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Review

Artificial intelligence in nursing education: A scoping review of intelligent tutoring systems-evidence and implementation gaps

Nevena K. Dicheva *, Ikram Ur Rehman, Laden Husamaldin, Sama Aleshaiker

School of Computing and Engineering, University of West London, London, UK

A R T I C L E I N F O

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A B S T R A C T

Background: The concept of ITSs is widely implemented across educational settings, but their adoption in nursing education remains poorly understood.

Objectives: To investigate the current state of evidence on ITS in nursing education, identify research gaps and provide recommendations for future research and practice.

Design: A scoping review based on the JBI methodology framework.

Methods: A systematic literature search was initiated (between June and October 2025) across several databases (IEEE Xplore, PubMed, MEDLINE, ERIC, ProQuest, ScienceDirect, and Google Scholar). Grey literature sources and websites of key organisations (e.g., NMC, NICE, IHI, NHS) were also searched. There were no date restrictions, but only articles in English were considered. The screening and selection process was based on the extended PRISMA-ScR framework.

Results: Initially, 881 records were retrieved, but 9 studies were included in our scoping review and analysed. Our results indicate that research on ITS in nursing remains limited, with most studies presenting incomplete ITS architectures that focus primarily on domain models or standalone concepts. Among the 9 studies, there is limited evidence suggesting considerations of user-needs evaluation, theoretical frameworks, empirical validation, or curricular integration.

Conclusions: Evidence on ITS in nursing education is limited and inconsistent. Our results led to recommendations for future research and practice, including developing a grounded theory of user perspectives, conducting rigorous empirical evaluations, designing and testing comprehensive ITS architectures aligned with nursing education philosophies, and promoting inclusivity by involving underrepresented populations and low-resource settings.

1. Introduction

Nursing education has undergone a significant and steady transformation from its early days to the present, encompassing not only theoretical but also practical educational practices, often known as simulation (Morin, 2014). Historically, the first simulation utilised in nursing education dates to 1911, when the adult-size, latex-based mannequin 'Mrs. Chase' was designed. Mrs. Chase specifically aimed for nursing education in the United States, enrolling in the Hartford Hospital Nurse Training Program in Connecticut and later gaining admission to nursing educational institutions across the United States (Grypma, 2012), with great success. Other simulations in which nursing students could apply theory to practice include role-playing, standardised patients, scenarios, and animal models (Nehring and Lashley, 2009). However, some of these methods may require more educators/supervisors, equipment, and hospital/clinical space, which remain significant challenges (Naismith et al., 2025). To overcome these drawbacks, and in line with advances in education over the past 20 years (Butt et al., 2018), implementing innovative pedagogies in nursing was vital. Such innovative methods include the use of computers and mobile phones, which do not require laboratory facilities or specialised placement in universities and hospitals (Blodgett et al., 2018). Currently, nursing learners benefit from innovative technologies, such as Augmented Reality (AR), Virtual Reality (VR), Mobile applications, Haptic devices, Chatbots, and Multimodal Systems (Dicheva et al., 2023b). However, there are some limitations, such as immersive sickness, technical issues, unclear long-

* Corresponding author.
E-mail addresses: 21498193@student.uwl.ac.uk (N.K. Dicheva), Ikram.Rehman@uwl.ac.uk (I.U. Rehman), Laden.Husamaldin@uwl.ac.uk (L. Husamaldin), Sama.Aleshaiker@uwl.ac.uk (S. Aleshaiker).

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term knowledge gain outcomes and a lack of personalisation and immediate feedback. Moreover, it is unclear whether and how educators' workloads are reduced or optimised by the computer-aided pedagogies in nursing education (Dicheva et al., 2023a).

One of the advances in modern education is Artificial Intelligence (AI), defined as algorithm-based technology that can mimic human intelligence (Sheikh et al., 2023). The concept of AI in education (AIED) has demonstrated dramatic improvements in educational outcomes, owing to its capacity to support global reach, personalised learning, and autonomy (Chen et al., 2020). However, AI in nursing education still faces social prejudice and ethical challenges (Chen et al., 2022), including concerns about algorithmic reliability, data veracity, and the potential loss of affective learning in nursing. Current reviews investigating AI educational technologies in nursing primarily examine the use of chatbots and Large Language Models (LLMs) (Labrague and Al Sabei, 2024; Zhang et al., 2024; Zhou et al., 2024). In addition, there are reviews which focus on the general aspect of AI in nursing education (Božić, 2024; Torabi et al., 2024), the role of AI in nursing education (Ma et al., 2025), integration of AI in nursing education (Chan et al., 2025), the roles, applications, and trends of AI in nursing education (Hwang et al., 2024), AI-based teaching pedagogies in nursing (Labrague et al., 2025), generative AI in mobile learning (Lai and Tu, 2024), the opportunities and challenges of AI in nursing education (Ramírez-Baraldes et al., 2025), and adaptive learning technologies in nursing education (Andersen et al., 2021). Despite several attempts in this area of education, the concept of Intelligent Tutoring Systems (ITS) was not explored in the above-mentioned published research. The idea of ITS refers to an AI-enabled, computer-aided application based on four main parts or models (domain, student, pedagogical, and interface models), which provides an interactive learning environment and instant, personalised feedback (Ji and Yuan, 2022). An ITS facilitates realistic communication between the student and the ITS itself (Chang et al., 2022a), as well as personalised, dynamic, and static feedback (Chang et al., 2022b), due to the incorporation of Deep Learning (DL) algorithms and Natural Language Processing (NLP), Natural Language Understanding (NLU), and Natural Language Generation (NLG) techniques in ITS development. The concept of NLP is a field of AI that enables computers to process and interact with human language. Within NLP, NLU refers to the ability of machines to interpret human language, while NLG refers to how machines process and generate human language (Iqbal and Ahmed, 2025).

Thus, the implementation of these AI techniques could help address the shortage of nursing education, as the ITS could largely mimic real-life student-lecturer/teacher communication (Thalaya and Puritat, 2022). In an ITS, the student model represents and manages data and information related to individual students, facilitating personalised learning. Each student is identified by a unique identification number (ID), and their data include personal information, learning progress, performance metrics, engagement patterns, and activity logs. Students interact with the ITS via the interface, and the tutoring model retrieves information from the domain model based on specific attributes, such as the student's knowledge level and performance (Nwana, 1990). The tutoring model generates hints and feedback based on the student's performance and determines future steps. It processes the logic for personalised tutoring and lesson generation, utilising the student model and domain model to provide adaptive and tailored learning experiences to students (Nwana, 1990). Despite these benefits of adaptive personalised learning, ITS acceptance and deployment in nursing education remain unclear. A recent, comprehensive systematic review of ITS in education revealed the most predominant educational fields where ITS has been applied, namely Computer Science (36.1%), Social Science (27.2%), Medicine (13.8%), Engineering (8.3%), and Mathematics (5.5%), highlighting a persistent evidence gap for ITS in nursing education. Although the ITS utilised in Medicine could also be applied in nursing education, the latter has its own specific philosophy and learning curve, mainly due to the distinct roles and emphasis of the cognitive, affective, and psychomotor dimensions in nursing education (Hoque, 2016; Nehring and Lashley, 2009).

Therefore, conducting a scoping review could be highly relevant for such an emergent and under-investigated topic. Scoping reviews are recognised as a methodological standard for mapping the extent and nature of evidence (i.e., ITS in nursing education) and for identifying literature gaps (Arksey and O'Malley, 2005). They are not aimed at providing solutions or new interventions, primarily because they do not investigate effectiveness or assess study quality. Instead, they highlight literature gaps and offer recommendations for further investigation (Peters et al., 2020). Additionally, scoping reviews provide comprehensive coverage without specific date constraints (in our case) on the topic of ITS in nursing education, while not discriminating against retrieved sources, thereby enhancing comprehensiveness. By systematically searching published and unpublished studies with diverse designs, this review will provide a realistic overview of the current state of the art of ITS in nursing education. A preliminary search of Science Direct and CINAHL (EBSCO) in July 2025 revealed no systematic literature review or scoping review that explicitly examines the concept of ITS in nursing education.

To the best of our knowledge, this is the first scoping review to systematically examine the application and evidence base of ITS in nursing education. Our scoping review aims to examine the current state of the evidence on ITS in nursing education by systematically searching relevant databases using predefined inclusion criteria. This aim will be achieved by identifying and describing relevant studies, synthesising reported limitations or barriers, and identifying literature gaps related to the concept of ITS in nursing education.

2. Review question

Our scoping review aims to examine published and unpublished evidence on ITS in nursing education and to provide direct recommendations for future research and practice. Specifically, our scoping review addresses the following research question:

What is the current state of the evidence on ITS in nursing education?

3. Inclusion criteria

The inclusion and exclusion criteria of our scoping review follow the Joanna Briggs Institute (JBI) guidance to utilise the Participants, Concept, Context (PCC) and inform the inclusion/exclusion criteria, as described below.

3.1. Participants

Our scoping review will consider studies related to nursing learners/students at any stage of their educational development and registration status, as well as registered nurses (including pre-registration/undergraduate, postgraduate/advanced practice, and nurse educators). Other healthcare professionals or students not in nursing will be excluded.

3.2. Concept

Our scoping review will consider studies of ITS, whether by their exact name or by alternative terms or terminology that researchers or developers might use to describe them. In our initial search, terms such as “adaptive systems” were sometimes used to describe ITS components; therefore, we have included these terms in our keyword search. In addition, any components and/or features developed or proposed for integration into an ITS in nursing education will be considered. Other AI-related technologies in nursing education, such as LLMs, chatbots, conversational and virtual agents, AI-based educational chatbots or AI-teaching assistants, and stand-alone AI techniques, will be excluded.

3.3. Context

According to Quinn (2000), nursing education is categorised as pre-registration (leading to a diploma or a Bachelor of Science degree) and post-registration including education for professional development, additional courses to enhance knowledge and mandatory institutional training. Importantly, nursing education occurs across both academic and clinical environments. This educational structure informs our operationalisation of the *Context* component of our PCC framework (i.e. nursing education). Therefore, sources related to any nursing education setting (classroom sessions and activities, skills or lab simulations, clinical placements, and online or blended learning) will be eligible for inclusion. In addition, sources from clinical settings where the intent of the ITS is educational or training-directed rather than focused on patient care will be eligible for inclusion.

Studies explicitly related to patient care or clinical decision-making communication that lack a specific educational objective will be excluded.

4. Types of sources

This scoping review considered a range of study designs, including, but not limited to, reviews, experimental and quasi-experimental study designs, including Randomised Controlled Trials (RCTs), non-RCTs, before-and-after studies, and interrupted time-series studies, were considered for inclusion. In addition, analytical observational studies, including prospective and retrospective cohort studies, case-control studies, and analytical cross-sectional studies, were considered for inclusion. This scoping review also considers descriptive observational study designs, including case series, individual case reports, and descriptive cross-sectional studies, for inclusion. Qualitative studies will also be considered that focus on qualitative data, including, but not limited to, phenomenology, grounded theory, ethnography, qualitative description, and action research. In addition, grey literature, such as conference papers, theses, and case reports, is approved for inclusion when relevant.

5. Methods

This scoping review is conducted in accordance with the JBI methodology for scoping reviews by Peters et al. (2020) and will be reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) (Tricco et al., 2018). The protocol for this scoping review has been registered in the Open Science Framework (OSF) (Foster and Deardorff, 2017) and can be found at: https://doi.org/10.17605/OSF.IO/BTDY5.

6. Search strategy

The search strategy aimed to locate both published and unpublished studies. A three-step search strategy was used in our scoping review. First, a limited initial search of ScienceDirect and CINAHL (via EBSCO) was conducted to identify relevant articles on the topic. Keywords from the titles and abstracts of relevant articles, together with the index terms used to describe them, were used to develop a comprehensive search strategy to identify relevant databases and information sources (see Appendix I). The search strategy, including all identified keywords and index terms, was adapted for each included database and information source. The reference lists of all included sources of evidence were screened for additional studies. Only studies published in English were considered, due to limited translation resources. No specific date restrictions were applied, as the aim of the scoping review was to examine all available literature in line with the inclusion criteria. The databases searched were IEEE Explore, PubMed, MEDLINE, ERIC, ProQuest (Dissertations and Theses), ScienceDirect, and Google Scholar. Sources of unpublished studies and grey literature were also searched (ProQuest Dissertations and Theses and Google Scholar). The website search included scientific, regulatory, and health care organisations such as the Nursing and Midwifery Council (NMC), the National Institute for Health and Care Excellence (NICE), the Institute for Healthcare Improvement (IHI), the National Health Service (NHS), and other relevant websites. Studies potentially relevant to our research question and inclusion criteria, but not open access, were obtained through the institutional library service (*name not provided to ensure anonymity*).

7. Source of evidence selection

Following the search, all identified citations were collated and uploaded into Zotero (Puckett, 2011) version 7.1, and duplicates were removed. Following a pilot test, titles and abstracts were screened by two of the authors to assess compliance with the review's inclusion criteria. Potentially relevant sources were retrieved in full, and their citation details were imported into the JBI System for the Unified Management, Assessment and Review of Information (JBI SUMARI) (Munn et al., 2019). The full text of selected citations will be assessed in detail against the inclusion criteria by two independent reviewers. Reasons for excluding sources at the full-text stage that do not meet the inclusion criteria were recorded and reported in the scoping review. There was no disagreement among the authors at any stage of the selection process. The results of the search and the study inclusion process are reported in the Preferred Reporting Items for PRISMA flow diagram (Tricco et al., 2018).

8. Data extraction

Two independent reviewers extracted data from papers included in our scoping review using Microsoft Excel, Version 16.101.3. The reviewers conducted a pilot test of the extraction tool on approximately four articles. The draft data extraction tool was modified twice. First, "country" was added, and all authors agreed. Second, "outcomes measured" was added as extracted information, which led to including "participants" (if applicable) as well. Where there were no participants' evaluations, this was marked as Not Applicable (N/A) in the Excel Information Sheet. The remaining data extraction items, as initially decided, remained unchanged. The complete data extraction was also used to summarise the analysed studies. In addition to study characteristics, the extracted data were in accordance with the PCC framework. Specifically, the data extracted in our scoping review were authors, study publication year, country, article type, design focus, ITS models, outcomes measured and number of participants (if applicable).

9. Data analysis and presentation

The extracted data from the 9 studies are presented in a table, followed by a narrative description of all studies. The data presented are based on the data extraction in relation to the PCC framework and our research question. Descriptive statistics are presented where applicable, and a qualitative synthesis of the included studies is performed.

10. Results

This section presents the results of our scoping review, beginning with the study inclusion strategy, followed by the narrative synthesis, and supplemented by data extracted in tabular form. Our recommendations for future research and practice, derived from our scoping review results, are also provided, framed as implications for future research and practice.

10.1. Study inclusion and characteristics

The search strategy for scoping reviews recommends identifying studies through methods other than database searches (website searches, citations, etc.) (Tricco et al., 2018), which was also applied in our search strategy. First, a total of 866 articles were retrieved from 7 databases, of which 32 were duplicates. After a second round of screening, 47 articles were carefully examined, and 40 were excluded because they did not meet the inclusion/exclusion criteria (14 were not about nursing education, and 26 did not describe an ITS). Finally, a total of 7 articles were included in the scoping review.

Second, an initial set of 15 sources was retrieved via other methods, namely websites ($n = 8$) and citation searching, including backwards and forward snowballing ($n = 7$). Of these, 6 were assessed for eligibility, and only 2 were included in the scoping review. Therefore, the combined initial search identified 881 studies, resulting in 9 studies included in this scoping review. This process is shown in the PRISMA flowchart described in Fig. 1. Some studies ($n = 2$) included in our scoping review were retrieved from other sources, i.e., Google (Schmidt, 2022) and citation search (Kopec et al., 1990), and the remaining 7 articles were retrieved through an accredited database search.

10.2. Study analysis

The 9 included studies in our scoping review are presented in chronological order to provide a clearer overview of the research over time, with a summary of the studies in tabular form, as recommended by the JBI guidelines for conducting scoping reviews (Peters et al., 2020). Given the relatively small number of included studies, the tabular presentation of the studies' characteristics is included in the main document (Table 1) rather than the appendix.

The first recorded investigation of ITS in nursing education was published in 1990 by Kopec et al., who presented “SmartBook” as the domain module before constructing an ITS for nursing education. Alongside domain experts, Kopec et al. designed concept maps for six sexually transmitted diseases (STDs) (acquired immunodeficiency syndrome (AIDS), syphilis, herpes, gonorrhoea, chlamydia and venereal warts). The authors explored the use of cognitive mapping techniques in designing the Smartbook, which was created using Apple's HyperCard. This design represents information graphically through linked nodes, mimicking a real book's outline. The information in the Smartbook is presented both graphically and textually, allowing students flexibility to explore different relationships between concepts. Students can always track previous steps using the textual and graphical information presented in each graph. In addition, the HyperCard, which was used for the design of the Smartbook, accommodates pop-up windows, map features, and a glossary, and also allows the implementation of other features such as synonym lists, video information, etc. The implemented domain model (i.e., the Smartbook) was tested by interviewing 11 nursing students while they used the Smartbook system, resulting in positive attitudes towards the information's relevance. Despite the initial positive outcomes, the authors acknowledged some limitations, such as interface and hardware constraints (limited screen size) and a limited sample size for the system's evaluation. They planned an RCT with three learner groups for the future (Kopec et al., 1990).

Koutsojannis et al. (2001) developed a web-based ITS prototype to educate nursing students about biomedical equipment. The educational materials comprised several chapters covering equipment such as ultrasound (USS), Magnetic Resonance Imaging Equipment (MRI), nuclear medicine, and others. Each chapter's learning outcomes focused on structure, manipulation, and safety standards, progressing from basic to more advanced topics, with meta descriptions. The ITS's student model included students' personal data, interaction parameters, and personal characteristics such as knowledge level, learning style, concentration level, computer literacy, and internet connection availability. A hybrid reasoning approach, combining simple neural components with symbolic rules (neurules), was applied, using keyword matching for responses. The promising initial functionality of the system, the provision of more information regarding the User Interface (UI), and a prototype evaluation with real users would have provided further insights into the

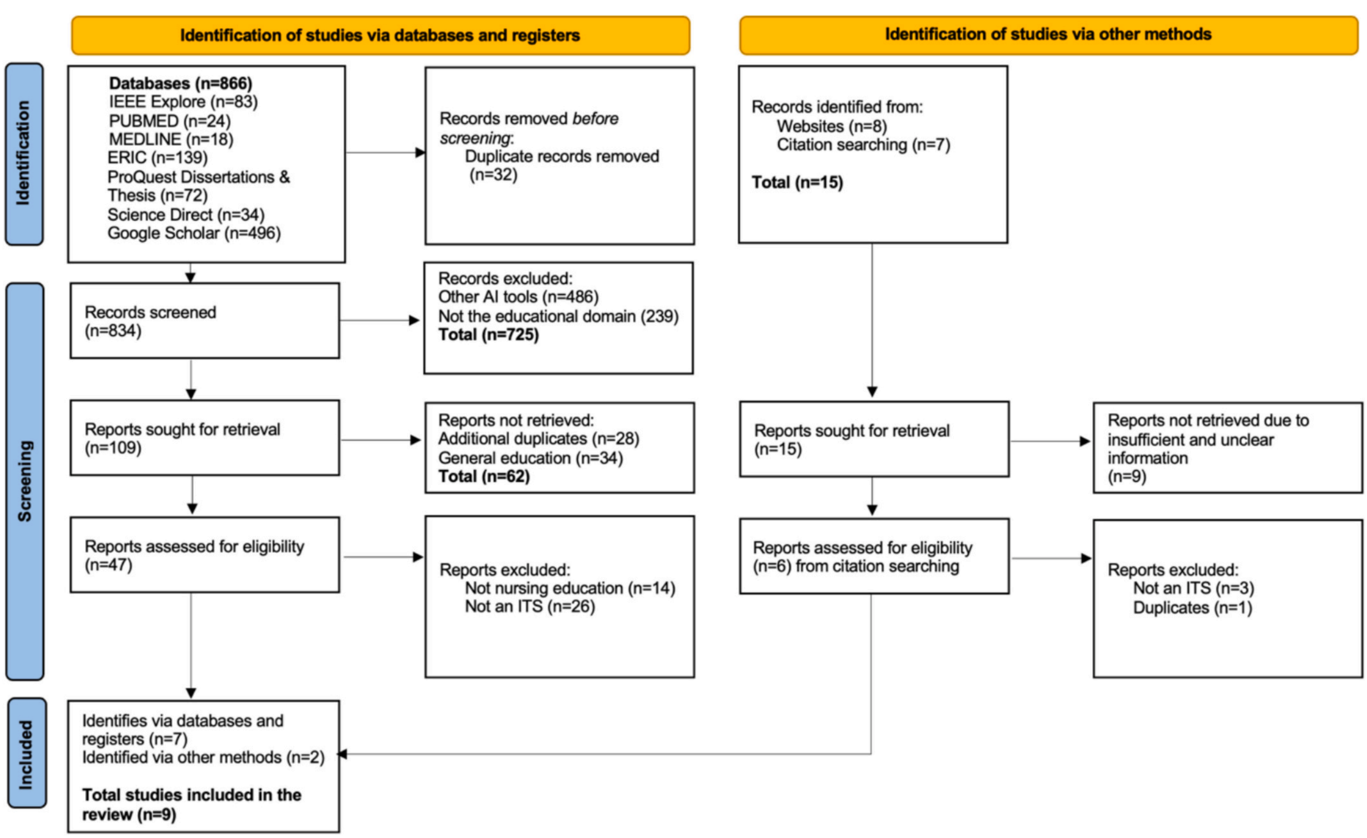

Fig. 1. PRISMA-ScR flow diagram illustrating the study selection process for our scoping review. Adapted from Tricco et al. (2018).

Table 1
Summary of the included studies: design focus, ITS models, outcomes, and participants.

Study ID	Domain Model	Student model	Tutoring model	AI / NLP and techniques	Outcomes measured	Participants
Kopec et al., 1990	Smart Book hypertext knowledge base on Sexually Transmitted Diseases (STDs); conceptual mapping of content	Outlined plans for learner profiling and progress tracking.	Proposed navigation guidance and formative feedback rules	Implemented in HyperCard; Early hypertext interface	Formative evaluation; usability and perceived usefulness.	11 undergraduate nursing students (classroom)
Koutsojannis et al. (2001)	Web-based biomedical-equipment knowledge representation using rule logic.	Planned prior-knowledge and skill profiles.	Expert-policy sequencing via neurules.	Conceptual web ITS architecture (rule + neural).	None -architecture proposal.	N/A
Hospers et al. (2003)	Procedural knowledge for clinical tasks; scenario knowledge base.	Action and error tracking for task performance.	Multi-agent pedagogy (Feedback, Explanation, Task-Observer)	Rule-based agent system; skills-lab interface.	Functional correctness; internal validation.	N/A
Samra et al. (2016)	Nursing-skills ontology within ISBLMS framework.	Educational-data-mining traces envisioned for learner modelling.	Data-mining-driven adaptivity and personalised feedback.	Conceptual design; no prototype.	Not assessed - design only.	N/A
Abuazizeh et al. (2020)	Nursing topics and tasks represented as state-space graph.	Dialogue knowledge state envisioned.	Tutor actions defined as state transitions.	Conversational ITS architecture (un-tested).	None-design proposed only	N/A
Abuazizeh et al. (2021)	Dialogue intents and nursing-communication frames.	Knowledge and affect representation of learner state.	Affect-aware response generation and tutoring prompts.	NLU + affect detection. Conversational ITS	Feasibility of affect detection; system functionality.	N/A
Schmidt (2022)	Anatomy and Physiology item bank within adaptive courseware	Mastery/confidence tracking within platform.	Adaptive sequencing and remediation rules.	Commercial adaptive courseware (AI tutor)	Course-exam Performance, self-reported use.	99 nursing students.
Sosnowski et al. (2023)	Scenario/ story graphs for patient interaction.	Dialogue- performance indicators representing skill state	Adaptive branching dialogue and reflective feedback.	NLP + story generation; web chat.	Usability and dialogue-quality ratings.	99 participants (71 computer science, 28 nursing students).
Qian et al. (2024)	Sterile-technique checklist encoded for robot tutor.	Skill-performance modelling via pose/ gesture tracking.	Real-time coaching with multimodal alerts and adaptive difficulty.	Computer vision + robotics; skills-lab setup.	Detection accuracy; usability and acceptance surveys.	9 new nurses and students (skills-lab pilot).

application of the ITS in nursing education (Koutsojannis et al., 2001).

Hospers et al. (2003) presented an agent-based Intelligent Nursing Educational System (INES) prototype for clinical procedures (i.e., skills acquisition), tailored for nursing students. The exercises (internal scenario tests) were incorporated via XML files and accessed through the student interface, which could be either 2-dimensional (2D) or text-based. The classical ITS architecture was extended with an additional multi-agent (rule-based) architecture, consisting of a central kernel that coordinates the remaining agents (proactive and reactive agents). Pre- and post-conditions were applied, and the "task observer" agent provided immediate hints with explanations. The system's functionality was tested, specifically INES feedback, where a student makes an error. An issue was initially discovered in which positive and negative feedback were displayed simultaneously, but this was overcome by updating the error agent to display only in the correct order, thereby preventing the correct signal from being sent in a misordered situation. The authors planned future implementation in a 3-dimensional (3-D) environment for more realistic learning experiences and VR (Hospers et al., 2003).

Samra et al. (2016) introduced an intelligent simulation-based learning management system with a data mining agent, optimising the classical ITS architecture by including a total of 7 modules, each with agents having specific roles. The Dialogue module consisted of an interface agent responsible for interaction and visualisation. The Communication module consisted of an individual communication agent that coordinates the interaction between the student and the ITS. The World module had a world agent, an avatar agent, and a path planning agent, which manage the virtual environment representation, present virtual environments, respond to queries, and monitor students' paths, respectively. The Expert module has an expert agent (navigates the next course of action for the students), a planning agent (evaluates learning objectives and plans individualised student actions), a simulation agent (simulates the tasks and provides answers), and a Tutoring module consisting of a tutoring agent responsible for organising materials and assessing students' performance. The Student Communication module consists of the student agent (which records the student's current learning state) and the information-based agent recording the interaction information. The Data Mining Module is an automatic system that communicates with the tutoring agent and coordinates tasks between the tutoring agent and the information collection agent, where the latter retrieves the requested specific information. Finally, the last agent from the data mining module is the data mining agent that analyses information on student performance/interactions through clustering-rule mining and sequential pattern mining to assess problem-solving and provide individualised hints. This integration of traditional ITS with Educational Data Mining (EDM) aimed to limit human supervision, especially in skill-based (psychomotor) education in nursing. This is proposed to be achieved by applying clustering (K-means algorithm) for grouping students, then utilising association-rule mining techniques (Apriori), followed by sequential pattern mining to identify and combine patterns, thus personalising feedback with the next task and the task selection. The author planned an evaluation of their approach's effectiveness; however, they presented their idea as a conceptual model, and further evaluation and data collection could be advisable (Samra et al., 2016).

Abuazizeh et al. (2020) proposed a hybrid, conversational ITS for nursing education, focusing on scenario-based learning and supporting automated planning and probabilistic state estimation. A specific scenario involving a patient with dementia was implemented, comprising 43 states, 12 actions, and 56 valid plans. The traditional ITS architecture was initially applied, with the tutoring model guiding students through scenario-based steps (such as caring for a patient with dementia), posing questions, and determining the next steps or actions for each student. This was achieved through Planning Domain Definition Language (PDDL)-based planning combined with a Dynamic Bayesian model that predicts the next action. At the same time, an NLP model (currently treated as a black box) maps the student's free-text answers into discrete observations for the state model. This proof-of-concept is promising; however, the scenario currently requires manual handling, which could be optimised by implementing NLP techniques. The authors have planned this as future work, alongside improving visibility and enriching scenarios, which could enhance learning outcomes and system functionality (Abuazizeh et al., 2020).

An emotion-aware conversational agent for ITS was designed for nursing students' simulation, based on a scenario, to provide nursing students with support (Abuazizeh et al., 2021). The agent, intended for integration into an ITS, responds to students via dialogue, achieved through the integration of an NLP model and a reasoning model. The PDDL maintains the dialogues, while the RASA (an NLP engine) manages student inputs. The Affect Control Theory (ACT), specifically BayesACT, contributes to the representation of emotional states, enables the simulation of realistic scenarios, and measures students' performance. However, the conversational agent was presented as a standalone concept, and details of its implementation within the ITS were not provided in the current study. The authors' plans involve exploring this concept and investigating controlled learning outcomes (Abuazizeh et al., 2021).

Schmidt (2022) presented a dissertation that examined the effects of implementing the commercial adaptive ITS, Pearson's Dynamic Study Modules (PDSM), in online courses for Anatomy and Physiology within nursing education. The non-experimental, quantitative study utilised archival data from the Anatomy and Physiology course (PDSM had already been embedded), collected over a full semester (16 weeks) at one university. The archival data comprised prior Grade Point Average (GPA), used as a covariate, PDSM utilisation logs, and course assessments. The data were obtained from 99 nursing students across 12 sections of the course, and the number of PDSM modules completed was categorised as “none”, “nominal”, “moderate”, and “saturated”. A Multivariate Analysis of Covariance (MANCOVA) was used to test whether the PDSM ITS had a statistically significant effect on assessment performance after adjusting for GPA. However, the authors reported limitations, including a small sample size and the lack of participant randomisation. In addition, no intervention was assigned by a researcher (only archival data was used), and causation was difficult to examine. The authors suggested future studies to explore separate sections of a module (not the overall semester) and to randomise participants (Schmidt, 2022).

The previous work of Abuazizeh et al. (2021) on designing a conversational agent was enhanced by Sosnowski et al. (2023), who evaluated the agent within Conversational Intelligent Tutoring Systems. An automatic story-generation approach was then applied, with interaction rules and state transitions encoded as a state space graph, and the conversational agent was evaluated for ITS in nursing education. This approach improved hint generation, and the data augmentation applied across multiple languages further enhanced the presented scenarios (dementia care) and dialogues. For validation, the NLU engine from the RASA evaluation framework was used in 3 experiments, each containing 5, 10, or 15 sentences per intent, alongside 2 additional experiments that used cross-validation and a Bidirectional Encoder Representations from Transformers (BERT) pre-trained model. The results showed an average Precision (83%–87%), Recall (79%–88%) and F1 score (78%–88%) for the cross-validation; all metrics were approximately 90%. The results for the BERT pre-trained model showed a reduced accuracy of approximately 82%, with the authors concluding that such a model could be more suitable for an open-context conversational agent and larger data. For usability evaluation, the Chatbot Usability Questionnaire (CUQ) and the Assessing User Satisfaction with Information Chatbots (AUS) were used to evaluate a total of 99 students (71 AI students and 28 nursing students). There was overall positive acceptance, with suggestions for improved chatbot functionality. The authors noted a positive outcome: students were often curious about exploring different paths in scenarios, suggesting the potential for incorporating serious games in later stages. However, the chatbot did not understand specific scenarios, leading to confused interactions in some cases. Future work directions point to attempts to solve these issues and to implement NLG to eliminate manual scenario creation (Sosnowski et al., 2023).

Qian et al. (2024) developed a robotic ITS, the Automated Sterile Technique Review and Instruction Device (ASTRID), through participatory design involving roboticists, nursing students, registered nurses, and nursing educators over a 2- year period. This innovative ITS was explicitly designed to teach nursing students how to perform central line dressing changes (CLDC), which are closely related to preventing Central Line- Associated Bloodstream Infection (CLABSI), thereby targeting the psychomotor aspect of nursing education. The ASTRID operates with a Stretch mobile manipulator, a camera, and a desktop computer. This collaboration allows students to monitor their practice of dressing changes on a simulated patient, providing real- time (task- based) feedback on any incorrect actions that could lead to the development of a CLABSI. The robot simulates scenarios via mobile manipulation, focusing on the most probable human errors (i. e., interruptions), and is divided into novice, intermediate, and advanced levels. Due to the ITS' s features, after each session, ASTRID produces a report that students can view on the computer monitor. They can evaluate their performance, as post- task feedback is also generated. The system was developed using Opencv 2 and MediaPipe, incorporating pixel positions and depth measurements to map the sterile field edges and build a 3 D model. The camera measures the students' pose using pre- built models (not specified), which first detect a human body and then incorporate landmarks into the 3 D space. The sterile techniques are monitored through the student’ s pose landmarks and the sterile drape. The ASTRID’ s effectiveness in detecting sterile techniques achieved an accuracy of 98. 6%, a precision of 95. 5%, a recall of 83. 5%, and an F 1 score of 0. 89, with a nurse educator having previously established the ground truth of incorrect techniques. In addition, ASTRID’ s feasibility was investigated among 9 participants (nurses) via a survey questionnaire assessing perceived usefulness and user engagement ($M = 4.70/5.0.0$, $SD = 0.41$), with feedback highlighting the high functionality of the feedback provided by the ITS and the system’ s engagement and usefulness. Important feedback indicated that nurses felt more comfortable practising in a”safe space” where they felt less judged and more relaxed, compared with their experience with a real evaluator/educator. Despite the positive outcomes overall, the authors acknowledged certain limitations, such as a limited sample size and scenario- specific implementation of the ITS in this specific environment (Qian et al., 2024).

11. Summary of the results and discussion

Of the 9 articles included in our scoping review, the majority ($n = 7$) were peer-reviewed publications, mostly conference proceedings; 2 were considered grey literature (Schmidt, 2022; Qian et al., 2024). Of the included studies, only 2 were published as journal papers (Kopec et al., 1990; Samra et al., 2016), 4 were published in conference proceedings (Abuazizeh et al., 2020; Abuazizeh et al., 2021; Koutsojannis et al., 2001; Sosnowski et al., 2023), 1 was a book chapter (Hospers et al., 2003), 1 was a doctoral dissertation (Schmidt, 2022), and 1 was a preprint (Qian et al., 2024).

The earliest study dates to 1990 (Kopec et al., 1990), and the latest to 2024 (Qian et al., 2024), with studies from 5 countries - Germany ($n =$

Table 2
Study characteristics.

Study ID	Year	Country	Publication Type
Kopec et al. (1990)	1990	USA	Journal article
Koutsojannis et al. (2001)	2001	Greece	Conference Paper
Hospers et al. (2003)	2003	Netherlands	Book Chapter
Samra et al. (2016)	2016	India	Journal Publication
Abuazizeh et al. (2020)	2020	Germany	Conference Paper
Abuazizeh et al. (2021)	2021	Germany	Conference Paper
Schmidt (2022)	2022	USA	Doctoral Dissertation
Sosnowski et al. (2023)	2023	USA	Conference Paper
Qian et al. (2024)	2024	USA	Preprint Conference Paper

3), Greece ($n = 1$), India (n = 1), the Netherlands (n = 1), and the United States of America (USA) (n = 3). Table 2 below presents these characteristics in terms of study identification, year of publication, publication type, design and settings.

Our scoping review revealed that the topic of ITS in nursing education remains under-investigated, indicating a significant research gap. Despite the broad publication time frame (1990–2024), we observed a steady publication presence from 2020 to 2024, with substantial gaps in the years prior (1990–2020). However, 3 of the 9 articles included in our scoping review (Abuazizeh et al., 2020; Abuazizeh et al., 2021; and Sosnowski et al., 2023) share overlapping authorship. Although this highlights continuous research interest and consistency in investigation and research practices, it further diminishes individual research efforts in this educational domain. Therefore, our findings align with previous investigations of ITS in education, confirming the scarcity of this concept in nursing education (Alrakhawi et al., 2023; Hwang et al., 2024; Dicheva et al., 2023a).

Another outcome of the studies' characteristics is that most were conducted in high-income countries (World Bank Team, 2024), except for the study in India by Samra et al. (2016). Our findings support one of the 9 recommendations of the "The future of nursing 2020-2030 report", which advocates providing equal opportunities for all nursing students, specifically those from geographically and socio-economically disadvantaged settings (Sumpter et al., 2022).

In our review, early work focused on presenting partial ITS architectures of the domain model of an ITS (Abuazizeh et al., 2020; Abuazizeh et al., 2021; Kopec et al., 1990; Koutsojannis et al., 2001; Samra et al., 2016), but not the student and tutoring models, which have equal, if not superior, value for an ITS due to the implementation of AI techniques. Despite the diverse scope of each study, only Hospers et al. (2003) presented a complete ITS, including the classical ITS architecture of domain, student and tutoring models, and further integrated a multi-agent design perspective. The remaining studies investigated conversational agents (Abuazizeh et al., 2020; Abuazizeh et al., 2021; Sosnowski et al., 2023) and robotics (Qian et al., 2024). One of the 9 studies examined an already embedded ITS in the nursing curriculum and its effect on nursing students' learning outcomes (Schmidt, 2022). One study emphasised the potential of extending an ITS architecture, highlighting the benefits of implementing data mining techniques (Samra et al., 2016).

None of the studies included in our scoping review provided guidance, a framework or a checklist on how the suggested ITS/component would be introduced and implemented in nursing education. Additionally, there was no evidence of investigation into nursing students' and nurses' awareness, preparedness, opinions and experiences of the concept of ITS, and how these would align with the design, development and implementation of an ITS in nursing education. This contrasts with other AI-enabled pedagogies in nursing, such as chatbot mobile applications (Dicheva et al., 2023a; Dicheva et al., 2023b), where prior investigation is more common. This difference could be explained by lower awareness among nursing students and nurses of the concept of ITS, compared with other technologies (chatbots, mobile applications, etc.). However, this assumption could be further verified by conducting a grounded theory study, which often addresses research questions when limited information is available (Morse, 1994). The context in which each study presented its approach to ITS in nursing education varied, including classrooms, online, laboratory settings and simulation. In terms of outcomes of interest and evaluation approaches, the majority were formative, and only 4 studies (Kopec et al., 1990; Schmidt, 2022; Sosnowski et al., 2023; Qian et al., 2024) included participants. Across all included studies, nursing students were the participants in the majority of studies, and registered nurses (newly qualified) were considered by only one study (Qian et al., 2024), suggesting further consideration of not only university-level nursing education but also the competencies and training that registered nurses should complete via their institutions.

Our scoping review highlighted a methodological gap, with non-experimental methodologies or formative designs. Most studies relied on these designs, and among the four studies that evaluated their proposed systems, quantitative approaches were predominantly used. These findings align closely with previous requests by the International Nursing Association for Clinical Simulation and Learning (INACSL) Franklin and Luctkar-Flude (2020) for larger heterogeneous samples, mixed-methods designs, and RCTs when investigating computer-aided pedagogies in nursing education.

Collectively, the findings of our scoping review indicate that the evidence base for ITS in nursing education is at an early stage of development. The relatively small and heterogeneous number of studies, the dominance of research conducted in high-income countries, and the limited number of research teams investigating this topic suggest that conclusions about the maturity and integration of ITS in nursing education should be interpreted with caution. Thus, the current literature suggests an emerging and evolving research area rather than consolidated evidence on ITS in nursing education. Therefore, further research could benefit from investigating the topic in broader geographic and socioeconomic contexts, employing diverse methods, and proposing solutions for the effective implementation of ITS within the nursing curriculum, both in pre- and post-registration educational settings.

Despite the limited research on ITS in nursing education, the cognitive domain (Kopec et al., 1990; Koutsojannis et al., 2001; Hospers et al., 2003; Schmidt, 2022; Abuazizeh et al., 2020), the affective domain (Abuazizeh et al., 2021; Sosnowski et al., 2023), and the psychomotor domain (Hospers et al., 2003; Qian et al., 2024) have been explored by the authors included in our review. This aligns with the fundamentals of nursing education, which emphasise equal representation of the three dimensions for optimised nursing educational practices (Hoque, 2016; Nehring and Lashley, 2009).

11.1. Implications of the findings for research and practice

Our scoping review aimed to provide an overview of the existing evidence on ITS in nursing education and to identify current gaps. The discussion of the results above contributed to a more comprehensive evidence map, resulting in clear recommendations for future research and practice. In terms of identified gaps, we utilised Miles' taxonomy (Miles, 2017) to identify research gaps linked to the results of our scoping review. These gaps include knowledge, methodological, empirical, theoretical and population gaps. A knowledge gap occurs when no evidence exists in the relevant field of interest, or when results differ from what is expected. A methodological gap refers to the lack of research methods applied to investigate specific topics or areas of interest. An empirical gap occurs when there is a lack of robust evaluation or verification of findings. A theoretical gap is the absence or inadequate presence of a theory needed to explain relationships or to integrate findings within a specific research context (Müller-Bloch and Kranz, 2015). The population gap refers to a study population that is underrepresented in an area of research in terms of geographical location or demographic characteristics (Robinson et al., 2011).

Table 3 illustrates the gaps, describes the evidence supporting each gap, and includes our recommendations.

12. Limitations

Several limitations should be acknowledged when interpreting the findings of our scoping review. First, the number of studies meeting the inclusion criteria was relatively small and heterogeneous. While the limited research highlights the novelty of this concept, it results in a narrow and diverse evidence base, thereby constraining the generalisability of our scoping review findings. Similarly, overlapping authorship across several of the included studies further limits the available evidence and underscores the small number of research teams examining the ITS in nursing education. Second, most of the included studies

Table 3
Identified research gaps and recommendations regarding ITS in nursing education.

Knowledge gap	Limited conceptualisation of how ITS can align with nursing philosophy, pedagogy, clinical reasoning, and curriculum requirements. No assistance of user-perspectives and conceptualisation investigation on how on nurses' or nursing students' awareness, preparedness, opinions, or experiences of the concept of ITS in nursing education.	Developing qualitative studies (e.g. grounded theory) to understand nurses' and nursing students' awareness, perceptions, readiness, opinions and experiences of ITS in nursing education. In parallel, developing a conceptual or pedagogical frameworks that specifically studies how an ITS aligns with the nursing philosophy, clinical reasoning and curriculum requirements. Consequently, these approaches can inform the design, features and functionalities of an ITS in nursing education.
Methodological gap	Majority of studies presented non-experimental and formative designs, and system or component evaluation mostly conducted via quantitative methods. Evaluation outcomes addressed feasibility or usability, not user experience, learning effectiveness, or knowledge/skill gains. Participants' demographics, population samples, and sampling strategies were insufficiently described.	Adopting qualitative and/or mixed-method designs and perform a continuous system's evaluation throughout its design and development, assessing all ITS components, prior to deployment.
Empirical gap	No direct evidence of the effectiveness of ITS in nursing education in terms of knowledge or skills acquisition or preparedness, or investigation of short- or long-term gains. No comparative studies assessing learning effectiveness or user experience.	Implementing RCTs and quasi-experimental studies comparing ITS-supported educational approaches in nursing to assess effectiveness in terms of educational outcomes, user satisfaction, self-efficiency and user experience.
Theoretical gap	Limited representation of fully functional ITS and overwhelming focus on the domain model rather than the student or tutoring models among studies presenting partial architectures. No representation of frameworks, theoretical models, or recommendations for integrating ITS in nursing curricula.	Developing and evaluating a holistic ITS (prototype or fully functioning system) specifically tailored to nursing education philosophies. Additionally, future work should empirically examine theoretical and pedagogical frameworks that support the integration of an ITS in the nursing curriculum and clinical mandatory training, including alignment with established and recognised nursing educational models.
Population gap	Limited representation of geographical locations and low- to middle-income countries. Limited investigation on ITS for the education and training of registered nurses.	Promoting inclusion of underrepresented populations in nursing, both in terms of demographics and diverse educational and professional ranks. Exploring ITS in design and deployment in low-resource contexts.

were conducted in high-income countries. Thus, the applicability of the findings to low- and middle-income countries with limited infrastructure, technological resources, and learner needs remains unknown. Third, there may have been inconsistencies in the definitions of ITS across studies and in the broader literature. Although the PCC framework was applied to enhance rigour and coherence, the close integration of educational and clinical practice in nursing may have introduced contextual ambiguity. In addition, the rapid development of AI means that conceptualisations of ITS may extend beyond the scope of our scoping review.

13. Conclusion

Our scoping review mapped the current evidence on ITS in nursing education. Searches across 7 major databases and selected grey literature sources identified 881 records, of which 9 studies met the inclusion criteria. The results suggested that ITS in nursing education remains in its infancy. The included studies mainly described partial ITS architectures centred on domain models, but these lacked a strong theoretical basis, empirical validation, or detailed information on integration into nursing curricula. Our results recommended that future work emphasise theory-driven, user-informed methods, develop and assess fully operational ITS frameworks aligned with nursing education principles, and include diverse populations and low-resource settings. Improving methodological rigour and enabling larger, more diverse study populations are essential for future research in ITS in nursing education.

Authors statement

All authors contributed towards this work. However, it is essential to note that this work will contribute towards the completion of a PhD programme of the corresponding author (Nevena K. Dicheva).

CRediT authorship contribution statement

Nevena K. Dicheva: Writing – review & editing, Writing – original draft, Conceptualization. **Ikram Ur Rehman:** Writing – review & editing. **Laden Husamaldin:** Writing – review & editing. **Sama Aleshaiker:** Writing – review & editing.

Ethics approval statement

No participants were involved in this research.

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Declaration of competing interest

The authors declare no conflict of interest.

Data availability

All data is presented in the manuscript (anonymity maintained, as per journal specific instructions).

Appendix I. Search strategy

("intelligent tutoring system" OR "intelligent tutoring systems" OR "intelligent tutor" OR "cognitive tutor") AND ("nursing students" OR "registered nurses" OR "nurse educator" OR "nursing faculty" OR "nursing education" OR "curriculum" OR "skills lab" OR "clinical placement") NOT ("chatbot" OR "Simulation" OR "large language model -LLM" OR "ChatGPT" OR "virtual reality" OR "augmented reality" OR "computer-assisted instruction"-CAI OR "patient education" OR "patient care")

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