

# The Essence and Role of Nurses in the Future of Biomedical and Health Informatics

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**Abstract.** The whole healthcare system is evolving fast due to environmental pressure related to pandemics, climate change, personnel shortages, and financial limitations, to name but a few. Nurses are central actors in the sustainability of healthcare systems. Rapid technological development can support innovative means for holistic and applied critical thinking to improve healthcare delivery based on the uniqueness of nursing. Nurses need to develop adaptive and scientific skills regarding technologies and develop and apply these for better use of “smart” systems in care delivery. The paradigm shift in nursing roles will impact all levels of care, from primary to specialized care, all age groups, from newborn to elderly care, as well as all domains, such as preventive, reparative, rehabilitation, and palliative care. The impact of technologies on human behavior addresses human-factors interaction, computer interaction, and other effects of technologies on wellbeing, including but not limited to robots and artificial intelligence -based assisting nursing deliveries. Nursing competencies need to be developed at all levels of education to prepare a mindset and culture of the healthcare workforce in a digital health system. Gamification and simulation as educational tools help prepare educators to educate healthcare clinicians and researchers who become key mediators between technologies and practice.

**Keywords.** Digitalization, Healthcare, Nursing, Education, Skills, Artificial Intelligence, Robots, Information Technology

## 1. Introduction

The health and care needs of populations are evolving. The increase of noncommunicable diseases in aging populations, as well as communicable diseases in general, and a lack of universal health coverage is a major global concern for healthcare systems [1]. The nurses are the closest health professionals to the population and the patients. Hence, their work is not only crucial to all health systems but also provides an opportunity for effective interventions on a large scale. The Covid-19 pandemic has shown the fragility of health systems and amplified the need for nursing. However, new means are needed to help nurses suffice and extend the impact of nursing. Digitalization provides an opportunity to harness data to better support care delivery across settings. The precision

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of data used is crucial in providing more accurate care for each health condition. Nurses contribute to generating precise and reusable data. But they need the competence to produce, validate and retrieve the data and aggregate it for relevant and interpretable meaning, allowing the best care for each health problem and bundles of health problems for patients individually. Augmented technology is needed with the increasing shortage of health professionals and the care environment, which is becoming increasingly complex. The term augmented technology refers to getting the right health-related information at the right time with the help of information technology (IT) in general.

## **2. Nursing Reengineering**

The information society and digitalization have enabled increased access to knowledge on health-related issues and care. Concurrently, the possibilities to improve population health literacy are growing and seen as an essential factor in empowering people [2]. Health literacy may be defined as “the achievement of a level of knowledge, personal skills, and confidence to take action to improve personal and community health by changing personal lifestyles and living conditions.” [3]. It has been interpreted as “the degree to which individuals can obtain, process, and understand the basic health information and services they need to make appropriate health decisions [4]. This definition may also be extended to the context of technology through digital health literacy [5].

Recently, a distinction between personal and organizational health literacy has been made, where the organizational health literacy focuses on how organizations equitably enable individuals to find, understand, and use information and services to inform health-related decisions and activities [6]. Increasing professionals’ and individuals’ health literacy and implementing advanced technologies in healthcare to better support individuals, professionals, and organizations transform the field of healthcare and nursing. Individuals become better empowered to monitor, sustain, and improve their own and their families’ health [7], while nursing will respond to more complicated and demanding needs. This transformation of nursing practice will better respond to the increasing needs of aging populations with challenges to recruiting and sustaining a sufficient and competent workforce on a global scale.

Adopting any technology in the health sector can only be done in collaboration with numerous specialists from the fields of health and technologies [8]. The level of collaboration may, however, differ. It may be described as multi-, inter-, or transdisciplinary collaboration. These three levels concern the varying degree of participation of specialists from different disciplines. “Multidisciplinarity draws on knowledge from different disciplines but stays within their boundaries. Interdisciplinarity analyzes, synthesizes, and harmonizes links between disciplines into a coordinated and coherent whole. Transdisciplinarity integrates the natural, social, and health sciences in a humanities context and transcends their traditional boundaries.” [9]. Learning to collaborate between disciplines is challenging, and it takes years to understand each other’s fields, terminology, and ways of working. These all are prerequisites for smooth and efficient collaboration. Although a transdisciplinary approach may not be needed in all technological adoptions in healthcare, a multidisciplinary approach may often not suffice [10].

Guidance on the appropriateness and relevance of technologies in health and healthcare is needed on content, use, and functionality aspects [11]. Nurses have an

important role in this work for improving health outcomes and reducing disparities [12]. Appropriate technological health development will require nurses' active involvement, as understanding the end user perspective is key in succeeding with developing and implementing technologies that support individuals' health, care processes, and service outcomes. On the organizational level, essential elements for successful technology adoption include an evidence-based approach, where competencies, infrastructure, and leadership meet to support the technology implementation needs. This can be boosted by designated roles placed on all hierarchical levels with responsibilities and authority to develop strategic goals and action plans for execution [13]. Developing practical implementation processes and attitudes to support the vision are also needed [14]. Leaders will benefit from easily available validated tools that help assess organizational readiness and attitudes towards technology. Research has shown that nurses' involvement in technological development and adoption is still scarce [15][16]. Hence, new means for enabling nurses to be better involved in these processes are needed. But also, interventions to support the development of an organizational culture of positive attitudes towards biomedical science and informatics as well as systematic development of sufficient competence to adopt new related technologies for different actors.

### 3. Biomedical Science and Health Informatics

#### 3.1. Nursing meets biomedical science and informatics

In a moving environment (migration, climate change) with biomedical science reaching a level of complexity never reached before, nursing is also facing a worldwide shortage of personnel stapled by leakage of personnel with a consequent risk, the loss of expertise. Nursing encounters with information technology represents both an opportunity and a risk. To overcome the risk, integrating new information technologies into practice must be considered a support for practice improvements, not as a replacement for professionals. The goal should not be to save money but to support the scope of practice and to improve quality (security, efficiency, equity) [17][18]. It would be tempting in a period of global shortage of healthcare personnel to act this way.

In the World Health Organization (WHO) report; *State of the world's nursing 2020*[19], the chronic shortage<sup>2</sup> [20] of nurses is described as a worldwide problem of a global shortage of health workers. We can hypothesize that the impact of shortage will be exacerbated by the loss of professional expertise due to the premature departure of nurses because of the exhaustion of professionals due to the increasing caregiver burden [21], worsened by absenteeism and the retirement of the baby boomer. This health policy problem might become a vicious circle for employers. Many solutions are already proposed by most of the national nursing associations. By WHO's *Global strategic directions for nursing and midwifery 2021-2025*, researchers [22][23][24] reduce the burden on the nurses. Education, leadership, organization, etc., are the most common topics. The use of technology is rarely proposed as a means of improvement.

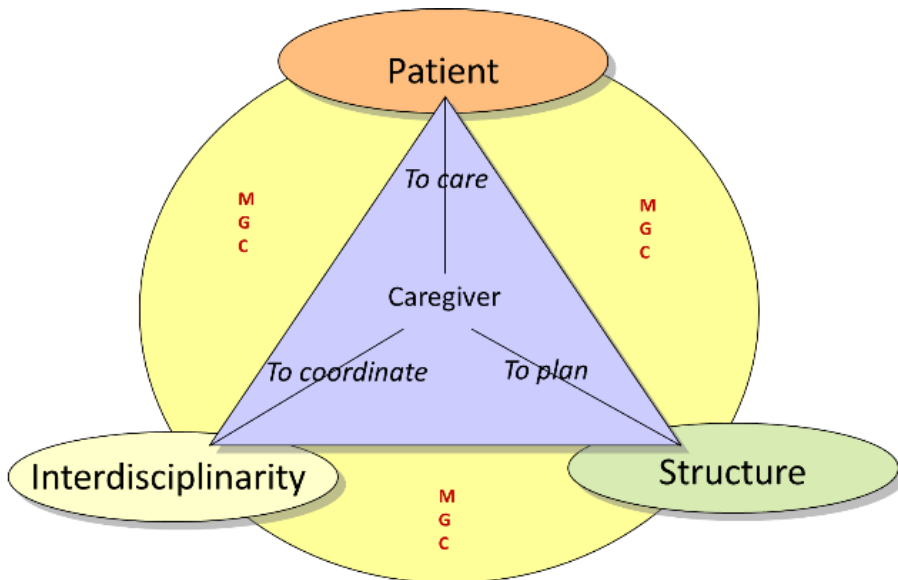
Aware of the complexity of the problem, especially after a health crisis like COVID-19, information technology is a new block that could be explored. To solve complex situations, the first step is to model reality [25][26]. In this paragraph, we shall conceptualize nursing in its complexity; this step is unavoidable before meeting

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<sup>2</sup> <https://www.who.int/news-room/fact-sheets/detail/nursing-and-midwifery>

biomedical sciences and informatics. To simplify the demonstration, let's describe the essence of nursing as a professional activity through three dimensions:

1. Caring, the core of nursing [27], it contains all the activities directly dedicated to the patient, family, or close helper. This means, for example, evaluation, surveillance, diagnosing, treating, teaching, supporting, etc., independently from any nursing theory.
2. In any type of setting, in particular hospitals, time is risk management, quality of life, and money. To reach the organizational goals, nurses play a central role in making things happen in time with the right patient and professional at the right place. This dimension has a practical application, multiple flow management.
3. Coordinating in an inter-professional environment, physicians, physiotherapists, occupational therapists, radiologists, etc., bring a specific point of view. With their presence 24/7, nurses are responsible for facilitating communication between professionals and patients.



**Figure 1:** Model of care Alain Junger 2010 (Management Governance Communication - MGC)

This model was built empirically before introducing an electronic health record (EHR) in the University hospital in Lausanne and was confirmed by a study on how nurses spend their time at work [28]. We must consider the meeting between nursing, biomedicine, and information sciences broader than this title. To reinforce nursing as a production of care, we need to take into account the two other dimensions. The use of information technologies as solutions should:

- Free the nurses from most time-consuming activities that are not clinical focused.
- Eliminate the mental burden of administrative, coding, organizational activities, and rules.
- Improved patient flow management, the logistic flows, and the communication as information flow of data.

- To care, coordinate and plan other dimensions of nursing play a central role.
- Safety as the goal of risk management. Prevention is multidimensional because every activity in the health care environment generates risks.
- Simultaneity, nurses face simultaneity of events constantly. When a nurse achieves care, she is also watching the patient, his monitor, answering questions, etc. When a particular activity is organized, it simultaneously requests the right patient, equipment, etc. Another example is taken from clinical practice. During a stay, a care project can combine different objectives, solve a problem, prevent risks, reinforce rehabilitation resources, and maybe accompany the patient with a chronic deficit.
- The simultaneity is also at the organization level. Many healthcare professionals are supposed to pay attention to the same patient.
- Continuity, during the hospital stay, any transfer, all along the clinical pathway, between shifts.
- Predictive and prospective are concepts thus far underestimated in nursing. The likelihood of clinical response after care or treatment is never 100%.
- The nurses themselves mostly provide interoperability. Manual entries are necessary for the use of medical equipment or the recording of results. Fortunately, the first solutions are available to connect tools to EHRs, this is far from a general reality and requires local adaptations to overcome the lack of standardization.
- Interdisciplinary / inter-professional / patient partnership. The multiplicity of actors all along a clinical pathway requires communication and coordination. This supposes standardized languages and procedures.
- The progress of biomedical sciences and technologies is changing the needs. The improvements create new opportunities, risk and benefits. Hospital accommodation becomes secondary to outpatient medicine. Genomics is changing the relationship to disease. The place of health promotion and patient involvement in managing their health is becoming more prominent.

### *3.2. Biomedical science and informatics meet nursing*

Biomedical science can be applied to the nursing process, including assessment, nursing diagnosis, planning, intervention, and evaluation. It supports evaluating a person's health status and allows the development of knowledge, interventions, and technology in healthcare and public health [29]. Using informatics allows nurses to access all available data to support the process. The physio-pathological aspects resulting in the data analyses drive part of the nursing process to help the patient manage or recover. The sociocultural aspects and the environment are also to be considered in the nursing process.

Genomics, the analysis of an individual's gene, is participating in precision health, helping nursing sustain and enhance evidence-based practice. When nurses implement precision health, it provides holistic and systemic care, including relatives and communities [30]. Biomedical science opens the analyses of the biomarkers to be explored with informatics tools. Biomarkers exploit the omics data issued from genes, proteins, and metabolism. The informatics tools should present the data in an understandable display giving a decision tool to the nurses where the nurses' expertise and judgment will finalize the analyses for a decision. Precision nursing based on

selected biomarkers helps educate the patient and the families in how they take care of their health and, for example, on the modern medication aspects.[31].

With the aging population, multidimensional disabilities and diseases are increasing. Home care is becoming more expanded and complex. With the help of well-defined biomarkers, biomedical science will help prevent illness and treat individuals at home. Systematic evaluation of the living and environmental conditions determines what type of care should be provided by whom.[32].

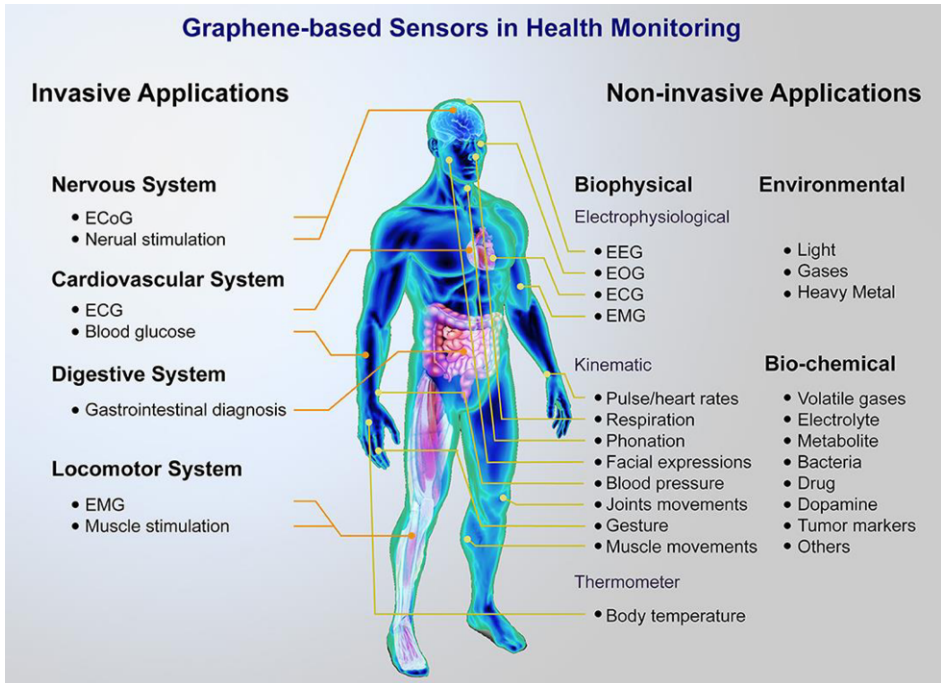
Biosensors are part of the exponential development of data storage, microchips, and wireless capacities. Many different biological variables can be registered and transmitted instantly. The condition of having appropriate well-designed software in collecting and aggregating data biosensors will improve efficiency and effectiveness to secure patient health and reduce costs. Patients will take advantage of empowerment for self-care and health prevention. The living environment is changing with the adoption of multiple sensors in daily life. An intelligent home uses many sensors and facilitates life, especially for older people. It increases the safety and security of monitoring the activity of the elderly. Patients with chronic conditions, such as those suffering from diabetes, benefit from the sensor developments.[33]. However, up to now, the data collected with sensors are not consistent with the Findable Accessible Interoperable Reusable principles (FAIR) [34]. To be FAIR the data stored must comply with common international standards.

Covid-19 boosted the development of distance consulting and tools for detection of the infections. One example is a Covid-19 detection system developed to analyze exhaled breath. Artificial intelligence and biomarkers facilitate the creation of this electronic nose in the analysis of the breath. The result is a low-cost, non-invasive, and portable system.[35].

Biosensors and online consultation reduce the cost of care, not only in rich regions but also in the middle- and low-income regions. The use of teleconsultation, together with online sensors is a key element for prevention and cost contained healthcare [36].

Nanotechnology allows many targeted body parts or cells to be reached, evaluated, and treated. Nurses have a role to play in knowing how it works and how the effects should be measured. Nurses' observations are important to be reported and used to ameliorate nanotechnology development.[37].

In the future, with the help of technology, part of the prevention should be driven through the Internet of Things (IoT), specialized applications on computers or smartphones, or implanted chips or other formats not yet known. The part of implanted chips is now just experimental, but this will surely be a major provider of health information in the future. The challenges are to collect the data inside the body and share the data outside of the body. Antennas of implantable devices are a key element for sharing data outside the body. Many obstacles should be solved [38]. The other main difficulty is the duration of the battery. Currently, research on how to charge the battery with body activities is done. New implantable devices are battery-free. There is functioning based on electricity produced by the body itself.[39]. As such, wearable devices are becoming more performant, collecting many health-related data and new technologies facilitate rapid access to data collected.[38].



**Figure 2.** Brief of graphene-based sensor platform for health monitoring. A major distinction can be made between non-invasive and invasive applications, including wearable sensors for monitoring biophysical, biochemical, environment signals, and implantable devices for nervous, cardiovascular, digestive, locomotor system [38].

#### 4. Virtuous circle of evidence-based nursing: from knowledge to practice

From a front bedside perspective [40], the development of the information sciences [41] combined with the progress of biomedical science are challenges for the future of nursing. Both will change the content of nursing and reinforce this role. Uncertainty is a growing characteristic in nursing practice as a cause of chaos and complexity. This is due as much to the evolution of the patient's multi-morbidity, the shortening of hospital stays, and the continuous evolution of technology as the multiplicity of human factors (culture, generation, poor health literacy, anthropology, etc.).

The early years of nursing informatics were influenced by medical informatics in a vision that was very much focused on the digitalization of paper documentation. The next step must answer the needs of the nursing professionals described in the previous paragraphs are very diverse to meet the functions of caring (evaluation, diagnosing, education, risk, crisis management, treating, prevention, etc.), coordination in a multi-professional environment, and planning.

Lifelong, each person will have episodes [42] in different structures. Each person will follow a clinical trajectory paced by episodes of care. These are determined by health problems, medical and surgical treatments, but also disabilities and dependencies from birth to death, and organized long clinical pathways.

To conceptualize a nursing information model as a part of a clinical information model, its essential to apply the concepts and models of information science to nursing science [43][44]. To remodel the nursing concepts [45][9], it becomes necessary to consider them as information or a set of data. From such a perspective, the paradigm is shifting. It is inevitable that a care model, in the data age, allows an integration of continuity, simultaneity, and interoperability centered on the patient. It becomes necessary to have an epistemological thought that describes how nursing science proposes an ontology that:

- Integrates sciences such as social science, biomedical science, management science, etc.
- Considers concepts, and their semantics through reference terminologies (ICNP, SNOMED, NANDA, LOINC, ICD, ICF, etc.)<sup>3</sup> and standards (ISO).
- Integrates the other professionals in a patient-centered multi-professional collaboration [46] also at a data and language level.

On such base, it is possible to imagine the development of artificial intelligence applied to nursing as their clinical dimension. Artificial intelligence or decision support tools must be expanded for all organizational, administrative, and planning activities. Most of these algorithms exist in other industrial fields but must be adapted. Even if this need is not a clinical priority, it becomes a priority to free nurses from many non-value-added, time-consuming activities that contribute to the loss of meaning in work.

## 5. Healthy populations with a focus on prevention

The key element of maintaining a healthy population is the collaborative activity of working on prevention instead of waiting for a disease declaration. Population health may be seen as a consequence of the health of a group of people, including patterns of health factors and outcomes, as well as policies and actions done to support a healthy population. The approach applies to individual, practice, organizational, and community levels [47]. Around the world and the communities' access to preventive action are very different, from no preventive action to high engagement in the prevention. Caring models also differ when including prevention in their concepts. Unfortunately, the quality of the prevention action is related to financing. The value of prevention could be statistically evaluated but seldom acknowledged in healthcare budgets. When a society bases the budget on the cost of treatment, including many actors for the payment, prevention is not put in place because the benefits will probably not be of value to the payer. Only a closed group of the population, healthcare professionals, and infrastructures can base caring on prevention and measure the health and financial benefits [48].

In prevention, the concept of early detection of a complication is crucial and could save lives [49]. Nursing narrative and nursing documentation could be used to predict adverse events in hospitalization and care. With the help of machine learning system analyzing structured nursing documentation together with non-structured documents analyzed with natural language processing systems and multimodal methods, researchers and technology developers are building alerts for better identification of adverse event

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<sup>3</sup> ICNP International Classification of Nursing Practice, SNOMED Systematized Nomenclature in Medicine, NANDA North American Nursing Diagnosis Association, LOINC Logical Observation Identifiers Names & Codes; ICD International Classification of Diseases, ICF International Classification of Functioning, ISO International Organization for Standardization.



risks [50]. In nursing documentation, if the structured data is well defined (description and scope) and used properly, it shows an efficient and holistic picture of the patient's situation and measures risks for impairment. The human-computer trust and nursing care expertise facilitate the acceptance of systems capable of analyzing data for patient evaluation.

Recently sustainability perspectives have gained more and more recognition within the healthcare sector, targeting different approaches from effectiveness, efficiency, economic and environmental perspectives [51]. In line with this the WHO is pushing for universal health coverage, which is built on strong, individual-centered primary health care where everyone has access to all necessary health [52]. However, discussions and action regarding the role and responsibility of the healthcare sector in environmental pollution and sustainability have thus far been insufficient, and these issues need now to be better acknowledged [39]. Environmental sustainability may be defined as "meeting the resource and services needs of current and future generations without compromising the health of the ecosystems that provide them and more specifically, as a condition of balance, resilience, and interconnectedness that allows human society to satisfy its needs while neither exceeding the capacity of its supporting ecosystems to continue to regenerate the services necessary to meet those needs nor by our actions diminishing biological diversity" [53]. When developing and adopting technologies into the healthcare setting, minimizing environmental harm needs to become a priority. Environmental sustainability thinking needs to be embedded in organizational education and practice throughout systems. However, environmental sustainability aspects become complicated to evaluate due to system effects. Regulatory authorities' actions to steer the development of a sustainable healthcare system is necessary for effective and sufficient outcomes.

## 6. Discussion

### 6.1. *Biomedical and health informatics applications to respond to nurses' shortages*

Nurses' shortage is a reality today and will increase in the future. According to WHO key facts 15.03.2022, "there is a global shortage of health workers, particularly nurses and midwives, who represent more than 50% of the current shortage in health workers". "Nurses play a critical role in health promotion, disease prevention and delivering primary and community care. They provide care in emergency settings and will be key to the achievement of universal health coverage" [54]. Countries are promoting health-related professions to attract more people to embrace this profession. To reach the WHO universal health coverage, the need for nursing services will increase. To respond to the increasing needs and consider the workforce shortages, new nursing care approaches should be adopted.

The collection of nursing activities data allows allocating the best person with the best competence to fulfill the patient's needs. Analyzing the data gives the opportunity to select what skills are needed to respond to the patient's needs. Once the skills are evaluated, the best professional to respond to the patient needs is called grade mix. Therefore, skill and grade mix is a way to dedicate the best competence to respond to patient needs based on the data collected. Competencies are not always fulfilled by a healthcare professional. A machine could also fulfill it. Robots, chatbots, or intelligent object of things can cover competencies to inform and or collect data from the patient.

Collection of basic patient assessment could be done by a robot or a chatbot. The health professional will, with her his expertise, analyze the data and finish the anamneses with the contact of the patient and or the family. The Internet of Things is the development of tools to help follow patients' health situations. IoT could fulfill all actions, not needing interpretation.

Artificial Intelligence will be used in many computer applications. The capacity of the AI to retrieve the most accurate information for the patient will play a key role in helping the nurses to respond to patient needs in terms of quality of care, safety, and ethical considerations. Nurses will play an active role in developing AI applications [55].

Hospital-at-home model developed in South Africa increases the access of care for poor people in rural once and for elderly persons. "Recent research shows that the hospital-at-home model is an effective strategy and can reduce costs on average by 42%, mortality by 20%, and re-admission rates by 6%, while improving outcomes and the patient experience" [36].

## *6.2. Informatics competence necessary in future nursing environments*

Ample research and different frameworks on informatics competencies for health professionals and leaders exist [56][57][58][59]. In nursing, these have mainly focused on knowledge, skills, and attitudes targeted at nursing students, entry-level nurses, general nurses, nurses in a specific role, and core competencies from an international perspective [60]. Recommendations for informatics teaching in nursing benefit curriculum development [61], and international networks aid in knowledge dissemination globally [13]. However, keeping up-to-date with the rapid development of technologies and the constantly changing healthcare environment is challenging. Hence, competence requirements regarding biomedical and health informatics from a nursing perspective will continue to evolve as nursing and healthcare transform, and digital health literacy becomes one key issue in service delivery.

Prior forecasts have, for example, highlighted future needs regarding informatics competence that targets omics [62], big data, and analytics [63]. However, as nursing is an action of collaborative care that involves individuals, families, and communities in all settings, more efforts are needed to clarify future competency needs regarding technological development and implementation of different actors, including the patients, their families, and professionals on different levels, in different settings and in different roles, as well as to find methods to develop the collaboration between these actors. Tailored instruments for measuring the development of competencies help guide continuous curriculum development for up-to-date education on undergraduate, graduate, and postgraduate levels as well as professional development are also needed.

## **7. Conclusions**

Healthcare professionals will benefit from the development and application of information technologies. Future tools will support the capture of essential objective health data from the population. The practice of nursing will change. It implies collaboration between nursing schools, employers, payers, and politics. Technology will never replace nursing expertise. Nurses' expertise guarantees delivering the best care to face a health problem in due time and financially adequate [64].

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