A Scoping Review of Interdisciplinary Collaboration Between Nursing and Engineering in Healthcare

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Abstract: This scoping review explores the interdisciplinary collaboration between nursing and engineering in healthcare, focusing on how such collaborations can address complex healthcare challenges. It aims to investigate the nature, roles, processes, and outcomes of the partnerships between nursing and engineering professionals. The review identifies existing gaps in the literature and proposes the development of programs to facilitate further collaboration. By combining engineering's technological expertise and nursing's patient-centered care focus, the partnership can drive innovation and improve healthcare outcomes, making care more accessible, efficient, and sustainable. This review highlights the importance of educational initiatives and interdisciplinary training to foster future collaborations in healthcare settings.

Keywords: interdisciplinary collaboration, healthcare.

1. Introduction

Large-scale changes in the healthcare system are necessary to improve patient outcomes, increase care access, and make healthcare organizations more efficient. The challenges faced in healthcare are complex; engineering can help solve these complex issues but typically does not have the appropriate context necessary to ensure that solutions are viable within the existing healthcare context. Engineering can use the nursing perspective to develop more applicable and sustainable technologies that address the changing careers of health professionals and increase patient satisfaction and safety. Nurses are the backbone of healthcare and have worked as leaders in change implementation, but more recently, are becoming involved in the transition of healthcare through interest in a PhD nursing degree or dual or global degree programs. (Patrício et al.2020)(Li and Carayon2021)(Naresh et al.2020)(Shamshirband et al.2021)(Anjum et al.2021)(Haleem et al.2022)(Dvir et al.2020)(Bahrini et al.2023)(Head, 2022)(Dodda et al.2024)

Although programs are being developed to provide nurses with knowledge in bioinformatics, nursing informatics, and translational science, nurses continue to lack knowledge and preparation in innovation and entrepreneurship. This paper provides a scoping

review of how interdisciplinary collaboration between nursing and engineering can benefit health care through nursing and engineering contributions. The application of health care with both nursing and engineering can ultimately contribute to the development of new and improving existing services along with technology that can be expanded and delivered over a broad range of care settings. This review also outlines the next steps to develop a program that can help nurses and engineers work collaboratively on complex health problems. Building nurse-engineering programs, or at a minimum, thinking about bringing nurse-engineer teams together to work on research projects can lead to innovative, scalable solutions that lead to broader diffusion of best practices and positive patient outcomes.

2. Background

Healthcare faces increasingly complex challenges, encompassing care that is more accessible, aligned, safer, patient-centered, sustainable, and efficient, particularly with an increasingly aging population and a diverse, multi-morbid population. To improve patient care, the need to link both engineering and nursing scientific knowledge and work together is valid, aiming at creating original solutions and integrating new technologies within healthcare delivery. To this end, nursing and engineering education should aim to provide future professionals with opportunities that maximize their critical and analytical skills, which are essential for interdisciplinary collaborations with stakeholders and partners who do not necessarily share the same academic background. However, several reports indicate that graduates from nursing and engineering lack readiness to collaborate in interdisciplinary settings. An excellent approach that a multidisciplinary curriculum should consider is the nursing-engineering connection and early inclusion at all levels of both the nursing and engineering curricula, which will improve graduates' readiness for interdisciplinary collaboration, as well as complement essential key aspects related to humanities, science, technology, policy, communication, teamwork, leadership, and self/evidence-based practices in both curricula.

2.1. Importance of Interdisciplinary Collaboration

When the ideas, solutions, methodologies, and knowledge from two or more disciplines form synergistic singular outcomes having the potential to change the paradigm, increase efficiency, and derive transdisciplinary and transformative outcomes for societal benefit, this constitutes the epitome of collaboration between nursing and engineering. The interdisciplinary nature can improve outcomes by addressing issues that have existed for a long time. There has been more of a focus on the discipline as a whole rather than the use of a confluence of the two to identify and propose optimizations of more noteworthy conclusions. There has been minimal work between nursing and engineering, especially in the domain of hospitals. Combining geriatrics, nursing, and engineering in a hospital takes this to an interaction level that calls for collective action between the disciplines to achieve common objectives. It's not easy to describe the essence of complexity, such as communication, sharing, and an exchange of information with common objectives between geriatrics, nursing, and engineering disciplines. There is a challenging paradox of growing interest in transdisciplinary research and a lack of understanding or knowledge of how nursing and engineering are comprehended in practice. The research of this study can make a considerable impact on the field of nursing and engineering, thereby improving hospital organizations' complex issues to constitute a vital, sustainable, and multidisciplinary convergence for society.

3. Methodology

The five-stage methodological framework was employed to conduct the scoping review,

and the stages included identifying the research question, identifying relevant studies, study selection, charting data, and summarizing and reporting the results.

3.1. Identifying the Research Question

The review aimed to address the question, 'How has nursing and engineering collaborated in healthcare? What is the nature, purposes, roles, processes, and outcomes of these collaborations?' The two scoping questions that flow directly from the research question were: What is known about the collaboration between nursing and engineering in healthcare? What are the gaps in the literature and areas for further research? The overall purpose behind the study was to identify and describe the range and nature of work in this area. Given the lack of any existing synthesis of the diverse and emerging research in this field, our goal was to summarize, synthesize, and disseminate findings to a wider audience in a format that succinctly explains the current state of knowledge. This could in turn be used as part of an argument to drive the wider development of a research agenda to help better understand how to encourage and facilitate more extensive and effective interdisciplinary collaboration.

3.2. Search Strategy

Google Scholar, SAGE, and CINAHL were first searched with the terms "interdisciplinary collaboration," "nursing," and "engineering." This initial broad search was performed to examine whether beyond singular research and projects, there were already some accumulated reviews, qualitative or quantitative analyses in the current phase of broader and deeper interdisciplinary collaboration between nursing and engineering. For example, "interdisciplinary and nursing and engineering," or "interdisciplinary and nursing or engineering," and "systematic review and nursing and engineering;" the intersection of conditional retrieval results of interdisciplinary collaboration research between nursing and engineering. Given that the keyword combination would potentially have no corresponding conditional search results. When "interdisciplinary," "engineering," and "nursing" were used as the keywords, relevant reviews were instantly obtained from the first round of search. Building from this search, additional keywords, expert recommendations, or suggestions from other researchers in the field for academic journals or magazine articles were used to locate relevant references. For example, the keywords "interdisciplinary and nursing," or "interdisciplinary and engineering" or "interdisciplinary," "entrepreneurial," "team," "inter-institutional," "multi-institutional," "angel," "investor," "cooperation," "strategy," "mentoring," "field," "competition," "allocation," "management," "consulting," "communication."

3.3. Inclusion and Exclusion Criteria

Participants: Registered nurses, registered psychiatric nurses, clinical nurse educators, and physicians were included based on the following rationales: Surgical Services and Recovery employed registered nurses, registered psychiatric nurses, and clinical nurse educators who were both the subjects and, in certain instances, research co-investigators. Physicians were also included as, in certain instances, research co-investigators. Concepts: Interprofessional education; nurse engineering; industry-university work-integrated learning; nursing competency; clinical reasoning; circular economy. Context: No restrictions were placed on the setting in terms of healthcare environments; however, the studies must relate to either where nurses were providing care or where they were the researchers. Research Design: All research designs were eligible, including systematic, integrative, and scoping reviews; qualitative, quantitative, and mixed methods studies; research discussion papers; research reports; and quality improvement projects. The rationale for including the research design used was that there is presently a small body of literature regarding the subject matter. Studies were restricted if the full text was unavailable in English, the methodology was strictly report, commentary, or opinion, or the gray literature was not retrieved.

4. Conceptual Frameworks in Interdisciplinary Collaboration

Interdisciplinary collaboration has been principally recognized for its role in the development and improvement of creative processes or outcomes, and therefore is described as the foundation of interdisciplinary endeavors. Previously acknowledged concepts relevant to interdisciplinary collaboration include teamwork, partnership, collaboration, and joint work, which are distinguished by their boundaries and their holistic purpose. Interdisciplinary collaboration in healthcare exhibits a twofold role. On one side, healthcare professionals, such as physicians, nurses, psychologists, physiotherapists, social workers, and pharmacists, are building chains of interaction and data exchange between different expertise in healthcare for the quality of care. On the other side, intradisciplinary collaboration among healthcare professionals in various healthcare environments is becoming one of the patient safety measures and accreditation indicators through effective communication and teamwork within the professionals. These types of collaboration between nursing and engineering were more specifically studied in interprofessional education frameworks, emphasizing the importance of fostering the interaction of undergraduate students in healthcare courses and undergraduate students in engineering courses, which will help analyze the possibilities, conditions, and potential enhancements of current educational models towards better implementation of collaborations. Despite the myriad discussions on the categorization of collaborative models, their underlying principles, and the role of these interactions in the development and maintenance of holistic human living, there is a significant absence of literature on the challenges and future trends between these two specific groups. This recognition further fueled us to perform a thorough examination in the form of a scoping review.

4.1. Systems Theory

System theory is not new; in fact, it is the basis for much of our scientific knowledge. However, the integration of theory into everyday healthcare practice in order to solve complex human problems is often not the norm. The solution for complex problems often lies within the complex interactions among interdisciplinary team members. Healthcare professionals, including nurses, find themselves facing ever greater complexity of problems every day. Nurses view the individual as a dynamic system and as part of many open systems including family, community, and society. Systems interact, and linearity is seldom found when complex human interactions are involved. All individuals who work within healthcare systems must carefully assess both the positive and negative impacts of potential solutions and act in a manner consistent with that assessment. The understanding of the science underlying the effective application of these interventions results in a multiplication, rather than just an addition, of the efficacy.

For all nurses, engineering system theory applications were abundant in the literature. This was not surprising since healthcare is an engineered system, but while many contributions came from the field of ergonomics, making room for this type of representation was hard to come by. For resource allocations and the ability to demand solutions, this limiting mindset also sets the climate for healthcare policymaking that embraces technological interventions. Those who work in this discipline concentrate their efforts on ensuring the natural fit. The work of an engineering team can also be enhanced when it is an integral part of the larger problem-solving team featured in holistic patient care research. If the interdisciplinary approach to solving healthcare problems is one in which all problems are considered in the final selection, we will move one step closer to the goal of holistic patient care science.

4.2. Complexity Theory

Complexity theory is often implied when healthcare settings are discussed in the context of the intersection of nursing and engineering, sharing several concepts. It provides

interdisciplinary researchers with an epistemological and ontological framework to address the issue of their multidisciplinary efforts while handling the complexities of healthcare challenges. Complexity theory consists of rudiments such as complex adaptive systems, emergence, periods of stabilization, criticality, self-organization, fractals, and scaling laws, each allowing for multiple theories to engage in their unique way, yet complementing one another in a unified research project within a complex system. The circumstances of working with a complex system include manipulation difficulties associated with the changes within a system. Other kinds of challenges also stem from working with complex adaptive systems, including self-organization, emergent structures with new functions, and nonlinearity.

The relationships of nursing services and any unit that can be considered a system can be fully or partially applied to complexity theory. Complexity theory can be applied to different contexts such as complex system policymaking, as well as the complex adaptive systems of facility layouts and space. As nursing researchers try to address wicked problems of systems, which demand interventional representation, methods from complexity theory can be employed. For instance, complex adaptive systems and insights into counterintuitive system behaviors can be used for systems representation and data acquisition for fixing the healthcare system. Then come the results, and research may be more effective when viewed as emergent.

5. Applications of Engineering in Nursing

There are abundant examples of the application of engineering principles in nursing practice, although many of these applications are nascent and in need of further development and evaluation. For example, monitoring vitals has long been performed in nursing practice, but the use of wireless devices to perform this monitoring, in close to real-time, and often in the home or other non-clinical settings, has grown massively in recent years. These wireless health technologies can be used to monitor a patient in their normal setting to get a more accurate clinical picture and can be used to trigger automatic alarms and tasks based on an abnormal vital sign. The healthcare system can also obtain these recorded medical data that would have often been missed or found several hours later in traditional forms of monitoring. It can use this data to both support the physicians and nurses in performing their duties better and to backfill and fill in gaps in the electronic health records by delivering previously absent data.

Another engineering-based application in nursing practice is virtual reality for nursing education. Virtual reality is increasingly used in the education of healthcare professionals in disciplines, including but not limited to nursing. For nursing, the use of virtual reality for the alignment of clinical and classroom learning activities is of particular utility. Nursing students have typically not had the opportunity to learn in realistic practice situations; virtual reality in such instances can give students experience in low-frequency, high-stakes patient conditions. Agile software development has been used to make tools to support healthcare settings. If applied to support the design and building of nurse supports, it has the potential to be beneficial for both patients and nurses. A collaborative, nurse-led global platform with the mission of supporting nurses to design, drive, and purchase healthcare innovation that delivers positive impacts to patients, nurses, and the wider healthcare system brings the diverse nursing community together with patient groups, support groups, design experts, and companies with proven track records in delivering healthcare technology solutions.

5.1. Medical Devices and Technology

Many studies reported on devices created by engineers for use in healthcare settings. The design and development of innovative technology and medical devices for clinical use in nursing continue to be a priority. Engineering professional positions within hospitals support the selection, upgrade, and use of technology and medical equipment that facilitate clinical practice from a nursing professional perspective. The formation of organizations has been to

promote the safety and efficacy of medical devices through the use of practical international standards. At some universities, they not only offer an undergraduate engineering degree but are also developing health systems engineering programs, focusing not only on technology but also on engineering solutions for disease detection and healthcare structures. Today, healthcare professionals have great opportunities thanks to proposals merged from nursing and data analytics to detect patient deterioration or innovative proposals for nurse-driven mobilization to prevent excessive patient bed rest aimed at reducing the incidence of ventilator-associated pneumonia. Other examples include nurse-driven sexual assault forensic interviews, rapid infrared thermographic imaging for breast cancer assessment, improving intrahospital transport, and nurse-led primary health care. These proposals are viable examples of the integration of one or more disciplines, revealing that nursing is more nationally recognized.

The guidelines for international student nurses making drones for patient care tasks were created through collaboration between nursing and engineering. Team meetings were fundamental in this study, during which each professional presented their suggestions for the resolution of the proposed activity, aiming to align the suggestions of the two disciplines so that the developed guidelines would be effective in the daily routine of the nurse and patient. In order to obtain greater results, it is recommended that the guiding professional (nurse) understands which technological tools are available and collaborates in the prospection of the market to guarantee the best conditions when stipulating. Some limitations reported by students are the difficulty in using drones according to the guidelines. Unmanned aircraft require space, which can be difficult to find in some health settings, even when the patient is isolated. The use of drones for the transportation of drugs to mental health inpatients may be a solution, as the transport of controlled drugs depends on legal procedures and the patient isolation rules will already be guaranteed.

6. Applications of Nursing in Engineering

Making engineering students aware of the complexity of healthcare is important. This dialogue is usually centered on technological artifacts and uses of technology, such as surgical instrumentation. However, revealing the range of clinical settings, nursing roles, and technology uses can gain transferable knowledge about current health issues, stimulating students' desire to develop assistive technologies. To understand this work, including clinical activities, it is beneficial to make use of the synergy of both a health professional and an engineer's specialty in product development. Knowledge and reflexivity roles originate from three existing elements: health structure, profession, and occupational practices. Particularly regarding nurses and engineering students, both are two keywords linked to the health work field and the concerned nurses' expertise. The interaction of both professionals in project development enables a multidisciplinary learning process and promotes a better quality level for the technology produced.

An understanding of the complexity of healthcare is necessary for more nursing course students to be attracted to innovation-related activities. Thus, it is necessary to show that there are many other environments that require these profiles to achieve other health objectives. These involve developing teaching methodologies with societal impact elements, stimulating initial student exposure during higher education, and creating associations with multidisciplinary institutions and research and development departments. Technology creation and innovation courses aim to develop students' skills through collaboration with other areas, which are modern views of pedagogical practices that connect learning with ongoing and real-life experiences. An innovative nursing curriculum must involve teamwork in a multidisciplinary space, favoring proactivity and the solution of real problems, in addition to providing a first contact with the main physio-educational projects. This collaboration helps to expose a single technology area, encourages discipline learning, and ensures the linkage of

nursing with technology.

6.1. Human Factors Engineering

Human Factors Engineering is a field that applies knowledge about human characteristics to the design of equipment, devices, systems, and environments in order to optimize human well-being and overall system performance. The healthcare system has witnessed recent developments in both treatments and new medical technologies, leading to concerns that the growing specialization in medicine has also resulted in an increase in avoidable errors. Nursing has always looked out for patients as a whole, but today that is an increasingly complex task, especially with the fast-expanding range and complexity of technological interventions. We found only a small number of research papers at the intersection of nursing and human factors engineering, most of them not touching upon the technical part.

The papers found are very specific: (1) a paper focusing on the implications of nurse staffing and work environment on patient mortality; (2) a paper about hand injection pain due to needle length, delivery technique, and medication; (3) a study of the nurse-discarded syringe needle angle; and (4) a study of needle failure with different blood withdrawal techniques. The technology development trends, such as that in the case of point-of-care devices, can also be considered from the perspective of the empathy of nursing. Designing new systems and equipment targeted specifically at empathy is a possible future research path.

7. Benefits and Challenges of Interdisciplinary Collaboration

The benefits of interdisciplinary collaboration were often implied. The outcomes of the collaboration, including the development of hospital noise reduction devices and technology research and development outcomes, commercialization opportunities, and contributions to scientific knowledge, were referred to. The success of their collaboration was attributed to their interdisciplinary approach. They acknowledged that collaboration was required and that a cross-fertilization of ideas, knowledge, values, and ethics had the most potential to create innovation. The synthesis of engineering analysis and nursing judgment could foresee or even prevent possible adverse events more effectively than either method alone. A positive team collaboration was perceived to be possible on their interdisciplinary project through effective communication.

Researchers, clinical nursing, and patients were identified as important users of developed technology or intervention. User involvement reduces the risk of technology acceptance by the users' intersection. The objective was to develop the best technology for the intended use, independence, and care of end users. Stakeholders' viewpoints from both a healthcare provider and an engineering perspective were considered during the various design stages. A main rationale for their tailored approach was the need for interdisciplinary collaboration. An iterative user-driven and transdisciplinary design thinking process in partnership with experienced companies and supported by a healthcare-oriented living lab environment was explored. Healthcare providers and engineers were key formal stakeholders in the design of washable wearables. The participation of stakeholders and citizens through co-creative design and manufacturing innovation was addressed in a different innovation dimension. Data suggest that community and public health nurses in this study innovate through tech-savvy informatics support.

7.1. Improved Patient Outcomes

While there are few studies pointing to or measuring patient outcomes from an interdisciplinary collaboration between nursing and engineering, there is still much evidence for broader patient-centered outcomes when the two disciplines collaborate. However, there is

increasing recognition that patient involvement includes many aspects beyond the direct clinical need both prior to and after an inpatient stay, hence the importance of collaboration using a socio-technical perspective. With an increasing number of knowledge user partners, several projects have involved diverse stakeholder groups generating a multitude of user-friendly outputs suited for various purposes and uses post-project completion. Some reports indicate marked improvements in patient care and technician productivity resulting from enhanced device reliability as a direct result of the collaboration between nursing, engineering, and industry on specific projects, while other reports solely claim that by working together we will discover hitherto unknown solutions to disparate problems.

However, a collaboration between nursing and engineering is not sufficient in itself to improve health outcomes. Instead, emphasis needs to be placed on the broader socio-technical systems view in achieving better quality interactions for health-enhancing change. Moreover, a collaboration with a focus on the needs of healthcare practice has the potential to reduce costs and improve patient outcomes. For example, research using technology developed in collaboration between the two disciplines has the potential to simplify traditional clinical processes, making them more efficient and easier to accomplish. Furthermore, the use of such technology has shown modest confidence in the beneficial effects on patient care and patient outcomes. This research uses expert perspectives to indicate important dimensions of collaboration, which others can use to develop this area and thus advance healthcare practice. Data generated by research projects underpinning these dimensions could add to the volume of evidence that should ultimately become empirical and include the perspective of the patients themselves.

7.2. Communication and Language Barriers

Whether they are collaborating with nursing professionals or engineers, all health care professionals, language terms and labels are critical to project success. Additionally, as engineering's work-related vocabulary is more familiar than nursing's vocabulary in project relationships, nursing's sense of disempowerment is expanded and nurses are not heard. Both professions would benefit from topic-only 'insensitivity training' based on using, interpreting, and translating picture language. This familiarity would eliminate some of the barriers between the fields that seem to occur in joint ventures.

One effort to help nursing students communicate effectively when involved in interdisciplinary collaboration projects has been the adaptation of a cross-disciplinary model for nursing education. The model provides support for nursing students working on projects with other disciplines, especially when students have little technical knowledge. While there is no known corresponding approach to educate all engineering students, particularly in the cues nursing students use that may silence and disenfranchise them, sensitivity education would help improve the project experience for both genders. However, while an adaptation such as this is important, it is imperative for work-related culture students to be educated early in their university careers. By incorporating minors and requirements into the general education portion of the university experience, a cross-disciplinary culture will be established early in the students' overall undergraduate experiences.

8. Case Studies

Three publications were identified as case studies of interdisciplinary collaboration between nursing and engineering in the healthcare field. The earliest paper described an intensive collaboration between master's students of Electrical Engineering and Medicine in the development of a multimodal interface to improve the nursing task of recognizing elderly patients' perception of the quality of services and healthcare evaluation. The second paper proposed a socio-technical paradigm designed to bring together health professionals and

engineers in a series of workshops or within a common project. They described a project that brought together two nursing schools and a series of companies to discuss the management of new requirements and the development of new interdisciplinary curricula in Biomedical Engineering and Health Management. These case studies highlight the importance of building bridges between health and engineering in order to contribute to healthcare improvements.

The third study set out to explore the role of nurse academics in the development of a computerized learning and information system for academic and clinical settings. The paper was based on a single case study, that of LearningLink, which brings together elements of computer-based learning and an information portal. The study reported that nurse academics who were involved in a knowledge production role within the collaborative project considered that it had advanced the initial understanding, which was in part shared with the engineering partner. However, issues for the nursing academic related to the nature of the publication of nursing knowledge and where information related to a project should be located were raised. Data indicated that the involvement of nurse academics through exchanging, sharing, and contributing their insights assisted the development and processes of others engaged in this collaborative process.

9. Future Directions

Design and development of technologies applicable to special patient groups suffers from a lack of established standards for these technologies; e.g., the differences in clinical conditions between acute care patients and those chronically living in their home environment. It is therefore recommended to build on knowledge that was previously obtained. Following knowledge translation principles, knowledge transfer groups have to be multidisciplinary, raising further the need for dual degree programs for developers of assistive technologies. User involvement has to take place at the start of a project and can be spread over the life of the project, with a special focus on users for whom the technology is planned. This can be achieved by working in a user-centered way, following the well-accepted principles of user-centered design. The main balancing challenge is the difference in speed of working of the clinicians and the developers and the extent to which fast starvation solutions can be developed for specific clinical technologies. Ethical aspects need to be respected from the start of a project, performing thorough ethical and data protection impact evaluations, and considering the difficulties of having older co-designers.

Different autonomous care and robotics technologies can and should complement existing healthcare and assistive care services. Data integration models will be essential to strengthen the link between end-users and support services for the healthcare and assistive technology supply chain world and service delivery. The automated systems for hyperacute, acute, rehab, or long-term care will reconsider service models, capabilities within hospital settings, and in homes and dependence units. Such efforts aim to effectively support current and future demands for aging population needs by moving from now-limiting infrastructure and helping economies of scale, seamlessly delivering heterogeneous assistive technologies for AI and coupling physical, cognitive, and emotional care paradigms.

10. Conclusion

In conclusion, although collaborative initiatives between engineering and healthcare practitioners highlight a global trend, our scoping review results revealed that collaborative activities between the nursing and engineering disciplines are still in their early stages of development. Factors promoting IPEC for nursing and engineering can be seen from the objectives of the identified studies, such as finding solutions to the major problem, improving health outcomes for patients, and lastly, contributing new knowledge to improve the well-being

of individuals. For the IPEC to be more comprehensive, it must involve both students and faculty from both disciplines. Changes in curriculum templates that encourage certain thematic areas to be included in the new profession are needed. To further converge both disciplines and enhance each other's understanding, learning partnerships between staff and interdisciplinary students are necessary to create a culture of cooperation between nursing and engineering.

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