RESEARCH PAPER

Artificial Intelligence–Powered Intelligent Tutoring Systems in Nursing Education: Advancing Personalized Learning, Clinical Competence, and Patient Safety — A Systematic Review

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ABSTRACT

Artificial intelligence (AI)-powered intelligent tutoring systems (ITS) are increasingly used in nursing education to personalize learning, strengthen clinical reasoning, and safeguard patient outcomes. This systematic review synthesized evidence on how AI-driven ITS, virtual patients, adaptive learning platforms, and generative AI chatbots influence nursing students' knowledge, clinical competence, and readiness for safe practice. Electronic searches of PubMed, CINAHL, Scopus, Web of Science, IEEE Xplore, and ERIC were conducted using Medical Subject Headings and free-text terms combining artificial intelligence, intelligent tutoring systems, nursing education, and patient safety, following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses 2020 guideline. Thirty-two primary and secondary studies published between 2014 and 2026 met the inclusion criteria. Findings show that AI-powered ITS and virtual patient platforms consistently improved knowledge retention, clinical reasoning, self-efficacy, and psychomotor skill acquisition compared with conventional teaching, while generative AI chatbots enhanced problem-solving, engagement, and satisfaction, though effects on higher-order thinking and cultural empathy remained mixed. Adaptive learning platforms and machine-learning prediction models supported early identification of at-risk students and individualized remediation. Ethical concerns, algorithmic bias, faculty unpreparedness, and infrastructural barriers were recurrent limitations across the included studies. Overall, AI-powered ITS represent a promising, though still maturing, pedagogical strategy for advancing personalized learning and clinical competence in nursing education, provided that human oversight, curricular integration, and structured ethics training accompany their adoption to protect patient safety.

Keywords: *artificial intelligence; intelligent tutoring systems; nursing education; personalized learning; clinical competence; patient safety; systematic review*

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1. INTRODUCTION

Nursing education stands at a pivotal juncture where technological innovation is reshaping how future nurses acquire knowledge, refine clinical judgment, and prepare for safe, competent practice. Over the past decade, artificial intelligence has moved from a peripheral curiosity in health professions education to a central pedagogical force, reorganizing how content is delivered, how learners are assessed, and how feedback is generated.[1-2] Among the many AI applications entering nursing classrooms and simulation laboratories, intelligent tutoring systems occupy a distinctive position because they are explicitly designed to replicate the individualized guidance that a skilled human tutor would provide, but at a scale and consistency that traditional faculty-to-student ratios cannot achieve.

An intelligent tutoring system is broadly defined as a computer-based instructional platform that uses models of the learner, the domain, and the pedagogy to adapt content, pacing, and feedback to each student's evolving needs.[3-4] The conceptual lineage of these systems stretches back to early computer-assisted instruction of the 1970s, when rule-based programs offered static branching logic, through the cognitive-tutor era of the 1980s and 1990s, when production-rule modelling allowed systems to track a learner's problem-solving steps in real time.[5] Contemporary ITS platforms, strengthened by machine learning, natural language processing, and generative AI, now converse with learners, generate case scenarios on demand, and continuously recalibrate difficulty based on performance data, moving the field from static computer-assisted instruction toward genuinely adaptive, dialogic tutoring.[6] In nursing specifically, this evolution has produced a heterogeneous ecosystem of tools: AI-enhanced virtual patients that simulate deteriorating physiology, conversational agents such as ChatGPT-based platforms that scaffold care-planning exercises, adaptive e-learning modules that reroute students toward remedial content when knowledge gaps are detected, and predictive analytics dashboards that flag students at risk of attrition or licensure failure.

The appeal of AI-powered ITS in nursing rests on three interconnected promises. First is personalized learning. Traditional lecture-based and even many simulation-based curricula deliver a largely uniform experience regardless of a student's prior knowledge, learning pace, or specific deficits, whereas adaptive tutoring systems continuously reassess the learner and adjust content sequencing accordingly, in principle allowing struggling students to receive targeted remediation while advanced students are permitted to progress more quickly.[1] Second is the cultivation of clinical competence and reasoning. Nursing practice depends on the kind of situated, iterative judgment described in Tanner's model of clinical reasoning, in which noticing, interpreting, responding, and reflecting cycle continuously as a patient's condition evolves.[7] Because well-designed ITS and virtual patient platforms can present dynamic, branching clinical scenarios with immediate feedback, they are theorized to accelerate the transition described by Benner from novice, rule-bound performance toward more intuitive, expert pattern recognition, by compressing years of clinical exposure into repeatable, low-stakes practice opportunities.[8] Third, and arguably most consequential, is the link to patient safety. Deficits in clinical knowledge and judgment among newly qualified nurses have long been associated with preventable adverse events, and international bodies have repeatedly called for education systems that produce practice-ready graduates capable of managing complexity and uncertainty without compromising safety.[9] The Quality and Safety Education for Nurses initiative and the World Health Organization's patient safety curriculum guide both position simulation-based and technology-enhanced learning as vehicles for closing the gap between classroom competence and safe bedside performance, a rationale that extends naturally to AI-powered tutoring platforms capable of rehearsing high-risk scenarios such as clinical deterioration, medication error recovery, and communication failures without endangering real patients.[10][11]

Despite this promise, the evidence base underpinning AI-powered ITS in nursing education remains fragmented. Existing reviews have tended either to survey AI applications in nursing broadly, without isolating the tutoring function specifically, or to examine intelligent tutoring systems in general K-12 or higher-education contexts without addressing the particular demands of clinical competence and patient safety that distinguish nursing from other disciplines.[12][13] Recent syntheses have begun to differentiate procedural efficiency from deeper cognitive engagement, noting that while AI systems reliably improve psychomotor and knowledge-based outcomes, their effect on higher-order thinking, clinical judgment under ambiguity, and culturally attuned, empathic care is less consistent and sometimes contested.[3] At the same time, commentators in digital health more broadly have cautioned that technology adopted uncritically risks depersonalizing care unless it is deliberately harnessed to reinforce, rather than replace, the human dimensions of clinical practice.[14] Nursing and artificial intelligence leadership groups have likewise called for a coordinated research agenda addressing workforce readiness, algorithmic transparency, and the ethical governance of AI-enabled learning and practice tools.[15][16][17]

Given these gaps, a focused, methodologically rigorous synthesis of the evidence on AI-powered intelligent tutoring systems in nursing education is warranted. This systematic review therefore aims to identify, appraise, and synthesize empirical studies examining the effects of AI-powered ITS, adaptive learning platforms, virtual patients, and generative AI tutoring tools on nursing students' personalized learning experiences, clinical competence, and preparedness for safe practice. By mapping the designs, populations, outcomes, and limitations of the available literature, the review seeks to clarify what is known, what remains uncertain, and what educators, curriculum designers, and policymakers should consider as they integrate these technologies into pre-licensure and continuing nursing education.

2. METHODOLOGY

2.1 Review design and reporting framework

This systematic review was conducted and reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses 2020 statement, which provides an updated, transparent framework for identifying, screening, and synthesizing evidence in health-related systematic reviews.[2] A structured protocol specifying the review question, eligibility criteria, information sources, search strategy, and data-extraction plan was drafted a priori and used to guide all subsequent stages of the review, reducing the likelihood of post-hoc changes to inclusion decisions and improving the reproducibility of the search and screening process.

2.2 Eligibility criteria

The review question was framed using a Population, Intervention, Comparison, Outcome, and Study design structure. Eligible studies enrolled nursing students, novice nurses, or nurse educators in academic or clinical training settings. The intervention of interest was any AI-powered intelligent tutoring system, adaptive learning platform, AI-enabled virtual patient or virtual simulation, or generative AI chatbot used for instructional or tutoring purposes within a nursing curriculum. Comparators, where present, included conventional lecture-based instruction, non-adaptive computer-based learning, mannequin-based simulation, or no intervention. Outcomes of interest encompassed knowledge acquisition and retention, clinical reasoning and judgment, psychomotor and procedural competence, self-efficacy and confidence, learner satisfaction and engagement, and any measure directly or indirectly related to patient safety readiness, including simulation performance and licensure-examination outcomes. Eligible study designs included randomized controlled trials, quasi-experimental studies, cross-sectional and cohort studies, mixed-methods studies, and prior systematic reviews or meta-analyses with clearly reported search and synthesis methods. Studies were excluded if they addressed AI applications limited to clinical decision support in direct patient care without an educational component, if they focused exclusively on medical, engineering, or general K-12 populations without nursing-specific data, if they were conference abstracts without full text, editorials, opinion pieces without original data, or if they were not published in English.

2.3 Information sources and search strategy

A comprehensive electronic search was conducted across six databases selected for their relevance to nursing, health sciences, and educational technology literature: PubMed/MEDLINE, the Cumulative Index to Nursing and Allied Health Literature, Scopus, Web of Science, IEEE Xplore, and the Education Resources Information Center. The search covered records published from January 2014 to February 2026, capturing the period during which AI-enabled virtual patients, adaptive tutoring platforms, and, subsequently, generative AI tools became prominent in nursing curricula. Reference lists of included studies and relevant prior reviews were hand-searched to identify additional eligible records, and forward citation tracking was performed for key included articles.[3][18]

Search terms combined controlled vocabulary, specifically Medical Subject Headings in PubMed and equivalent CINAHL subject headings, with free-text keywords connected using Boolean operators, and were adapted iteratively for each database's syntax. The core concepts searched were artificial intelligence and its subtypes, intelligent tutoring systems and adaptive learning, nursing education, and clinical competence or patient safety, combined using the AND operator across concept blocks and the OR operator within each block. Table 1 summarizes the Medical Subject Headings and corresponding free-text terms applied across databases.

2.4 MeSH and free-text search table

Table 1. Medical Subject Headings (MeSH) and free-text search terms by database

Concept block	MeSH term(s)	Free-text / keyword terms	Databases applied
Artificial intelligence	Artificial Intelligence; Machine Learning; Natural Language Processing; Deep Learning	AI; generative AI; large language model; ChatGPT; chatbot; predictive analytics	PubMed, CINAHL, Scopus, Web of Science, IEEE Xplore, ERIC
Intelligent tutoring / adaptive learning	Computer-Assisted Instruction; Educational Technology	Intelligent tutoring system; ITS; adaptive learning; personalized learning;	PubMed, CINAHL, Scopus, Web of Science, IEEE Xplore, ERIC

		virtual tutor; conversational agent	
Nursing education	Education, Nursing; Students, Nursing; Education, Nursing, Baccalaureate	Nursing curriculum; nursing student; undergraduate nursing; pre-licensure nursing	PubMed, CINAHL, Scopus, Web of Science, ERIC
Simulation / virtual patient	Simulation Training; Computer Simulation; Patient Simulation	Virtual patient; virtual reality simulation; high-fidelity simulation; clinical simulation	PubMed, CINAHL, Scopus, Web of Science
Clinical competence / patient safety	Clinical Competence; Patient Safety; Clinical Reasoning; Judgment	Clinical judgment; clinical decision-making; competency-based education; safe practice	PubMed, CINAHL, Scopus, Web of Science, ERIC

An illustrative PubMed search string combined these blocks as follows: ("Artificial Intelligence"[MeSH] OR "Machine Learning"[MeSH] OR chatbot OR "generative AI") AND ("Computer-Assisted Instruction"[MeSH] OR "intelligent tutoring system" OR "adaptive learning") AND ("Education, Nursing"[MeSH] OR "Students, Nursing"[MeSH]) AND ("Clinical Competence"[MeSH] OR "Patient Safety"[MeSH] OR "clinical reasoning"). Equivalent strings were built for CINAHL, Scopus, Web of Science, IEEE Xplore, and ERIC using each platform's controlled-vocabulary and field-tag conventions.

2.5 Study Selection Process

All records retrieved from the six databases were imported into a reference-management system, and duplicate records were removed automatically and then verified manually. Two reviewers independently screened titles and abstracts against the eligibility criteria, and full texts of potentially eligible studies were then retrieved and independently assessed by the same two reviewers. Disagreements at either stage were resolved through discussion, and a third reviewer was consulted where consensus could not be reached. The study-selection process, including the number of records identified, screened, excluded, and included at each stage, was documented using a PRISMA 2020 flow diagram.[2]

2.6 Data Extraction and Quality Appraisal

A standardized, piloted data-extraction form was used to capture author, year, country, study design, sample and sample size, population, AI-based intervention and tutoring modality, comparator, data-collection tools, outcome measures, analytic technique, and principal findings for each included study. Two reviewers extracted data independently, cross-checked entries for accuracy, and resolved discrepancies by consensus. Methodological quality was appraised using design-appropriate tools: the Cochrane risk-of-bias tool for randomized controlled trials, the Joanna Briggs Institute checklist for quasi-experimental studies, and the Mixed Methods Appraisal Tool for studies combining quantitative and qualitative components. Quality appraisal informed the interpretation and weighting of findings during synthesis but was not used as a basis for excluding studies, in keeping with current guidance for reviews spanning heterogeneous study designs.

2.7 Data Synthesis

Because of substantial heterogeneity in interventions, outcome measures, and study designs, a narrative, thematic synthesis was undertaken rather than a statistical meta-analysis. Findings were grouped into four overarching themes that emerged inductively from the data: personalized and adaptive learning platforms, AI-enabled virtual patients and simulation, generative AI chatbots and conversational tutors, and predictive analytics for at-risk student identification. Within each theme, effect directions, magnitude where reported, and consistency across studies were compared, and ethical, technical, and institutional barriers reported across studies were synthesized separately as a cross-cutting theme.

3. RESULTS

3.1 Study Selection and Characteristics

The database search, hand-searching of reference lists, and citation tracking together identified an initial pool of records that, after removal of duplicates and title/abstract screening, yielded a set of full texts assessed for eligibility. Following full-text review, thirty-two studies satisfied the inclusion criteria and were retained for synthesis. The included studies comprised randomized controlled trials, quasi-experimental studies, cross-sectional and mixed-methods studies, and systematic reviews or meta-analyses, published between 2014 and 2026. Studies originated from a geographically diverse set of countries, including the United States, Portugal, Sweden, Singapore, Spain, Türkiye, Taiwan, South Korea, Malaysia, China, Saudi Arabia, and multi-country collaborations, indicating that interest in AI-powered nursing tutoring tools is a genuinely global phenomenon rather than confined to a single health system.

3.2 **Personalized and Adaptive Learning Platforms**

Several included studies examined AI-driven adaptive learning platforms that adjust content sequencing and difficulty according to individual performance. These platforms were consistently reported to improve knowledge retention and learner engagement relative to static, lecture-based instruction, primarily by directing struggling students toward targeted remedial content while allowing more advanced students to progress at an accelerated pace.[1] Broader reviews synthesizing AI-based teaching pedagogies across nursing programs similarly reported that adaptive platforms, alongside natural-language-processing tools, supported more individualized feedback loops than were achievable through conventional teaching alone, although the authors cautioned that the evidence base for adaptive learning specifically, as distinct from AI-enabled simulation, remained comparatively thin and dominated by single-institution studies.[12] Predictive-analytics research reinforced this personalization theme from a different angle: a quantitative study applying eight machine-learning algorithms to longitudinal academic records from 773 baccalaureate nursing students found that a single year of academic performance data could correctly predict graduation outcomes for more than 80% of students, with accuracy rising to 90% after the second year and 99% after the third, demonstrating the feasibility of early, data-driven identification of students who might benefit from individualized remediation before attrition or licensure failure occurs.[19] A related systematic review of predictors of student success across baccalaureate nursing programs corroborated that standardized test scores, course grades, and grade point average remain the most consistently reported predictors, providing a validated foundation upon which AI-based early-warning systems can be built.[20]

3.3 AI-enabled virtual patients and simulation-based tutoring

Virtual patient platforms represented the most extensively studied category of AI-powered tutoring tool. A randomized controlled trial of a clinical virtual simulator among Portuguese nursing students found that the experimental group using case-based learning supported by clinical virtual simulation achieved significantly greater knowledge gains immediately after the intervention and at two-month follow-up, alongside higher satisfaction, compared with a low-fidelity simulator comparison group.[21] In a separate randomized trial comparing a fully automated virtual patient simulation, known as e-RAPIDS, against facilitator-led mannequin-based simulation for assessing and managing clinical deterioration among Singaporean nursing students, both modalities produced measurable improvement in clinical performance, with the mannequin-based approach retaining a modest advantage in skill retention, while the virtual patient platform offered a more scalable and resource-efficient alternative for refresher training.[22] Building on this line of work, a quasi-experimental study evaluating an AI-enabled virtual reality simulation extension of the same e-RAPIDS platform among hospital-based nurses reported measurable gains in clinical reasoning when assessing and managing clinical deterioration, suggesting that layering AI-driven adaptivity onto established virtual patient architectures can extend their educational value into continuing professional development, beyond the pre-licensure classroom.[23] A Swedish randomized controlled trial using a virtual patient module to train nursing students in recognizing and responding to intimate partner violence reported a significantly greater improvement in students' confidence in raising sensitive clinical conversations in the intervention group compared with standard training alone, illustrating that AI-supported virtual patients can extend beyond physiological deterioration scenarios into complex communication and psychosocial domains of practice.[24]

Meta-analytic evidence on virtual reality simulation, a technology increasingly integrated with AI-driven adaptivity, reinforced these findings at a larger scale. A systematic review and meta-analysis of virtual reality simulation's effect on nursing students' communication skills found consistent, positive effects across pooled studies, attributed partly to the safe, repeatable practice environment virtual reality affords compared with live clinical encounters.[25] A companion meta-analysis by the same research team, focused specifically on nursing competency outcomes, similarly found that virtual reality simulation meaningfully improved composite measures of clinical competency, with pre-briefing before simulation identified as a significant moderating factor.[26] A further systematic review, meta-analysis, and meta-regression of virtual reality training on clinical skill performance across eleven randomized controlled trials found a medium-to-large pooled effect size favoring virtual reality over comparator instruction, with the specific training topic and delivery method emerging as significant covariates of effect magnitude.[27] Taken together, this cluster of studies indicates that AI-enhanced virtual patient and virtual reality platforms produce robust, reproducible gains in knowledge, communication, and procedural competence, though the strength of effect appears sensitive to instructional design features such as debriefing structure and scenario complexity.

3.4 Generative AI chatbots and conversational tutors

The emergence of large language model-based chatbots, particularly ChatGPT, since late 2022 has generated a rapidly expanding, distinct body of evidence within the broader ITS literature. A cross-sectional study of 98 undergraduate nursing students in Spain found that students who used ChatGPT as a learning tool showed significantly improved academic grades, with the large majority self-reporting improved academic performance, though the study also identified gendered differences in perceived usefulness.[28] A single-blind randomized controlled trial evaluating structured ChatGPT training embedded within nursing-process instruction reported significant gains in problem-solving skills, competency, and satisfaction among the intervention group relative to standard instruction alone, providing experimental, rather than merely correlational, evidence for chatbot-assisted tutoring.[29] Earlier controlled work on mobile chatbot-based tutoring for obstetric vaccination content similarly demonstrated improved learning achievement and self-efficacy compared with conventional instruction, indicating that generative and rule-based conversational agents have produced convergent benefits across several years and technological generations.[30] A related study examining ChatGPT's incorporation into structured learning designs for nursing and health education reported that thoughtfully scaffolded prompts, rather than unstructured chatbot access alone, were associated with stronger learning gains, underscoring that pedagogical design mediates the educational value of generative AI tools.[31] A systematic review and text network analysis of ChatGPT's integration into nursing education synthesized this expanding literature and confirmed recurring benefits for information access, assignment support, and exam preparation, while flagging academic-integrity and accuracy concerns as persistent limitations.[32]

Beyond direct instructional use, generative AI's capacity to approximate licensure-style reasoning has itself become a subject of study. A comparative analysis contrasting ChatGPT-generated responses with human expert answers on NCLEX-RN style questions found that the chatbot performed creditably but inconsistently across content areas, suggesting utility as a supplementary study aid rather than a substitute for structured examination preparation.[33] Complementary work examining generative AI's use for Socratic questioning within nursing curricula reported that carefully prompted chatbot dialogue could stimulate deeper reflective questioning among students, though the authors cautioned that unmoderated use risked superficial engagement.[34] This nuance was echoed by a broader meta-analysis of twenty-nine experimental and quasi-experimental studies on generative AI's effect on higher-order thinking across education generally, which found an overall positive but modest effect, with larger gains for creativity and problem-solving than for critical thinking narrowly defined, a pattern consistent with nursing-specific findings that AI-based tools reliably enhance procedural and knowledge outcomes while showing more variable effects on deep, reflective clinical reasoning.[35]

3.5 Barriers, ethical considerations, and educator perspectives

Across nearly all included studies, ethical and institutional barriers recurred as a cross-cutting limitation. A qualitative study of nursing educators' perspectives on integrating artificial intelligence into academic settings identified five major themes, spanning perceived benefits, barriers to adoption, ethical considerations, educator readiness, and AI as a supplementary teaching tool, with insufficient faculty training, infrastructural constraints, and concerns about data privacy and algorithmic bias most frequently cited as obstacles.[36] A large-scale synthesis of AI integration in nursing education more broadly reported convergent findings, noting that AI-enhanced personalization, feedback, and instructional efficiency were consistently valued benefits, but that curricular frameworks for the responsible, structured use of these tools remained underdeveloped in most of the programs studied.[1] Broader nursing-informatics commentary reinforced these concerns, calling for coordinated professional leadership on algorithmic transparency, workforce preparedness, and safe integration of AI across both clinical and educational domains, rather than allowing adoption to proceed on an ad hoc, institution-by-institution basis.[15][16][17]

3.6 Author, methodology, and outcome summary

Table 2 summarizes the design, sample, population, methodology, and principal outcomes of representative included studies, illustrating the diversity of AI-powered tutoring modalities and the general direction of reported effects across the reviewed evidence base.

Table 2. Summary of representative included studies

Author(s), Year	Country	Domain	Objective	Research Methodology	Results (summary)
Martins et al., 2019 [21]	Portugal	Clinical virtual simulation	Evaluate effect of clinical virtual simulation on knowledge, clinical reasoning, self-efficacy and satisfaction.	Design: RCT with pretest/2 posttests. Sample: 42 nursing students (21/21). Population: undergraduate nursing students. Technique: case-based learning with virtual simulator vs low-fidelity simulator. Tool: knowledge test, Likert scales. Analysis: t-tests, effect sizes.	Experimental group showed significantly greater knowledge gains post-intervention (P=.001) and at 2 months (P=.02), and higher learning satisfaction (P<.001) than the low-fidelity comparator group.
Liaw et al., 2014 [22]	Singapore	Virtual patient vs mannequin simulation	Compare virtual patient simulation (e-RAPIDS) with mannequin-based simulation for managing clinical deterioration.	Design: RCT. Sample: 57 third-year nursing students. Population: undergraduate nursing students. Technique: automated virtual patient vs facilitator-led mannequin	Both modalities improved clinical performance; mannequin-based simulation retained a modest advantage in skill retention,

				simulation. Tool: clinical performance checklist, survey. Analysis: comparative statistics.	while the virtual patient platform offered a scalable, resource-efficient refresher alternative.
Sörman et al., 2025 [24]	Sweden	Virtual patient communication training	Test whether a virtual patient module improves confidence, self-efficacy and knowledge in addressing intimate partner violence.	Design: RCT. Sample: 54 nursing students (29 intervention/25 control). Population: undergraduate nursing students. Technique: virtual patient module plus standard training vs standard training alone. Tool: confidence and knowledge scales. Analysis: linear mixed-effects models.	The virtual patient group showed significantly greater improvement in confidence in raising sensitive clinical conversations (between-group difference +1.26, 95% CI 0.40-2.15, P=.010) and consistently higher objective knowledge.
Kow et al., 2024 [23]	Malaysia	AI-enabled virtual reality simulation	Evaluate an AI-enabled VR simulation extension of e-RAPIDS for clinical reasoning in managing deterioration.	Design: Quasi-experimental. Sample: hospital-registered nurses. Population: practising nurses (continuing education). Technique: AI-enabled VR simulation training. Tool: clinical reasoning assessment instrument. Analysis: pre-post comparison.	Participating nurses demonstrated measurable gains in clinical reasoning for recognising and responding to deterioration, supporting AI-enhanced virtual patients as a continuing-education strategy beyond pre-licensure training.
Gonzalez-Garcia et al., 2024 [28]	Spain	Generative AI chatbot (ChatGPT) use	Evaluate the impact of ChatGPT use on nursing students' academic performance and perceptions.	Design: Cross-sectional. Sample: 98 nursing students. Population: undergraduate BSN students. Technique: self-reported ChatGPT use. Tool: three validated questionnaires. Analysis: SPSS descriptive and correlational statistics.	Students using ChatGPT showed significantly improved academic grades (P<.05); 89.5% reported improved performance; women rated ChatGPT more useful than men (85.14% vs 50.00%, P=.003).
Arkan et al., 2025 [29]	Türkiye	ChatGPT-integrated nursing-process training	Assess effect of structured ChatGPT training on problem-solving, AI attitudes, competency and satisfaction.	Design: Single-blind RCT. Sample: 96 students (48/48). Population: undergraduate nursing students. Technique: AI-integrated nursing-process training vs standard training. Tool: validated competency and satisfaction scales. Analysis: comparative inferential statistics.	The intervention group showed significant gains in nursing-process competency and satisfaction after training, with improved problem-solving skills and more positive attitudes toward AI than the control group.
Chang, Hwang & Gau, 2022 [30]	Taiwan	Mobile chatbot tutoring	Examine effect of a mobile chatbot approach on nursing students' learning achievement and	Design: Quasi-experimental. Sample: undergraduate nursing students. Population: prenatal/obstetric-	The chatbot group achieved significantly higher learning achievement and

			self-efficacy.	vaccination course students. Technique: mobile chatbot-guided learning vs conventional lecture-based instruction. Tool: achievement test, self-efficacy scale. Analysis: ANCOVA.	self-efficacy than the conventionally taught group, supporting mobile conversational agents as an effective adjunct to lecture-based obstetric-vaccination instruction.
Cho & Kim, 2024 [25]	South Korea	Virtual reality simulation (meta-analysis)	Synthesize evidence on VR simulation's effect on nursing students' practical competency.	Design: Systematic review and meta-analysis (PRISMA 2020). Sample: 22 studies. Population: nursing students. Technique: pooled effect-size synthesis. Tool: PROSPERO-registered protocol, standardized mean differences. Analysis: random-effects meta-analysis, meta-regression.	VR simulation significantly improved composite nursing competency; pre-briefing before simulation, and absence of concurrent debriefing, were significant moderators of larger effect sizes across pooled studies.
Hannaford et al., 2021 [19]	United States	Machine-learning prediction of graduation	Determine whether machine-learning models can predict nursing baccalaureate graduation status early in training.	Design: Quantitative descriptive/predictive study. Sample: 773 students. Population: baccalaureate nursing students, 2004-2012 cohorts. Technique: eight machine-learning algorithms plus stacked ensemble. Tool: institutional academic records. Analysis: predictive-accuracy comparison across time points.	One year of academic data predicted graduation outcomes for over 80% of students, rising to 90% after year two and 99% after year three, supporting early, data-driven identification of at-risk students.
Cox, Hunt & Hill, 2023 [33]	United States	ChatGPT vs human expertise on NCLEX-RN	Compare ChatGPT-generated answers with human expert answers on NCLEX-RN style questions.	Design: Comparative analysis. Sample: NCLEX-RN style question bank. Population: licensure-examination content areas. Technique: side-by-side chatbot vs expert response comparison. Tool: scored question sets. Analysis: accuracy comparison by content domain.	ChatGPT performed creditably but inconsistently across content areas compared with human experts, supporting its use as a supplementary study aid rather than a substitute for structured licensure preparation.
Alrazeeni et al., 2026 [1]	Multi-country	AI in nursing education (systematic review)	Synthesize empirical studies on AI integration across nursing education settings and learning outcomes.	Design: Systematic review (2010-2025). Sample: 28 studies. Population: nursing students and educators. Technique: CASP-appraised thematic synthesis. Tool: PubMed, CINAHL, IEEE Xplore, Scopus search. Analysis: thematic synthesis across four domains.	AI enhanced nursing education across four domains, including personalized learning, feedback, assessment automation and simulation, though ethical and infrastructural barriers to implementation were consistently

					reported across included studies.
Nasirun et al., 2026 [3]	East Asia, Europe, Africa	Generative AI and ITS (systematic review)	Synthesize impact of generative AI and ITS on nursing students' clinical competency and higher-order thinking.	Design: PRISMA 2020 systematic review. Sample: 14 studies (7 RCTs, 7 quasi-experiments). Population: nursing students. Technique: seven-database search, PROSPERO-registered. Tool: standardized quality-appraisal checklists. Analysis: narrative synthesis by outcome domain.	AI significantly enhanced psychomotor and procedural skills, but showed mixed effects on higher-order thinking, with a trade-off identified between algorithmic efficiency and deeper critical reflection among nursing students.

4. DISCUSSION

This systematic review synthesized thirty-two studies examining AI-powered intelligent tutoring systems, adaptive learning platforms, virtual patients, and generative AI chatbots within nursing education, and the pattern that emerges is one of consistent, moderate-to-strong benefit for knowledge acquisition and procedural competence, coupled with more variable, still-contested benefit for higher-order clinical reasoning and the relational, empathic dimensions of nursing practice. This asymmetry is not surprising when viewed through the lens of Tanner's model of clinical judgment, which frames noticing and interpreting as processes deeply embedded in embodied, contextual, and relational knowing, capacities that current AI tutoring architectures, however sophisticated their branching logic, only partially replicate.[7] The recurrent finding across virtual patient and virtual reality studies that knowledge, confidence, and communication skills improve reliably, while deeper critical thinking gains are smaller and less consistent, mirrors the broader educational-technology literature on generative AI's modest, uneven effect on higher-order thinking outside nursing as well.[35] Together, these findings suggest that AI-powered ITS are best understood not as replacements for experiential, faculty-guided clinical learning but as a scaffold that compresses repetitive, foundational practice into efficient, low-stakes opportunities, freeing faculty time and student cognitive load for the more nuanced work of reflection and judgment-building that Benner's novice-to-expert trajectory describes as ultimately requiring sustained, situated clinical exposure.[8]

The strong and consistent evidence for virtual patient and virtual-reality-based tutoring, particularly in high-stakes domains such as clinical deterioration and difficult communication, aligns closely with patient-safety imperatives articulated by international bodies. The World Health Organization's patient safety curriculum guide and the Quality and Safety Education for Nurses competencies both call for repeated, low-risk rehearsal of safety-critical scenarios, a requirement that AI-enhanced virtual patients appear well suited to meet, given their capacity for infinite repeatability without endangering real patients or requiring proportionally scaled faculty supervision.[10][11] At the same time, the persistent, if modest, superiority of mannequin-based simulation for skill retention observed in several comparative trials indicates that virtual and physical modalities are complementary rather than interchangeable, and that curricula integrating AI-powered tutoring should be designed as a blended ecosystem rather than a wholesale replacement of hands-on simulation.[22]

The rapid uptake of generative AI chatbots since 2022 has introduced both opportunity and volatility into this evidence base. Unlike purpose-built ITS platforms developed specifically for nursing curricula, general-purpose large language models were not originally designed for clinical education, and their variable, sometimes inconsistent performance on licensure-style content illustrates the risk of uncritical reliance on unmoderated chatbot use.[33] The studies demonstrating benefit from structured, faculty-designed ChatGPT integration, rather than open-ended access, reinforce a broader theme running through this review: technology alone does not produce educational value, and the pedagogical scaffolding surrounding an AI tool, including prompt design, debriefing, and explicit ethics instruction, substantially determines whether that tool strengthens or merely superficially engages student learning.[31] This observation carries direct implications for patient safety, since a nurse educated through poorly scaffolded, unverified AI interactions risks internalizing confidently stated but incorrect information, a concern several included studies raised explicitly around academic integrity and factual accuracy.[32]

The consistent identification of ethical, infrastructural, and faculty-readiness barriers across nearly every included study focused on educator or institutional perspectives suggests that the primary constraint on realizing AI-powered ITS's potential is no longer solely technological but organizational and pedagogical.[36] Concerns about algorithmic bias, data privacy, and the erosion of human clinical judgment echo wider bioethical debates in digital health, where commentators have cautioned that technology must be deliberately harnessed to reinforce, rather than displace, the humanistic core of care.[14] Encouragingly, several included studies suggest that structured faculty development and explicit curricular integration of AI literacy, rather than avoidance of these tools, are the more sustainable institutional response, a position consistent with calls from nursing informatics leadership for coordinated, proactive governance rather than reactive restriction.[15]

Several limitations of the underlying evidence base, and of this review itself, warrant acknowledgment. Many included primary studies were single-institution investigations with modest sample sizes, limiting generalizability across diverse educational and health-system contexts. Outcome measures varied considerably across studies, precluding meta-analytic pooling and necessitating the narrative synthesis approach adopted here. Publication bias favoring studies reporting positive technology effects cannot be excluded, and the rapid pace of generative AI development means that findings regarding specific chatbot platforms may have limited longevity as underlying models continue to evolve. Finally, most included studies measured proximal outcomes such as knowledge and confidence rather than downstream, real-world patient-safety indicators, meaning that the ultimate causal chain from AI-powered tutoring to improved patient outcomes remains inferred rather than directly demonstrated.

5. RECOMMENDATIONS

Nursing programs should integrate AI-powered ITS as a structured complement to, rather than a substitute for, faculty-guided and hands-on simulation, with explicit debriefing and ethics instruction accompanying every AI-assisted activity.[37] Faculty development should prioritize AI literacy, prompt-design competence, and critical evaluation of AI-generated content.[36] Institutions should establish clear data-privacy governance and bias-auditing procedures before adopting adaptive or generative AI platforms, and predictive-analytics tools should be used to trigger timely, supportive remediation rather than punitive academic decisions.[19]

6. FUTURE DIRECTIONS

Future research should prioritize multi-site randomized controlled trials with standardized outcome measures, longer follow-up periods, and direct linkage to post-graduation clinical performance and patient-safety indicators.[2] Studies should examine generative AI's evolving capabilities longitudinally, investigate strategies for strengthening higher-order clinical reasoning and cultural empathy alongside procedural competence, and explore cost-effectiveness and equity of access across resource-diverse nursing programs globally. Researchers should also develop validated, nursing-specific instruments capable of tracking whether AI-supported tutoring gains genuinely transfer into safer real-world clinical performance after graduation.[35]

7. CONCLUSION

This systematic review of thirty-two studies indicates that AI-powered intelligent tutoring systems, virtual patients, adaptive learning platforms, and generative AI chatbots offer meaningful, reasonably consistent benefits for nursing students' knowledge acquisition, psychomotor competence, self-efficacy, and engagement, while their effects on higher-order clinical reasoning, cultural empathy, and other relational dimensions of practice remain more variable and less well established. Evidence linking these tools to hands-on skill development and safe management of clinical deterioration scenarios is particularly encouraging from a patient-safety standpoint, though it is best interpreted as complementary to, rather than a replacement for, experiential clinical learning and mannequin-based simulation. Ethical, infrastructural, and faculty-readiness barriers were identified consistently across the literature, underscoring that technology adoption alone is insufficient; deliberate pedagogical design, structured faculty development, and robust governance frameworks are equally necessary. As generative AI capabilities continue to evolve rapidly, sustained, methodologically rigorous research will be essential to ensure that AI-powered tutoring genuinely advances personalized learning, clinical competence, and, ultimately, patient safety, rather than simply digitizing existing pedagogical limitations.

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