

Towards Trustworthy Intelligent Tutoring Systems for Nursing Education: Integrating Nurse-Informed Design with a Frugal Neuro-Symbolic Architecture

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Extended Abstract

Nursing education is increasingly expected to provide personalised, scalable, and clinically meaningful learning experiences while responding to educator shortages, growing student numbers, limited placement opportunities, and rapidly evolving healthcare environments (Weberg, Chan, and Dickow 2021). These pressures have led to the adoption of technology-enhanced learning and renewed interest in innovative and student-centred pedagogies within healthcare education (Jeong and Lim 2022). Consequently, nursing education has explored a broad range of computer-aided educational approaches, including virtual reality, augmented reality, simulation systems, mobile learning applications, haptic devices, and chatbots (Dicheva et al. 2023). Although many of these technologies demonstrate educational potential, important limitations remain regarding explainability, accessibility, educator involvement, adaptive support, and long-term educational effectiveness (Franklin and Luctkar-Flude 2020). Recent interest in large language models and conversational AI has introduced further concerns surrounding reliability, hallucinations, transparency, privacy, educator trust, and ethical deployment within healthcare education (Abujaber et al. 2023).

One AI-enabled learning environment that may address several of these limitations is the Intelligent Tutoring System (ITS). Traditionally, ITSs combine domain, tutoring, student, and interface models to provide adaptive instruction, individualised support, and immediate formative feedback (Nwana 1990). Through natural-language processing and adaptive learning techniques, ITSs may support realistic communication scenarios, individualised learning experiences, and scalable educational assistance (Haq et al. 2020). Compared with isolated educational technologies, ITSs are particularly promising because they can support students and educators within one integrated learning environment. Despite this potential, ITS research in nursing education remains limited. Earlier reviews in this doctoral research found that ITS-related studies represented only a small proportion of AI research in nursing education. They also identified limited attention to student modelling, tutoring strategies, explainability, educator oversight, pedagogical alignment,

and the wider educational context in which these systems are introduced. Importantly, no nurse-informed conceptual or design-oriented framework was identified to guide ITS development within nursing education.

This gap became the central motivation for this doctoral research. The project adopts a multi-phase, sequential exploratory mixed-methods and design-oriented approach. Phase One used grounded theory interviews to explore nurses' and nursing students' awareness, perceptions, expectations, concerns, and educational requirements regarding ITS adoption. These qualitative findings informed the development of the CARE-ITS framework. The framework comprises Content Alignment; Adaptive and Accessible Learning; Retention of Human-Centred Learning; Ethical and Trustworthy AI; Individualised Learning Support; Timely and Explainable Feedback; and Sustainability and Educator Support. The framework was subsequently evaluated and refined through expert validation ($N = 20$), with 95–100% agreement across the overall evaluation criteria (means = 4.40–4.55 out of 5).

Phase Two translated the validated CARE-ITS framework into the design, development, and evaluation of EduNurse, a functional web-based ITS prototype for scenario-based nursing education. EduNurse uses a frugal neuro-symbolic assessment architecture that combines domain-adapted embeddings, deterministic educational constraints, structured rubrics, retrieval-grounded explanations, adaptive progression logic, and educator supervision. The grading pipeline does not use a generative large language model. Instead, it uses semantic similarity as one source of evidence alongside explicit relevance, rubric, safety, and uncertainty checks. This enables the system to provide structured formative feedback while retaining appropriate boundaries for educator oversight.

The research contributions achieved to date include:

1. **A substantial literature contribution through two complementary published reviews.** A mixed-methods systematic review of computer-aided pedagogies (Dicheva et al. 2023) and a scoping review of ITSs in nursing education (Dicheva et al. 2026) critically examined the existing evidence base. Together, they identified gaps that informed the subsequent phases of this doctoral research.
2. **An empirical contribution through a learner needs**

analysis for ITS in nursing education. This doctoral research presents a learner needs analysis employing a grounded theory approach to investigate nursing students' and nursing professionals' awareness, perceptions, educational requirements, and implementation expectations of ITSs. The study addresses an important gap within the literature by providing an empirically grounded understanding of the pedagogical, educational, and implementation requirements that should inform the design and development of AI-supported educational systems for nursing education.

3. **A methodological contribution through the translation of qualitative findings into a design-oriented conceptual framework.** This doctoral research demonstrates a systematic approach for translating empirically derived learner needs, pedagogical considerations, and implementation requirements into actionable design guidance. This provides a transparent transition from qualitative findings to educational AI design that may inform future research within nursing and other professional education domains.
4. **The development of the CARE-ITS conceptual framework.** Derived from the learner needs analysis, CARE-ITS is a nurse-informed, design-oriented conceptual framework. The framework addresses key components including content alignment, adaptive and accessible learning, retention of human-centred learning, ethical and trustworthy AI, individualised learning support, and timely and explainable feedback. By translating the identified educational requirements into AI system design principles, CARE-ITS provides an evidence-based framework to support the design and implementation of trustworthy ITSs within nursing education.
5. **The design, development, and evaluation of EduNurse, a domain-specific ITS prototype for nursing education.** Guided by the CARE-ITS framework, this research presents a scenario-based ITS prototype (EduNurse) that translates empirically derived learner needs, pedagogical considerations, and framework-guided design principles into a functional educational system. EduNurse does not introduce a new AI technique. Its contribution is how it brings established approaches together within a nurse-informed ITS architecture designed around the pedagogical requirements of nursing education. Within EduNurse, semantic similarity is used alongside educational decision rules to assess written scenario responses and provide feedback and learner support. This forms the basis of its frugal neuro-symbolic approach to scenario-based learning and assessment. In doing so, this research demonstrates how AI techniques can be applied within a trustworthy ITS that is informed by empirical educational requirements and aligned with the pedagogical, professional, and ethical principles of nursing education.

The formal evaluation of EduNurse is complete. The evaluation combines nursing learners' questionnaire responses, linked system-interaction records, technical-performance logs, and an independent nursing-educator audit of assess-

ment outputs. Data analysis is now being undertaken to examine the extent to which EduNurse demonstrated the intended CARE-ITS capabilities and achieved the doctoral research objectives.

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