THE CONCEPT AND DEVELOPMENT OF DIGITAL TECHNOLOGIES IN NURSING CARE

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Abstract

The digital transformation of nursing represents a qualitative change in the organization and provision of care that goes beyond the simple digitization of documentation. The article examines the development of digital nursing technologies (DNT) within the framework of information technology and their impact on patients, professional and non-professional caregivers, as well as medical institutions. Based on an extensive scoping review of over 19,000 materials, a holistic, nursing-focused methodology for evaluating DNT performance has been proposed, covering 47 areas of outcomes. It was found that research mainly focuses on patient-centered outcomes, while outcomes related to the quality of caregivers' lives and administrative aspects remain insufficiently studied. A special emphasis is placed on the progress of digital developments – from telemedicine and tracking to artificial intelligence systems and reinforcement of medical decisions. It is concluded that there is a need for unified assessment tools and improvement of digital skills of nurses for reliable implementation of digital developments in nursing care.

Keywords: digital technologies, digital nursing technologies, nursing care

Introduction

Digital transformation in nursing care represents a fundamental qualitative change in the organization and delivery of care rather than merely the electronic

conversion of paper-based documentation. It involves the systematic use of digital technologies to support information exchange, data analysis, decision-making, and predictive processes within nursing practice. In contemporary scientific literature, this transformation is closely linked to the concept of Nursing Informatics, which integrates nursing science, information science, and computer science to improve patient outcomes, nursing workflows, and healthcare system efficiency.

The rapid expansion of digital nursing technologies (DNT) has significantly reshaped nursing care across formal and informal care settings. These technologies include telehealth platforms, mobile health (mHealth) applications, sensor-based monitoring systems, electronic nursing care plans, clinical decision support systems (CDSS), and artificial intelligence (AI)-driven tools. While their potential to enhance care quality, patient safety, and operational efficiency is widely acknowledged, their increasing diversity has created substantial challenges for evaluating real-world effectiveness. As research activity intensified, it became evident that existing evaluation approaches were fragmented and inconsistent, limiting comparability across studies and preventing the development of a robust evidence base for nursing-specific digital interventions.

To address this challenge, a comprehensive outcome framework for evaluating the effectiveness of digital nursing technologies was developed. The framework was constructed through a large-scale scoping review that screened more than 19,000 publications and included 123 studies that met strict inclusion criteria emphasizing real-world effectiveness rather than purely technical performance. Using a combination of inductive and deductive methods, supported by expert consultation, the authors systematically identified outcome areas and measurement tools applied in digital nursing research.

The resulting framework categorizes the effects of digital nursing technologies into four primary outcome target groups: Persons in need of care, Formal

caregivers, including professional nurses, Informal caregivers, such as family members, and Healthcare organizations.

Across these groups, the framework defines 47 specific outcome areas, encompassing both frequently assessed and often neglected domains. Patient-related outcomes, such as psychosocial well-being, safety indicators, and intensity of service utilization, are most commonly evaluated. In contrast, outcomes related to caregiver quality of life, organizational working conditions, staff retention, and access to care remain insufficiently explored. Moreover, the literature reveals a lack of standardized outcome measurement tools, particularly for caregiver and organizational outcomes, which limits the comparability and generalizability of findings.

Overall, the development of a nursing-centered DNT outcome framework represents a significant advancement in digital nursing research. It provides a structured and theory – informed roadmap for evaluating digital technologies across multiple levels of care, enabling researchers and practitioners to identify evidence gaps and improve methodological consistency. By applying such frameworks, healthcare organizations can better assess the true impact of digital technologies on patient care, nursing practice, and institutional performance, thereby supporting informed decision-making and sustainable digital transformation in nursing care.

Digital transformation in nursing care is not just the electronic conversion of paper documents, but the qualitative transformation of the concept and development of digital technologies in nursing care

Digital transformation in nursing care is not just the electronic conversion of paper documents, but the qualitative transformation of the care process through information exchange, analysis and forecasting. In modern literature, this process is studied in close connection with the concept of "Nursing Informatics" (Nursing Informatics) Measuring the Effectiveness of Digital Nursing Technologies: Key Insights

The rapid expansion and diversification of digital nursing technologies (DNT) have created significant challenges for consistent evaluation of their real-world effectiveness. DNT include a broad range of tools - from telehealth and sensor systems to clinical decision support and ICT solutions - used in formal and informal care environments. However, as research in this field grew, it became evident that existing evaluation approaches were fragmented, making it difficult to compare study outcomes or draw general conclusions about the true effectiveness of these technologies in nursing practice.

Purpose and Need for a Framework.

The discussed article aimed to address this gap by developing a comprehensive outcome framework specifically tailored to DNT effectiveness evaluation. Previous frameworks (such as those for general health information systems or telemedicine) offered valuable dimensions but lacked a nursing-specific focus, especially regarding outcomes relevant to caregivers and organisational processes. The absence of a unified structure limited the comparability of findings and the ability to identify research gaps across studies.

Framework Development Methodology

To construct the framework, the authors conducted a scoping review of studies focusing on the acceptance, effectiveness, or efficiency of digital nursing technologies. From an initial pool of more than 19,000 titles, they identified 123 studies that met strict inclusion criteria emphasizing real-world effectiveness rather than purely technical performance. They applied both inductive and deductive methods, supplemented by expert consultation, to systematically derive outcome areas and assign outcome tools used in the literature.

Core Elements of the DNT Outcome Framework

The resultant DNT outcome framework categorises potential effects of digital nursing technologies across four primary target groups: Persons in Need of Care, Formal Caregivers (e.g., professional nurses), Informal Caregivers (e.g., family members), Healthcare Organisations

This outcome framework provides a detailed and nursing-centred pathway for researchers and practitioners to assess the real-world effectiveness of digital technologies - moving beyond disparate measures toward a more consistent and theory-informed evidence base[4].

Measuring the Effectiveness of Digital Nursing Technologies

The evaluation of digital nursing technologies (DNT) remains a critical challenge in modern healthcare, as interventions vary widely - from decision support systems and mobile health applications to assistive robots and virtual reality platforms. A recent study developed a comprehensive outcome framework to systematically measure the effectiveness of digital nursing technologies across multiple levels of care [5]. The framework identifies four primary outcome target groups: persons in need of care, formal caregivers, informal caregivers, and healthcare organisations. Within these groups, the study categorised 47 specific outcome areas, encompassing both commonly assessed aspects, such as patient psychosocial health and care process quality, and frequently neglected domains, including caregiver quality of life, organisational working conditions, and access to care .Analysis of 123 studies revealed that while patient-related outcomes, such as psychosocial well-being, intensity of service utilisation, and safety indicators, were frequently assessed, caregiver and organisational outcomes remain underexplored. Formal caregivers were primarily evaluated for guideline compliance, relationship to patients, and workload, whereas informal caregivers were rarely assessed beyond caregiver burden. Organisational outcomes often focused on process quality, operational efficiency, and communication, yet critical areas like staff retention, financial performance, and broader access to care were seldom considered. The study also highlighted the lack of standardised measurement tools across these outcome areas. While patient psychosocial outcomes were often measured using validated instruments such as geriatric depression scales, cognition tests, and quality-of-life assessments, tools for evaluating caregiver or organisational outcomes were inconsistent or applied only

once across studies. This heterogeneity hinders the comparability of results and underscores the need for systematic, evidence-based evaluation tools [5].

Overall, this outcome framework provides a structured roadmap for future research and practice, ensuring that evaluations of digital nursing technologies are both comprehensive and comparable. It allows researchers to identify gaps in current evidence, particularly concerning caregiver well-being and organisational performance, while guiding the development of standardised instruments for outcome measurement. By applying this framework, healthcare organisations can better assess the true impact of digital technologies on patient care, nursing practice, and institutional efficiency, ultimately supporting informed decisions for technology adoption in clinical settings [5].

Second wave (interactivity and Monitoring): in the period 2019-2023, especially affected by the global pandemic, nurses have developed remote communication tools with patients - mHealth and telemetry systems. Effectiveness and Acceptance of Digital Nursing Technologies.

Digital technologies are increasingly integrated into nursing care, offering potential to enhance patient outcomes, improve caregiver efficiency, and optimize healthcare processes. Recent research highlights both the promise and the challenges associated with implementing these technologies in diverse care settings. According to Krick et al. (2019), a scoping review of 715 studies across 69 countries, the most frequently investigated digital tools include information and communication technologies (ICT), robots, and sensor-based monitoring systems. These technologies primarily support care delivery, organizational processes, and patient safety. Despite this widespread research, significant gaps remain in home-based, informal care, and cross-sectoral care settings, where adoption and impact are underexplored.

The review also emphasized that studies overwhelmingly focus on acceptance (59% of studies) and effectiveness (60%), whereas efficiency or economic evaluation is rarely examined (5.8%). Target groups include patients, formal

caregivers such as nurses, and, to a lesser extent, informal caregivers. Importantly, informal caregivers are represented in only 8% of studies, highlighting a critical gap in understanding how digital tools support family-based care. Study designs vary in quality, with a substantial number of studies lacking control groups or rigorous methodologies, limiting the generalizability of findings.

Complementing these insights, a framework developed by Mair et al. (2020) for evaluating the effectiveness of digital nursing technologies provides a structured, nursing-centered approach. The framework identifies outcomes across four groups: patients, formal caregivers, informal caregivers, and healthcare organizations. Key outcome areas include psychological health, functional status, workload, care process quality, and organizational efficiency. The authors note that, while patient-focused outcomes are widely assessed, caregiver and organizational outcomes remain underrepresented, and standardization of outcome measures is needed to facilitate comparability across studies.

Together, these studies underscore that while digital nursing technologies have demonstrated potential to improve care delivery, research remains fragmented, particularly regarding economic impact and caregiver-centered outcomes. Advancing the field requires high-quality empirical studies, standardized evaluation tools, and expanded investigation into underrepresented care settings. By bridging these gaps, digital nursing technologies can be more effectively integrated into practice, ultimately improving patient care and supporting both formal and informal caregivers [2,7]. Second wave (interactivity and Monitoring): in the period 2019-2023, especially affected by the global pandemic, nurses have developed remote communication tools with patients.

Second wave (interactivity and Monitoring): in the period 2019-2023, especially affected by the global pandemic, nurses have developed remote communication tools with patients - mHealth and telemetry systems [2,4].

Third wave (intellectual care): by 2024-2026, artificial intelligence (AI), machine learning (ML), and Decision Support Systems had moved to the center of nurse work. Nurses' Perceptions and AI Integration in Digital Nursing Technology

Digital nursing technologies, including artificial intelligence (AI) tools, are increasingly integrated into clinical practice, aiming to enhance patient outcomes, improve operational efficiency, and support nurses' decision-making. Evidence from Krick et al. (2019) and related studies demonstrates that nurses' acceptance of digital tools is influenced by three key factors: attitude toward technology, subjective norms, and perceived behavioral control, in line with the Theory of Planned Behavior. Positive attitudes, supportive organizational culture, and nurses' confidence in their digital competence are all critical determinants of successful technology adoption. Nurses are more likely to engage with digital tools when they perceive clear benefits to patient care, experience encouragement from colleagues and leadership, and feel adequately trained to operate these systems.

AI-based technologies, such as predictive analytics, clinical decision support systems, and automated monitoring platforms, have shown measurable benefits in both patient care and operational management. AI can detect early signs of clinical deterioration, optimize treatment planning, and reduce errors, thereby improving patient safety and clinical outcomes. Moreover, AI streamlines administrative tasks such as scheduling and documentation, reducing nurses' workload and enabling them to focus on direct patient care. These systems also support proactive resource allocation, helping healthcare teams manage high-demand periods effectively and improve workflow efficiency.

Despite the demonstrated advantages, several challenges limit the widespread integration of AI in nursing. Ethical and practical concerns, including data privacy, algorithmic bias, and over-reliance on automated systems, may undermine nurses' confidence or compromise patient safety if not adequately addressed. The literature emphasizes the importance of transparent, fair, and

accountable AI algorithms, as well as structured training programs to equip nurses with the necessary digital literacy and competencies. Furthermore, empirical research highlights the gap in understanding how AI affects nurse job satisfaction, workflow, and long-term patient outcomes, particularly in diverse healthcare settings.

Overall, the current evidence indicates that AI and digital nursing technologies hold substantial potential to enhance clinical practice, yet effective implementation depends on supporting nurses' acceptance, ensuring adequate training, and addressing ethical considerations. Future research should focus on longitudinal studies examining the impact of AI on both patient-centered outcomes and nurses' professional experiences, as well as strategies to optimize adoption across various clinical environments. By bridging these gaps, digital nursing technologies can be effectively integrated, ultimately improving patient care and empowering nurses in the digital era [6,8].

Types of digital technologies and their role in nursing.

The literature review shows that the technologies used in nursing practice today are divided into the following   literature review shows that the technologies used in nursing practice today are divided into the following groups: Electronic care plans (Electronic Nursing Care Plans - ENCP): the literature review shows that the technologies used in nursing practice today are divided into the following groups: Electronic care plans (Electronic Nursing Care Plans - ENCP): these systems help the nurse to create a care plan that is standardized for the patient but tailored to individual needs. Researchers argue that ENCP systems increase the accuracy of nursing diagnostics [7].

Clinical Decision Support Systems (CDSS): by analyzing the data entered by the nurse (e.g. vital signs), the system automatically detects signs of danger. Clinical Decision Support Systems (CDSS): by analyzing the data entered by the nurse (e.g. vital Clinical Decision Support Systems (CDSS): by analyzing the data entered by the nurse (e.g. vital signs), the system automatically detects signs of

danger. For example, it provides a warning about the possibility of developing sepsis or bed ulcers [16].

M-Health and wearable sensors: data on heart rate, breath frequency and blood oxygen saturation (SpO2) are sent directly to the nurse's tablet using sensors installed on the wrist or body of patients Smart and Digital Nursing Technologies in Hospitals

The integration of smart and digital nursing technologies in hospitals has significantly transformed clinical care, with a focus on improving patient safety, workflow efficiency, and nursing competence. Among emerging innovations, IoT-enabled smart mattresses and sensor-based monitoring systems have been identified as particularly impactful. These devices automatically reposition patients to prevent pressure ulcers, monitor vital signs in real time, and reduce the physical workload of nurses, thereby allowing them to devote more attention to direct patient care [5]. Nurses generally perceive these technologies as beneficial; however, successful adoption depends on the usability, integration into existing workflows, and inclusion of nursing staff in implementation processes [5].

Beyond bedside technologies, broader digital nursing tools – including electronic health records (EHRs), mobile health applications, and clinical decision support systems (CDSS) - have demonstrated measurable improvements in documentation accuracy, communication, and care coordination. By facilitating real-time data access and supporting data-driven decision making, these tools enhance the quality of care and reduce preventable errors [2]. Furthermore, AI-powered analytics and predictive tools allow for early detection of clinical deterioration and support efficient resource allocation, contributing to improved patient outcomes and operational efficiency [3].

Despite these benefits, the literature highlights several challenges. Training and digital competency of nurses are critical for the effective use of technologies, as lack of proficiency can hinder adoption and limit clinical impact [3]. Organizational factors such as leadership support, workflow alignment, and

ongoing evaluation are also essential to maximize benefits and mitigate risks such as alert fatigue or over-reliance on automated systems [2,3]. Thus, while smart and digital nursing technologies hold substantial potential, their success depends on a combination of technological, educational, and organizational factors. Future research should focus on longitudinal assessments of patient outcomes, nurse workflow impact, and strategies for sustainable integration of these tools across hospital settings [5, 9].

Digital competence and educational foundations. The development of technology is demanding new skills from nurses. digital competence and educational foundations. The development of technology is demanding new skills from nurses. Research in 2024 shows that the digital literacy of nursing students is the basis of their professional training Digital Proficiency Among Nursing Students The rapid digitalization of healthcare necessitates that nursing students possess robust digital skills, health literacy, and familiarity with artificial intelligence (AI) applications. Recent evidence indicates that nursing students demonstrate high levels of digital knowledge and skills, alongside positive attitudes toward the integration of AI and digital transformation in healthcare settings. Senior nursing students tend to outperform juniors in terms of digital competencies, highlighting the cumulative effect of academic exposure on practical digital literacy. Importantly, the study revealed significant positive correlations between knowledge of digital transformation, digital skills, digital health literacy, and attitudes toward AI, suggesting that these competencies are mutually reinforcing. Students who understand digital tools more thoroughly are more likely to feel confident in using AI applications and other digital health technologies in clinical practice [9].

Despite generally favorable results, several barriers impede the effective adoption of digital technologies among students. Limited infrastructure, insufficient hands-on training, and concerns regarding data security were commonly reported challenges [9]. Conversely, access to reliable internet, availability of digital tools,

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and increased awareness of digital healthcare benefits were cited as key facilitators. These findings underscore the importance of incorporating structured digital literacy and AI-focused modules into nursing curricula to better prepare graduates for modern, technology-driven clinical environments [15]. By systematically addressing these educational and infrastructural gaps, nursing programs can equip students with the competencies needed to enhance patient care, streamline clinical workflows, and adapt effectively to evolving digital healthcare landscapes [9,15].

Despite these strengths, gaps remain that may affect the quality of nursing education. Areas such as technical knowledge, integration of digital tools into curriculum design, and digital pedagogy were identified as weak points, suggesting that faculty development programs should address these deficits. Targeted interventions can include workshops, practical training modules, and mentorship programs focused on bridging the gap between digital familiarity and pedagogical application. By enhancing both technical and teaching competencies, academic nurse educators can ensure that nursing students acquire the digital skills necessary for effective clinical practice, patient safety, and innovation in healthcare delivery [10].

In conclusion, the study underscores the necessity of structured digital literacy programs tailored to educators' age, experience, and professional exposure. Strengthening these competencies not only empowers faculty but also has a downstream effect on the preparedness of nursing graduates, fostering a workforce capable of navigating the evolving digital landscape of modern healthcare [10].

Comparative studies in Norwegian and Swedish higher education institutions have shown that the positive attitude of students towards technology causes them to effectively use digital tools in clinical practice. Nursing Students' Attitudes Toward Digital Technology in Geriatric Care. Digital technologies are rapidly becoming integral to modern healthcare, yet nursing students' perceptions of

these tools vary depending on patient populations. Recent research conducted among Norwegian and Swedish nursing students revealed that while students generally hold positive attitudes toward digital technology in healthcare, they demonstrate notable concerns regarding its use with older adults. Students recognized that digital tools can enhance communication with colleagues, facilitate clinical decision-making, and improve patient care quality. Statements such as "Using digital technology devices makes my communication with other health professionals faster" and "Information from digital devices helps me provide better care to patients" reflect their overall enthusiasm for technological integration in clinical practice [16].

Despite this optimism, students exhibited skepticism regarding older adults' ability to use digital tools effectively. Many agreed that explaining digital technology to older patients requires significant patience, and that older adults often fear using technology due to security concerns or perceived complexity [16]. This highlights a crucial educational and clinical challenge: nurses must be prepared to support patients with varying levels of digital literacy, particularly in geriatric care settings where technology adoption is often slower.

The findings emphasize the importance of incorporating targeted digital literacy and communication training into nursing curricula. Preparing students to assist older adults in using digital health solutions not only improves patient engagement but also ensures that technological advances translate into better care outcomes. Practical modules should address strategies for teaching, guiding, and motivating patients with low digital competence while reinforcing students' own technical skills [16].

While nursing students are increasingly positive about digital technologies in general, their concerns about older adults' technology use underscore the need for educational interventions that combine technical proficiency with pedagogical skills. Strengthening both digital competence and patient-focused teaching strategies will be essential to empower future nurses to successfully integrate

technology into diverse healthcare settings [16]. At the same time, digital literacy of academic educators (nurse educators) is also an important factor, they are actively introducing virtual simulations into the educational process Digital Literacy Among Academic Nurse Educators

Digital literacy has emerged as a critical competency for academic nurse educators, who are responsible for preparing future nurses for a technology-driven healthcare environment. A recent study assessed the current levels of digital literacy among nursing faculty and identified key factors influencing competence [10]. The study found that overall digital literacy among academic nurse educators was moderate, with educators demonstrating higher proficiency in digital application and social responsibility but weaker skills in technical knowledge and pedagogical integration of digital tools [10]. This indicates that while educators are generally comfortable using technology and understand its ethical implications, they may struggle with more advanced technological skills and the effective incorporation of digital resources into teaching.

Several demographic and professional factors were significantly associated with higher digital literacy. Younger educators exhibited greater proficiency than older colleagues, highlighting the influence of generational familiarity with digital tools. Additionally, educators with 6 – 15 years of teaching experience and those who actively kept up with advancements in digital technology scored higher on digital competence assessments. Importantly, regular use of digital tools, including AI-based applications such as ChatGPT, was positively correlated with literacy, emphasizing that hands-on engagement reinforces theoretical knowledge and confidence in applying digital technologies in educational settings [4, 10].

Conclusion

Digital and smart nursing technologies, including CDSS and AI-based tools, have significant potential to improve quality of care, patient safety, and clinical efficiency. Their effective use depends not only on technological availability but

also on nurses' and educators' digital competence, training, and organizational support. Studies show that strong digital literacy among nursing students and educators enhances confidence, adoption, and clinical impact of digital tools. However, gaps in infrastructure, practical training, and pedagogical integration remain. Strengthening digital education, supporting faculty development, and fostering digital resilience are essential to ensure the sustainable and effective integration of digital technologies in nursing practice.

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