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From Simulation to Integration: Innovation and Challenges in Virtual Simulation Technology for Nursing Education and Talent Development in China

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Abstract: The global ageing population and increasing burden of chronic diseases have created an urgent demand for highly qualified, application-oriented nursing professionals. However, traditional nursing education models face multiple challenges, including a disconnect between theory and practice, difficulties in training for high-risk procedures, uneven distribution of clinical resources, and insufficient training in humanistic care. This necessitates paradigm-level innovation and transformation. This article explores the role of virtual simulation technology as a core driver in propelling China's nursing education from traditional models toward a new paradigm of deep integration among teaching, learning, and practice. It also analyzes the associated challenges.

Keywords: Virtual simulation technology; Nursing education; Talent development; Blended learning

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1. Introduction

1.1. Background and problem statement

The global ageing population and the shift in the spectrum of chronic disease continue to intensify pressure on healthcare systems, imposing greater requirements on geriatric care personnel. Traditional training models struggle to meet the diverse and complex demands of contemporary nursing practice. Consequently, developing novel training pathways to produce substantial numbers of high-caliber, application-oriented healthcare professionals is pivotal to addressing these challenges [1]. Existing nursing training models exhibit significant structural deficiencies: theoretical knowledge remains detached from practice, leaving students ill-equipped to manage complex clinical problems; high-risk training opportunities are scarce, undermining their emergency response capabilities and confidence; systemic competencies such as team collaboration are often neglected. These

shortcomings constrain both the caliber and efficiency of the workforce, hindering the achievement of a "high-quality, efficient nursing service system" and demonstrating the inevitability of systemic educational reform.

1.2. Virtual simulation technology as a solution

To address the practical challenges in nursing education, virtual simulation technology offers a critical solution. This technology enables the intuitive presentation of knowledge points and operational procedures, supporting students in efficiently enhancing practical skills and learning outcomes through immersive, risk-free simulation training. It effectively mitigates the limitations inherent in traditional teaching methods, such as scarce resources, high risks, and substantial costs [2]. Virtual simulation encompasses a broad spectrum of technologies, forming a comprehensive system that progresses from basic to advanced and from partial to holistic. This spectrum includes standardized patients (SPs), partial task trainers, computer-based simulations, and VR, AR, and MR technologies. VR emphasizes immersive experiences, AR provides augmented reality assistance, and MR enables interaction between virtual and real elements. Altogether, these technologies propel nursing education towards more systematic and in-depth development [3].

The core value of virtual simulation technology lies in establishing a secure, controllable, and repeatable high-fidelity training environment. Within this setting, students can repeatedly practice high-risk procedures such as emergency resuscitation without risk, transforming knowledge into muscle memory. Furthermore, by simulating complex clinical cases and team scenarios, it systematically cultivates clinical judgement and collaborative skills. This elevates it beyond a mere auxiliary tool, transforming it into a strategic fulcrum bridging theory and clinical practice, propelling students towards competency. However, fully realizing this "strategic fulcrum" potential remains hindered by critical challenges in the current application. Many teaching attempts remain fragmented, confined to isolated skill training, failing to systematically integrate virtual simulation into the comprehensive curriculum and practice chain of nursing talent development. Specifically, the core issue requiring urgent exploration in both research and practice remains how to achieve the transition from "single-point simulation" to "end-to-end integration"—that is, how to deeply integrate it with classroom theory, clinical placements, and even assessment and evaluation, thereby genuinely and efficiently bridging the gap between theory and practice.

1.3. Core focus: Innovation and integration

Virtual simulation technology is systematically reshaping nursing talent development models by establishing a technical framework ranging from low-fidelity to high-fidelity simulations. It drives transformation across three dimensions: at the innovation level, it propels fundamental shifts in teaching methodologies and approaches; at the integration level, it achieves deep convergence with curricula, practical training, and assessment systems; and at the ecosystem level, it facilitates the establishment of an open, collaborative new paradigm for nursing education. Through a blended teaching model integrating virtual and physical elements, this technology employs a closed-loop process of "pre-class virtual preparation–offline practical sessions–post-class virtual review." This approach effectively overcomes resource constraints, deepens knowledge comprehension, and compensates for practical limitations, establishing itself as an effective pathway for the digital transformation of laboratory teaching [4].

Virtual simulation technology in nursing education effectively enhances students' procedural proficiency, adaptability, and overall learning outcomes by replicating real-world scenarios, offering personalized learning pathways, and delivering precise assessments. This facilitates a shift in nursing education from "simulation training" towards "integration with practical operations." However, its implementation faces multiple challenges,

including technological integration, the transformation of teaching roles, and the refinement of evaluation mechanisms [5–7].

Moving forward, for virtual simulation technology to transition from an "effective tool" to a "paradigm shift," it must rely upon three pillars: systematically embedding simulation within the curriculum, establishing dedicated teams of professional facilitators, and implementing structured feedback mechanisms. Concurrently, attention should be paid to the long-term benefits of simulation training and its tangible impact on patient clinical outcomes. By developing standardized integrated courses, the gap between theory and practice can be bridged, thereby driving the comprehensive implementation of innovative education.

2. Literature search and methods

2.1. Retrieval strategy

Database search: Primarily includes China National Knowledge Infrastructure (CNKI) and Wanfang Data Knowledge Service Platform.

Search time frame: Chinese core journals and degree theses published between 2015 and 2025.

Search keywords: Virtual simulation technology; Nursing education; Nursing teaching; Talent cultivation; Blended learning.

2.2. Inclusion and exclusion criteria

Inclusion criteria:

(1) Research subjects: involving Chinese nursing students or practicing nurses

(2) Research topic: Explicitly examining the application, efficacy, or challenges of virtual simulation technologies (including VR, AR, computer simulation, and medium-to-high fidelity simulation manikins) in teaching or training contexts

(3) Research type: Empirical studies (randomized controlled trials, quasi-experimental research, mixed-methods research), high-quality review literature, as well as expert consensus documents and technical standards

(4) Publication language: Chinese

Exclusion criteria:

(1) Non-research literature such as conference abstracts, news articles, and notices

(2) Literature with duplicated research content or incomplete data

(3) Literature for which the full text cannot be obtained

(4) Literature unrelated to the theme of nursing education

2.3. Literature screening and data analysis

Screening process: An initial literature search yielded 50 articles, which were reduced to 19 after deduplication using reference management software such as NoteExpress. Initial screening involved reviewing titles and abstracts to exclude clearly ineligible studies. Full texts of the remaining articles were then downloaded and critically read, with a second screening conducted against inclusion and exclusion criteria. Ultimately, 19 articles were retained for in-depth analysis.

Methodology: This study employed thematic analysis. Research subjects, types of virtual simulation technology applied, pedagogical integration models, teaching outcomes, and reported implementation challenges

were extracted, synthesized, and compared. The aim of this analysis was to systematically map the practical trajectory of virtual simulation technology in nursing education, tracing its progression from "technology application" to "pedagogical integration."

3. The evolution of virtual simulation technology and pathways to application integration

The application of virtual simulation technology in Chinese nursing education is not monolithic; it constitutes a multi-tiered, dynamically evolving technological spectrum. The progression of this spectrum not only reflects the iterative advancement of the technology itself but also profoundly drives fundamental innovation in nursing teaching models and paradigms (as illustrated in **Figure 1**).

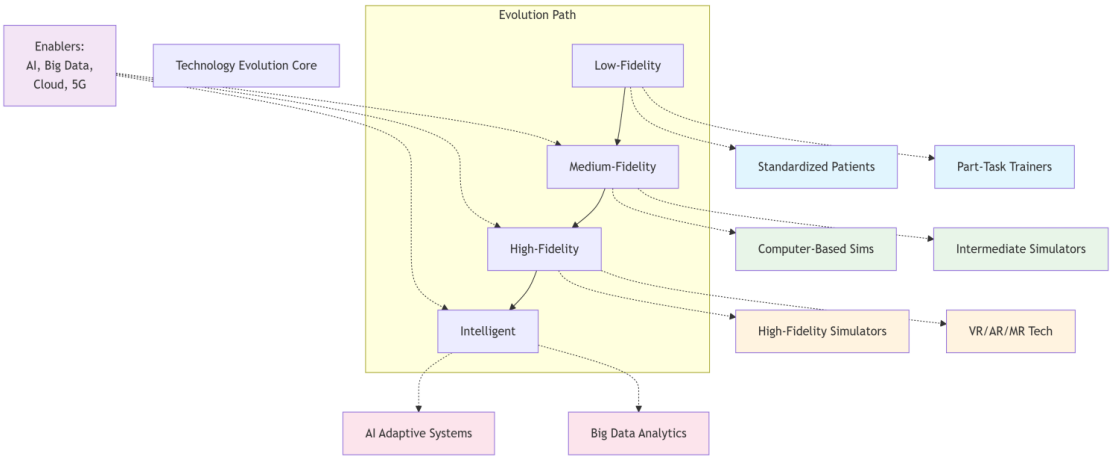

Figure 1. The genealogy of virtual simulation technology and pathways for application integration

3.1. Innovation in the technical dimension

Innovation in virtual simulation technology is primarily manifested in its technical dimensions, forming a continuum of fidelity ranging from low to high, and advancing rapidly towards intelligent capabilities. Within this spectrum of low to high fidelity, simulation technologies at different levels possess distinct advantages and disadvantages alongside specific application scenarios, collectively forming a complementary ecosystem.

3.1.1. Low-fidelity simulation

Taking standardized patients and task trainers as examples, the former focuses on developing nursing students' communication skills during consultations, compassionate care, and fundamental physical examination abilities; the latter provides repetitive muscle memory training for specific techniques such as intravenous injections and catheterization. Their advantages are low cost and ease of implementation, forming the foundation of competency development. For instance, a three-stage training model incorporating "virtual simulation platforms—simulation models—standardized patients" has been shown to effectively enhance nursing students' procedural skills, clinical reasoning abilities, and communication adaptability, while simultaneously fostering greater empathy and improving the learning environment [8]. In addition, a study employing a blended approach of online theoretical instruction combined with virtual simulation training has also been conducted. In teaching female patients

catheterization techniques, the case study encompassed three phases: pre-procedure preparation, task execution, and post-procedure feedback. The conclusion drawn was that integrating virtual simulation technology with foundational nursing practical training effectively utilizes training time, enhances students' practical skills and comprehensive abilities, and elevates teaching quality [9].

3.1.2. Mid-fidelity simulation

These primarily encompass computer-based virtual simulations and intermediate-level simulation manikins equipped with basic physiological response capabilities. They can replicate common clinical scenarios, enabling nursing students to learn condition assessment, medication management, and fundamental decision-making, thereby serving as a vital bridge between theoretical knowledge and clinical practice. Research indicates that the application of virtual simulation technology in undergraduate nursing clinical teaching significantly enhances students' mastery of knowledge regarding responsibilities and procedures, alongside boosting their learning interest. This demonstrates the technology's efficacy and value for cultivating nursing practice competencies [10].

3.1.3. High-fidelity simulation

Highly realistic simulation manikins and virtual/augmented reality technologies form the core. These manikins can display lifelike physiological signs (such as pupil dilation, breath sounds, and pulse) and dynamically respond to interventions, making them exceptionally suited for comprehensive skills training and team collaboration in complex clinical scenarios. VR/AR technology, by constructing fully immersive or blended environments, provides nursing students with access to scenarios rarely encountered in traditional laboratories or clinical settings (such as earthquake rescue operations or operating room procedures), significantly expanding the boundaries of teaching. For instance, in the field of AR technology, research has demonstrated the application of AR combined with immersive experiential teaching in vascular surgery nursing education, effectively enhancing nurses' specialized practice capabilities and improving teaching quality, making it suitable for promotion and application in clinical nursing education [11].

3.1.4. Trend towards intelligence

At present, virtual simulation technology is undergoing deep integration with artificial intelligence and big data analytics, advancing towards intelligent systems. AI-driven adaptive simulation systems dynamically adjust the difficulty and progression of clinical scenarios based on learners' real-time performance, delivering personalized challenges to each individual. By capturing and analyzing data throughout the entire procedure, the system generates feedback reports far more nuanced than mere "correct/incorrect" assessments. These reports pinpoint precisely where trainees excel and where they fall short in clinical decision pathways, procedural efficiency, and team communication. This enables a transformation from "experiencing simulation" to "insightful learning."

3.2. Teaching and paradigm innovation

Virtual simulation technology is driving the evolution of nursing education paradigms from "single-skill training" towards "holistic competency development." Its application now extends beyond clinical procedures, requiring students to navigate emotional, ethical, and emergency scenarios presented by standardized patients or virtual characters within high-fidelity environments. This systematically hones core competencies, including communication, empathy, teamwork, and critical thinking.

The flexibility of virtual simulation technology renders it an ideal vehicle for multiple advanced teaching methodologies: Problem-based simulation: Utilizing authentic clinical scenarios as starting points, guiding nursing students to explore solutions through simulation and autonomously construct knowledge; Integration of flipped classrooms with simulation: Students acquire theoretical knowledge via online resources prior to class, while classroom time is entirely dedicated to high-value simulation activities and in-depth debriefing, optimizing the teaching process and maximizing classroom time utilization; Interdisciplinary simulation education: By replicating authentic healthcare scenarios, students from nursing, clinical medicine, pharmacy, rehabilitation and other disciplines collaborate within unified teams to address clinical challenges. This approach effectively dismantles professional silos, fostering the teamwork capabilities and mutual professional respect essential for future healthcare practice.

These practices constitute fundamentally technology-driven innovations in teaching methodologies. Virtual simulation facilitates "contextualized learning" and, through integration with blended learning and flipped classroom approaches, it reconfigures teaching processes, transforming the teacher's role into a facilitator. It has evolved from an auxiliary tool into a core driver for nursing education's transition towards a student-centered, competency-oriented, and integrated model.

4. Implementation and effectiveness of application integration

The value of virtual simulation technology in Chinese nursing education has transcended its initial role as a mere "simulation" tool for single-skill training and is now increasingly integrated throughout the entire talent development process. The core of this integration is its effective bridging of the gap between theoretical knowledge and clinical practice, fostering the generation and application of nursing students' comprehensive competencies within authentic scenarios. This integrated practice manifests primarily across three key dimensions: integration with the classroom system, alignment with clinical practice, and fusion with the assessment framework (as illustrated in **Figure 2**).

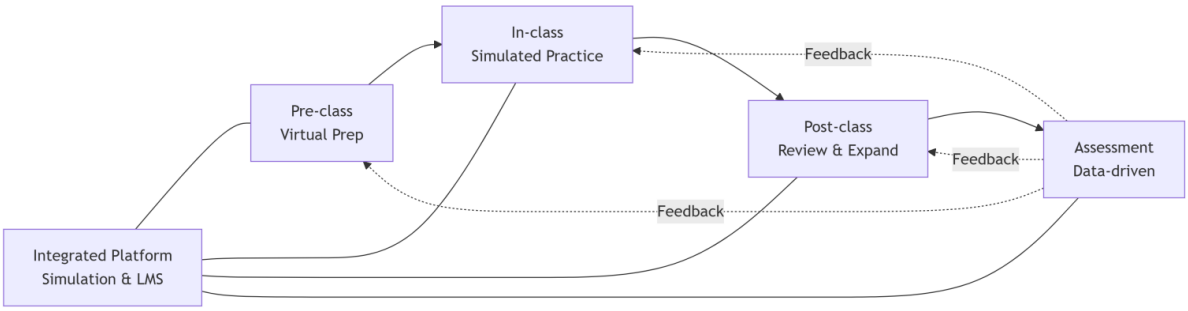

Figure 2. Practical application and outcomes of virtual simulation technology integration

4.1. Integration with the classroom system

The success of virtual simulation teaching hinges on its systematic integration into the entire talent development program, rather than remaining a mere embellishment or isolated event within the curriculum. This integration manifests through vertical consolidation and horizontal interconnection. From the point of vertical consolidation, simulation teaching follows pedagogical principles throughout the academic program: junior students utilize basic skills simulations to familiarize themselves with operational procedures; intermediate students employ complex

case simulations to integrate multidisciplinary knowledge and hone clinical reasoning; senior students undergo comprehensive high-fidelity simulations and interprofessional training to refine their pre-clinical competencies. From the point of horizontal interconnection, simulation activities are closely interwoven with theoretical courses, serving as "instant laboratories" for applied knowledge. In a stroke nursing practical training program, the integration of the SuperStar Learning Platform with virtual simulation technology demonstrates that this approach effectively enhances nursing students' theoretical performance, practical skills, and depth of learning. This highlights the positive value of deeply integrating information technology with nursing education in optimizing practical teaching processes and enhancing comprehensive educational outcomes [12]. For instance, following instructions on the pathophysiology of heart failure, corresponding high-fidelity simulation cases are immediately deployed. This enables nursing students to experience how theoretical knowledge is applied in clinical decision-making for monitoring, assessment, and intervention. Such systematic embedding ensures simulation teaching objectives align closely with overall course goals, forming a spiraling, continuously reinforcing learning loop.

4.2. Integration with clinical practice

Virtual simulation serves as an irreplaceable conduit for bridging the gap between clinical practice and education, with its efficacy increasingly supported by a growing body of evidence. In specialist nursing education, research has developed a virtual simulation training platform for ultrasound-guided intracardiac electrogram-localized tunneled PICC catheter placement. Its scientific validity and practicality were validated through the Delphi method and pre-experimental studies. Application results indicate that this platform enhances nurses' theoretical knowledge, reduces procedural apprehension, and boosts confidence and satisfaction. This demonstrates the innovative value of virtual simulation technology in nursing skills training, though challenges remain regarding technical maturity and clinical translation [13]. Taking hemodialysis nursing education as an example, research has explored the application of smart teaching models integrating virtual simulation, intelligent assessment, and blended online-offline learning, which indicates these approaches enhance nursing students' procedural skills and clinical adaptability, representing a robust practice in nursing education's transition from simulation training to deep integration [14]. Their value is directly reflected in key metrics, such as shorter job adaptation periods, higher first-attempt success probability in computerized procedures, more comprehensive patient assessment capabilities, and faster emergency response times. This is particularly evident in the "Transition to Practice" program. For newly recruited nurses or those nurses transitioning to new roles, healthcare institutions utilize high-fidelity simulation to recreate typical clinical scenarios in forthcoming departments. Virtual simulation technology effectively stimulates learning interest among new nurses, enhances their theoretical and practical competencies, and strengthens their overall professional competence [15].

In pre-service training for specialist dental nurses, this technology also improves practical skills and comprehensive capabilities by simulating authentic clinical scenarios [16]. Furthermore, head-mounted VR headsets, used as supplementary teaching tools, significantly elevate junior nurses' professional knowledge, operational skills, and training satisfaction, demonstrating considerable potential for wider adoption [17]. This "pre-adaptation" training not only rapidly enhances role-specific competencies but also allows nurses to familiarize themselves with workflow procedures, team culture, and communication protocols within a secure environment. This approach substantially mitigates the "reality shock" experienced upon entry into clinical practice, reduces initial error rates, and safeguards patient safety.

4.3. Integration with the evaluation system

The integrated value of virtual simulation is profoundly reflected in the transformation of assessment systems. It propels nursing education evaluation from traditional, sole summative assessments (such as end-of-term written examinations or OSCE stations) towards continuous, multidimensional formative evaluation. Within simulation environments, every decision, procedure, and communication by trainees is simultaneously recorded and analyzed by the system. This enables assessment to extend beyond merely determining whether the final action was "correctly performed," delving deeper into the cognitive processes of "how it was done" and "why it was done that way."

This integration has fostered a more scientific paradigm for competency assessment. By analyzing vast operational datasets, educators can precisely evaluate nursing students' proficiency in clinical procedures, communication skills, critical thinking, and decision-making. Meanwhile, interprofessional simulation training enables objective evaluation of nursing students' performance alongside physicians, health managers, and other roles in teamwork, leadership, and role recognition. This data-driven, refined evaluation not only provides objective evidence of teaching effectiveness but also generates personalized competency profiles for each student. These profiles provide clear direction for students in future learning, truly achieving the principle of "assessment-driven learning." As outlined in the *Expert Consensus on Technical Standards for Virtual Simulation Applications in Clinical Skills Training*, which systematically establishes its technical framework, its core encompasses four key components: virtual simulation content design and modelling, management platform interfaces, quality evaluation, and data transmission and security. It emphasizes that content should possess high fidelity, strong interactivity, and cross-platform compatibility. This provides medical schools and healthcare institutions with a critical technical framework and practical guidance for virtual simulation training and assessment of clinical practice skills, thereby promoting the standardized development and deep application of this technology [18].

5. Discussion: Challenges faced and future directions

The application of virtual simulation technology in Chinese nursing education has demonstrated significant effectiveness, progressively evolving from "simulation" towards "integration" to become an integral component of the nursing talent cultivation system. Nevertheless, the development of the technology still faces numerous challenges. It is imperative to define the path forward, based on summarizing achievements and analyzing existing issues.

5.1. Summary of outcomes and mechanism analysis

The key outcomes of virtual simulation teaching in nursing education manifest in three principal aspects: First, it markedly enhances nursing students' clinical confidence and decision-making capabilities. Through repeated practice within a safe, controlled environment, it effectively reduces anxiety when encountering real patients for the first time. Secondly, compared to traditional teaching methods, simulation instruction demonstrates superior knowledge retention rates and skill transfer efficiency. Finally, it systematically hones students' overall clinical performance, particularly in high-risk or complex scenarios such as managing emergencies or navigating challenging communications. These outcomes are supported by robust educational theories: Experiential Learning Theory emphasizes "learning by doing," with virtual simulation technology creating a closed-loop experiential cycle for nursing students – progressing from specific procedures to reflective observation, then abstract generalization and proactive application, thereby deepening learning outcomes; Situational Learning Theory posits that learning is fundamentally a process of engaging in social practice and becoming part of a "community of

practice."

5.2. Challenges and obstacles faced

Despite its promising prospects, the deep integration of virtual simulation technology still faces multiple challenges. Cost and resource constraints are the foremost obstacles. High-performance simulation equipment, dedicated facility construction, and software updates and hardware maintenance cause financial burden for many institutions. Faculty development presents another major bottleneck. The success of simulation-based teaching relies heavily on the competence of facilitators, who should not only master technical operations but also excel at providing guided feedback before and after simulations. Currently, systematic faculty training frameworks remain inadequate. Technical barriers and ethical dilemmas cannot be ignored: rapid technological iteration leads to equipment becoming obsolete; physiological side effects, such as motion sickness, impact user experience for some participants. Furthermore, ethical issues concerning patient privacy within simulated scenarios, the use of behavioral data, and balancing "high realism" with "psychological safety" require urgent regulation. Challenges in translating evidence persist at the implementation level. Although extensive research confirms the efficacy of simulation-based teaching, converting this evidence into standardized, actionable curricula and practice guidelines widely adopted across different regions and institutions remains a complex undertaking.

5.3. Future development directions

To address the aforementioned challenges and leverage current opportunities, the future advancement of virtual simulation in nursing education should concentrate on three interconnected levels.

At the research level, there is an urgent need for more high-quality, long-term monitoring empirical studies. These studies should extend beyond examining immediate pedagogical effects to evaluating the long-term impact of simulation training on nurses' professional competencies and, ultimately, on patient outcomes.

At the technological level, embracing cutting-edge innovations is essential. Priorities include the development of AI-driven adaptive simulation systems that tailor scenario difficulty and feedback in real-time based on learner performance; exploration of the metaverse's potential for creating immersive, collaborative medical education environments; and the promotion of research into portable, low-cost simulation devices to improve equitable access. Leveraging big data analytics can facilitate a more nuanced assessment of the learning process, enabling truly personalized teaching strategies.

At the practical and strategic level, systematic development is paramount. This involves establishing standardized simulation course frameworks and robust evaluation systems to ensure consistent educational quality. Simultaneously, fostering cross-institutional, cross-regional, and international collaboration—through simulation teaching alliances and cloud-based platforms—is crucial to maximizing the sharing and utilization of high-quality educational resources. Furthermore, digital literacy must be recognized as a core competency for nursing professionals. Future nurses will need to proficiently use virtual simulation tools while also demonstrating data security awareness and advanced information processing to adapt to and shape the evolving smart healthcare landscape.

Through the coordinated progression of these strategic frameworks, resource integration, and competency development, a future-oriented nursing workforce can be cultivated, leading to a comprehensive leap in training quality [19].

6. Conclusion

Virtual simulation technology is profoundly transcending its role as a mere teaching tool. Through innovations in high-fidelity simulation, virtual reality, and intelligent methodologies, it is fundamentally revolutionizing traditional nursing education models. Maximizing its value does not hinge on isolated technological application, but on its systematic, end-to-end integration into curriculum design, teaching practice, and competency assessment. This approach effectively bridges the gap between theoretical knowledge and clinical practice.

In the future, sustained innovation and strategic integration are essential for enhancing the quality of talent cultivation in the health sector. To this end, the following pathways are proposed, requiring concerted efforts from both academia and industry:

(1) For educational institutions

Efforts should be made to systematically integrate virtual simulation into the curriculum framework, to develop standardized simulation course frameworks, and to establish a dedicated training mechanism for professional "facilitators" to ensure teaching quality.

(2) For healthcare institutions

It can be widely applied in pre-service training for new nurses and skills enhancement for practicing nurses, particularly for high-risk, low-frequency clinical scenarios. This accelerates the progression from novice to competent practitioner, safeguarding patient safety.

(3) For academia and industry

They must jointly address practical challenges, including cost investment, faculty development, technological ethics, and evidence translation. By establishing cross-institutional collaborative alliances and cloud-based resource platforms, they can maximize the utilization efficiency of high-quality resources.

The ultimate objective is to establish a next-generation health workforce development ecosystem centered on learner development, with simulation technology serving as the pivotal bridge. This ecosystem will be more integrated, efficient, and capable of flexibly addressing the complex challenges within the global health domain.

Disclosure statement

The authors declare no conflict of interest.

Author contributions

Lin Li: Led the conceptualization and design of the study, performed the literature retrieval and analysis, and drafted the full manuscript.
Lina Chen: Assisted with data collation and interpretation, and contributed to manuscript revision.

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