing a standardized, low-risk, repeatable virtual-simulation training platform represents a critical strategy to resolve persistent teaching bottlenecks and improve the quality of nursing graduate preparation.

1.2. Research Significance

Traditional nursing laboratory training frequently provides insufficient hands-on practice, yields inconsistent technical performance, and gives inadequate attention to

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clinical-reasoning development. As a result, new nursing graduates often demonstrate slow clinical on-boarding, poor environmental adaptability, and inadequate capacity for emergency response. Virtual-simulation platforms recreate authentic clinical settings via three-dimensional digital environments. Restructuring practical-training curricula around standardized workflows and real-world patient cases, these platforms deliver immersive, interactive, repeatable training experiences. They help standardize student performance, build clinical reasoning early in training, and narrow the competency gap between classroom laboratory work and clinical practice [3]. Virtual training also reduces supply-related expenses and procedural hazards. It enables full-cohort, end-to-end skill building and process-oriented performance review. This carries tangible value for cultivating practice-ready nursing practitioners with solid technical skills, rigorous standards, and strong professional ethics. It also delivers innovative frameworks and tools for blended-learning reform in nursing education.

2. Platform Design Objectives and Guiding Principles

2.1. Design Objectives

The platform follows core design aspirations: learner-centered instruction, virtual-physical integration, standardized practical training, and intelligent competency development. Rooted in real-world nursing-education demands, it delivers a systematic, standardized, reusable, and interactively up-gradable virtual-training ecosystem with four major objectives.

First, it faithfully reproduces clinical nursing contexts. Three-dimensional virtual environments replicate general-hospital ward layouts, including patient rooms, treatment rooms, and nurses' stations, alongside realistic medical equipment. The immersive, risk-free simulation strengthens students' clinical adaptability and operational proficiency.

Second, it implements a closed-loop learn-practice-assess-evaluate teaching framework [4]. Integrated modules for theoretical instruction, virtual skill drills, automated assessment, and data analytics support self-directed preview, repeated practice, mistake-driven review, and enable targeted, personalized faculty guidance.

Third, it overcomes physical limitations of conventional laboratory training. By harnessing the zero-consumable, highly repeatable, low-risk nature of virtual simulation, it addresses shortages of lab space and hardware, and enables repeated practice for high-risk procedures, conserving resources and mitigating training-related safety risks [5].

Fourth, it automates practical-training assessment and visualizes teaching analytics. Embedded algorithms track learner pathways, correct-incorrect action logs, practice duration, and error frequencies. Objective algorithm-supported evaluation identifies individual learning gaps and supplies actionable data to inform targeted instruction and curriculum refinement [6-7].

2.2. Design Principles

Reflecting the rigor, standardization, and safety imperatives of nursing training, the platform adheres to six foundational design principles.

2.2.1. Contextual Authenticity

Virtual scene layouts, equipment models, and procedural sequences mirror real-world clinical standards. This ensures strong alignment between simulation activities and clinical practice and prevents learners from acquiring maladaptive work habits [3].

2.2.2. Instructional Standardization

Course content strictly complies with nursing education standards, curriculum syllabic, nurse licensing examination criteria and clinical practice specifications, ensuring unified, scientifically sound training content [8].

2.2.3. Safety and Controllability

Step-locking, error-alert prompts and operation reminders are embedded to avoid offline-training hazards such as infection and physical injury, thus enabling safe practice of high-risk clinical procedures [9].

2.2.4. Practicality and Usability

The platform features concise interfaces, intuitive logic and user-friendly operations. It supports anytime-anywhere web-based access and fits pre-class, in-class and post-class learning scenarios [9].

2.2.5. Human-Computer Interactivity

Diversified interaction modes including dragging, clicking and workflow linkage are supported. Real-time operation feedback forms a dynamic training cycle: perform-identify errors-reinforce mastery [10].

2.2.6. System Scalability

Built on a modular architecture with reserved expansion interfaces, the platform can incorporate additional specialized-nursing and emergency-nursing training modules to keep pace with updates in teaching content and clinical technologies [4].

3. Overall Architecture Design of the Platform

Adopting development philosophies of layered decoupling, modular design, low redundancy and high compatibility, this platform employs a classic four-tier distributed architecture (Figure 1). Each layer undertakes distinct responsibilities, provides hierarchical support and operates collaboratively to guarantee stable platform performance and function delivery.

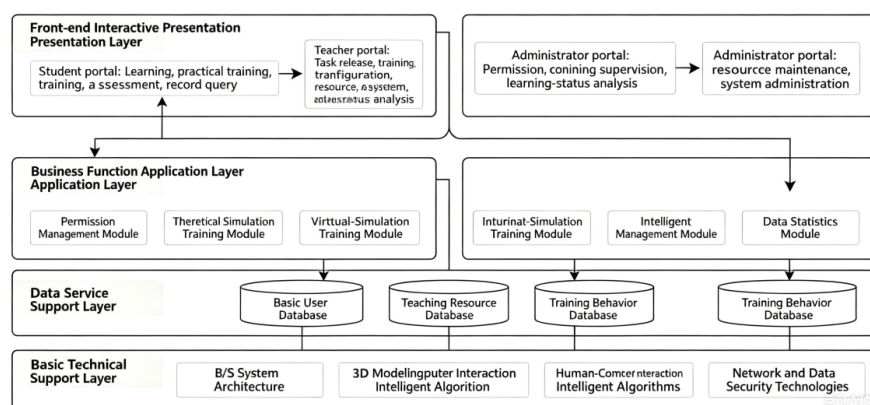


Figure 1. Overall Architecture of the Platform

3.1. Front-End Interactive Presentation Layer

This layer provides visual operation portals for students, teachers and administrators, including student learning-training interfaces, teacher teaching-management interfaces and system administrator maintenance interfaces. It realizes core functions of human-computer interaction, function presentation, operation guidance and result feedback. Web-browser access on personal computers is supported; no dedicated client software is required, and multi-device compatibility is achieved.

3.2. Business Function Application Layer

Serving as the core functional carrier, this modular layer consists of six sub-modules: user permission management, theoretical resource learning, virtual-simulation training, intelligent assessment and scoring, teaching management, and data statistics and analysis. It covers full-cycle workflows including curriculum learning, skill training, assessment-evaluation and teaching administration, underpinning the closed-loop practical-teaching model.

3.3. Data Service Support Layer

This layer guarantees reliable platform data operation. It categorizes and stores basic user datasets, teaching-resource datasets and student training-behavior datasets, enabling fast retrieval, intelligent computation, secure backup and full-activity tracing. It not only

sustains smooth operation of simulation scenarios and functions, but also generates data evidence for learning-status analysis and teaching improvement.

3.4. Basic Technical Support Layer

This is the underlying technical foundation. Powered by B/S architecture, 3D modeling, Web3D virtual-simulation techniques, intelligent behavior-recognition algorithms and network security technologies, it delivers comprehensive technical backing for scene construction, human-computer interaction, automated scoring and stable runtime performance, while supporting good compatibility and iterative upgrades. The system employs state machine logic to track operation sequences, segmenting continuous operational flows into discrete states and transitions. It extracts action events through behavior recognition algorithms, and then determines, through the state machine, whether the action in the current state is legal and whether it triggers process progression. Each state can be configured with guard conditions and time constraints, enabling precise identification of violations such as skipped steps, omitted steps, reversals, and timeouts, while simultaneously recording operational progress in real time. By combining the recognition results with scoring rules, the system can output traceable and interpretable itemized scores along with immediate feedback, elevating the system from merely "being able to recognize actions" to "being able to judge processes, guide operations, and automatically score".

4. Curriculum Content Design

Guided by real-world clinical job requirements and grounded in nursing teaching standards and practical-training syllabi, curriculum content follows the philosophies of progressive learning, virtual-physical integration, and theory-practice integration. Contents are restructured into four modules: basic cognition, skill training, comprehensive practical training, and assessment-evaluation, forming a complete stepped closed-loop learning system.

4.1. Basic Cognition Module

Centered on theoretical knowledge consolidation, this module revolves around the Three Basics of Nursing. It covers knowledge and skill points including nosocomial infection prevention and control, patient safety, fundamental nursing theories, medication principles and core nursing regulations. Supplementary courseware, question banks and interpretation of key and difficult points consolidate students' theoretical foundation and remedy the common pitfall in traditional training: over-emphasis on hands-on drills while neglecting underlying principles.

4.2. Skill Training Module

This is the core practical-training component. It covers clinical nursing tasks: vital-sign measurement, aseptic techniques, oral care, nasogastric tube feeding, urinary catheterization, subcutaneous injection, intravenous infusion, oxygen therapy, and nebulization therapy. Standardized three-dimensional simulation environments are equipped with standard-operation videos, step-by-step graphic guides and reminders for error-prone steps, allowing students to conduct self-paced full-procedure simulation. Real-time error correction and pop-up warnings flag reversed workflows, broken aseptic protocols and missing steps, helping learners correct mistakes repeatedly and internalize standardized practices. Relying on the platform's interactive virtual patient role, situational voice dialogue, patient emotion feedback module, and privacy scene triggering mechanism, learners are guided to communicate and respond with virtual patients during skill training, implementing respectful care practices, privacy masking, and information confidentiality handling, achieving simultaneous progress in skill training and professional quality cultivation.

4.3. Comprehensive Practical Training Module

This module targets clinical-thinking and comprehensive-intervention competencies and breaks the limitation of isolated single-skill drills. Scenario-driven training

environments are built from authentic clinical cases. Multiple basic-nursing skills are integrated within complete diagnostic-therapeutic workflows. Learners are guided to finish integrated nursing tasks: condition assessment, intervention implementation, patient observation and health education. Training shifts from discrete skill practice toward comprehensive clinical-competence building, effectively shortening the competency gap between classroom training and clinical practice [3].

4.4. Assessment-Evaluation Module

A three-dimensional evaluation framework combining formative assessment, summative assessment and comprehensive-competence evaluation is constructed. Formative assessment records students' preview, practice and review behaviors, and compiles statistics such as practice frequency, accuracy rate and error distribution. Summative assessment automatically scores practical performance on standardization, completeness and proficiency, following standardized test items and scoring rubrics. Comprehensive-competence evaluation adopts clinical scenario cases to examine clinical decision-making, skill integration and emergency-response capacity. It realizes standardized, process-oriented and refined practical-training evaluation and addresses subjectivity and one-sidedness found in conventional assessment.

5. Design of the Platform Application-Effect Evaluation System

This study constructs a multi-dimensional, closed-loop platform application effect evaluation system, combining systematic quantitative data with subjective feedback from teachers and students to comprehensively assess the effectiveness of platform-based practical teaching, enabling continuous monitoring of platform teaching effectiveness and dynamic optimization of teaching quality. The system mainly conducts comprehensive evaluation around three dimensions: student learning effectiveness, platform usage performance, and teaching application effectiveness (Table 1). The teaching closed loop formed by this evaluation system, which includes "practical implementation - intelligent assessment - effect evaluation - iterative optimization," can accurately identify teaching shortcomings and platform deficiencies, providing a reliable basis for personalized teaching guidance, curriculum content optimization, and platform function upgrades. This effectively promotes the development of nursing practical teaching towards standardization, intelligence, and refinement (As shown in Figure 2).

Table 1. Multi-dimensional Closed-Loop Application Effect Evaluation System for Nursing Virtual Simulation Training Platform

Level 1 evaluation dimension	Secondary evaluation content	Data source	Purpose of Evaluation
Students' learning effectiveness	Practical training scores, operation accuracy, distribution of error-prone points, and learning completion degree	Quantitative data automatically captured by the platform backend	Objectively evaluate the effectiveness of students' improvement in nursing operation skills
Platform usage performance	Operational fluency, scene simulation, interactive experience, and resource integrity	Subjective questionnaires and usage feedback from teachers and students	Identify shortcomings in platform functionality and guide iterative optimization of functional design
Teaching application effect	Comparison of teaching effectiveness between virtual training mode and	Comprehensive evaluation of teaching research and	Scientifically evaluate the practical application value of the teaching model combining

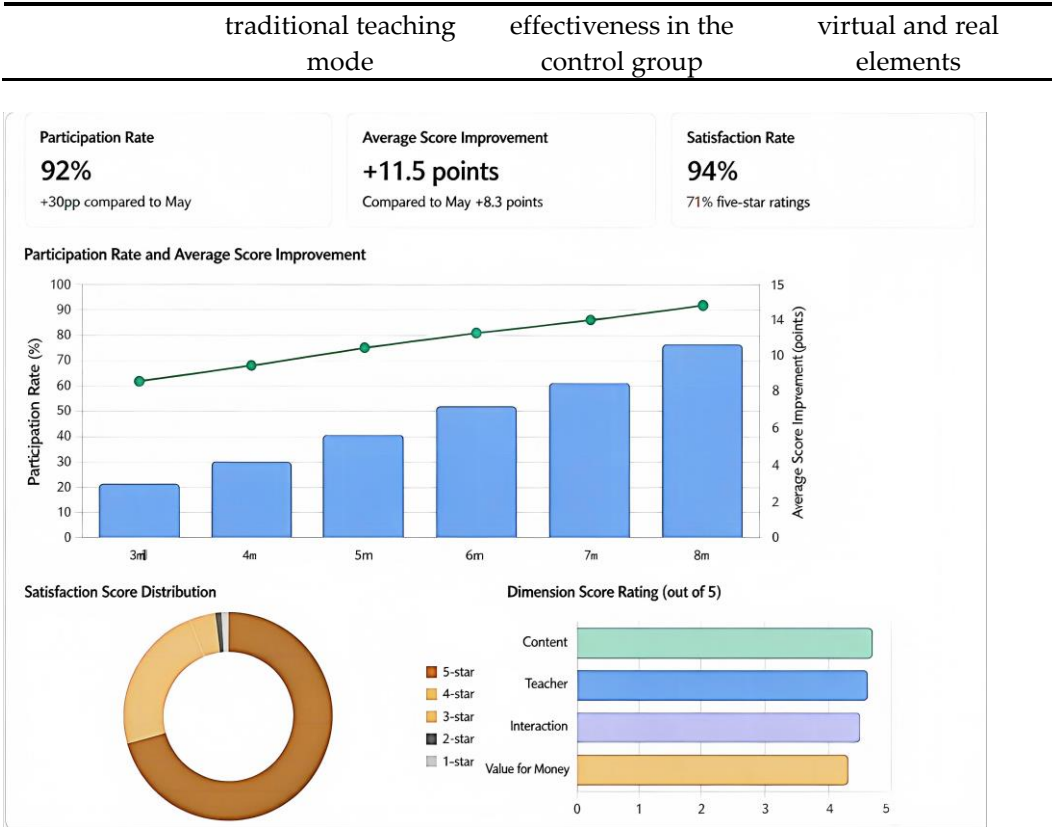


Figure 2. Evaluation of the Application Effect of the Nursing Virtual Simulation Training Platform

6. Conclusion and Prospect

Based on the shortcomings of nursing training teaching and the development trend of educational digitization, this study designed and constructed a "Virtual Simulation Training Platform for Basic Nursing Techniques" that integrates theoretical learning, virtual practical operation, intelligent assessment, and effect evaluation. The platform adopts a four-tier hierarchical architecture, relying on a modularized curriculum system and an intelligent assessment mode. The Web3D training assets within the platform are developed based on the WebXR compatibility standard, with native support for porting and extending to immersive hardware such as VR head-mounted displays. This effectively addresses issues such as high consumption of materials in traditional nursing training, high operational risks, limited training frequency, and subjective assessments. It effectively standardizes students' basic nursing operations, cultivates clinical thinking, enhances job adaptability, and provides good practical support for the reform of nursing training education. Currently, this platform only covers the practical training content of basic nursing skills, and the resource system still needs further expansion. The platform currently operates solely on the web, and the immersive interactive effect still needs to be optimized. In addition, the platform lacks the support and verification of large-scale teaching application data. In the future, we will fully leverage the scalable advantages of the platform, continuously expand practical training resources such as specialist nursing and emergency nursing, rely on the existing WebXR compatible asset base, combine VR and artificial intelligence technologies to optimize interactive experience and simulation effects, expand the scope of teaching applications, continuously improve the intelligent assessment and effect evaluation system, continuously optimize platform functions, and promote the in-depth implementation of the virtual-real combined nursing training teaching model, thereby facilitating the high-quality development of digital teaching in nursing majors.

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