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Review Article

AI-Driven Virtual Simulation on Clinical Competence in Nursing: A Narrative Review

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ABSTRACT

The integration of artificial intelligence (AI) into virtual simulation has transformed nursing education by enabling immersive, adaptive, and learner-centered clinical training environments.[1,2] AI-driven virtual simulations offer personalized learning pathways, real-time feedback, and data-informed performance assessment, addressing limitations of traditional clinical education.[3,4] Clinical competence in nursing involves the integration of cognitive, psychomotor, and affective domains, all of which can be supported through intelligent simulation technologies.[5] This narrative review synthesizes existing literature on AI-driven virtual simulation and its impact on clinical competence in nursing education. Key areas reviewed include theoretical foundations, AI technologies used in virtual simulation, effects on competence domains, learner and faculty perspectives, and implementation challenges. Evidence suggests that AI-driven virtual simulation enhances clinical reasoning, procedural confidence, communication skills, and learner engagement.[6-8] Strategic integration of AI-enabled virtual simulation may strengthen competency-based nursing education while ensuring patient safety and educational consistency.[9,10]

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KEYWORDS

• Simulation-based education • Clinical competence • AI Technology • Nursing education • Reflective learning • Clinical reasoning

INTRODUCTION

Clinical competence is a core outcome of nursing education and is essential for ensuring safe, effective, and ethical patient care. Competence encompasses knowledge application, psychomotor skill performance, clinical judgment, communication, and professional behavior.[1,2] Traditional clinical education relies heavily on hospital-based placements; however, increasing student enrollment, limited clinical sites, patient safety concerns, and variability in learning opportunities have challenged the adequacy of conventional models.

Simulation-based education has emerged as an evidence-based strategy to supplement clinical learning by providing safe, controlled, and repeatable practice environments.[2] Advances in digital technologies have further expanded simulation modalities, leading to the development of virtual simulation environments.[4] Artificial intelligence has enhanced these environments by enabling adaptive learning, intelligent feedback, and data-driven assessment.[6] AI-driven virtual simulation represents a significant innovation with the potential to support competency-based nursing education and address gaps in traditional clinical training.[3,7]

Clinical Competence in Nursing

Clinical competence in nursing is a multidimensional construct integrating cognitive, psychomotor, and affective domains. Cognitive competence includes knowledge acquisition, clinical reasoning, and decision-making abilities. Psychomotor competence refers to the accurate and safe execution of clinical procedures. Affective competence encompasses communication skills, empathy, teamwork, and ethical practice.

Competency-based education frameworks emphasize measurable outcomes, mastery learning, and progression based on performance rather than time. Achieving consistent clinical competence remains challenging due to unequal clinical exposure and subjective assessment methods. Simulation-based approaches, particularly AI-enhanced virtual simulation, align well with competency-based models by offering standardized yet individualized learning experiences.[6]

Evolution of Virtual Simulation in Nursing Education

Virtual simulation has evolved from simple screen-based case scenarios to immersive, interactive environments using virtual reality (VR), augmented reality (AR), and mixed reality (MR).[4] Early virtual simulations provided linear learning experiences with limited adaptability. Contemporary systems incorporate AI to create dynamic, responsive clinical scenarios.[6]

Virtual simulation allows learners to engage in realistic patient care situations without risk to real patients. Studies have shown that virtual simulation improves learner confidence, knowledge retention, and preparedness for clinical practice.[4,8] The addition of AI enhances realism and personalization, distinguishing AI-driven virtual simulation from traditional digital learning tools.

Artificial Intelligence Technologies in Virtual Simulation

AI-driven virtual simulation integrates multiple technologies to support learning and assessment. Machine learning algorithms analyze learner performance data to identify patterns, predict learning needs, and personalize simulation pathways.[6] These systems can modify scenario complexity in real time based on learner responses.

Natural language processing enables realistic verbal interactions between learners and virtual patients, supporting communication and clinical interviewing skills. Intelligent tutoring systems provide immediate, tailored feedback and reflective prompts, enhancing metacognitive learning. Computer vision and motion tracking technologies are increasingly used to assess psychomotor performance objectively. Collectively, these AI technologies support comprehensive competence development across learning domains.[3,6]

Impact on Cognitive Competence

AI-driven virtual simulations enhance cognitive competence by promoting active clinical reasoning and decision-making.[7] Learners are required to interpret patient data, prioritize care, and respond to evolving clinical situations.[4] Adaptive algorithms ensure that learners are challenged at appropriate levels, supporting higher-order thinking.

Research demonstrates that nursing students using AI-enhanced virtual simulation show significant improvements in knowledge retention, diagnostic accuracy, and clinical judgment.[8] These outcomes align with the goals of competency-based education and support the integration of AI-driven simulation into nursing curricula.

Impact on Psychomotor Competence

Psychomotor skill acquisition requires repeated practice and timely feedback. AI-driven virtual simulations allow learners to rehearse procedures multiple times without patient risk. Intelligent feedback systems provide immediate correction, reinforcing proper technique and reducing error repetition.

Although virtual simulation cannot fully replace hands-on clinical experience, evidence suggests it enhances procedural understanding and skill readiness.[4] When combined with mannequin-based simulation and clinical practice, AI-driven virtual simulation contributes to comprehensive psychomotor competence development.[2]

Impact on Affective and Communication Competence

Communication and professional behaviors are essential components of nursing competence. AI-enabled virtual patients can display emotional responses, cultural variations, and ethical dilemmas, enabling learners to practice therapeutic communication and empathy.

Virtual team-based simulations supported by AI have been shown to improve interprofessional communication and teamwork skills. These affective learning outcomes are critical for safe patient care and are difficult to achieve consistently in traditional clinical placements.

Learner Engagement and Self-Directed Learning

AI-driven virtual simulation supports learner engagement through interactive scenarios, gamification, and personalized feedback.[3,7] Learning analytics dashboards enable students to monitor progress and identify areas for improvement. These features promote self-directed learning and reflective practice.

Studies indicate that learners report higher motivation, satisfaction, and confidence when using AI-enhanced virtual simulations compared to traditional teaching methods.[8] Such engagement is particularly valuable in large nursing programs with limited faculty resources.

Faculty Perspectives and Curriculum Integration

Faculty play a pivotal role in integrating AI-driven virtual simulation into nursing education.[15] Educators recognize its value for standardizing learning experiences and supporting competency assessment.[6] However, challenges include technological proficiency, curriculum alignment, and interpretation of learning analytics.

Faculty development programs and institutional support are essential to ensure effective implementation. Blended learning models combining virtual simulation, mannequin-based simulation, and clinical practice are recommended to optimize competence development.[2,4]

Ethical and Implementation Challenges

Ethical considerations associated with AI-driven simulation include data privacy, algorithmic bias, and transparency in automated assessment. Ensuring equitable access to advanced simulation technologies is a major concern, particularly in resource-limited settings.

Technical challenges include high initial costs, infrastructure requirements, and system maintenance. Despite these barriers, strategic planning and policy support can facilitate sustainable adoption of AI-driven virtual simulation.[9,10]

CONCLUSION

AI-driven virtual simulation is a transformative educational innovation with strong potential to enhance clinical competence in nursing.[3,6] By supporting cognitive, psychomotor, and affective learning domains through adaptive, immersive, and data-driven environments,

it addresses many limitations of traditional clinical education.[4,8] While ethical, technical, and faculty-related challenges remain, evidence supports its role as a valuable complement to existing teaching strategies.[2] Future research should focus on long-term competency outcomes, cost-effectiveness, and ethical governance to guide widespread implementation.[9]

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