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Integrating Emerging Areas of Nursing Science into PhD Programs

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Abstract: The Council for the Advancement of Nursing Science aims to "facilitate and recognize life-long nursing science career development" as an important part of its mission. In light of fast-paced advances in science and technology that are inspiring new questions and methods of investigation in the health sciences, the Council for the Advancement of Nursing Science convened the Idea Festival for Nursing Science Education and appointed the Idea Festival Advisory Committee to stimulate dialogue about linking PhD education with a renewed vision for preparation of the next generation of nursing scientists. Building on the 2010 American Association of Colleges of Nursing Position Statement "The Research-Focused Doctoral Program in Nursing: Pathways to Excellence," Idea Festival Advisory Committee members focused on emerging areas of science and technology that impact the ability of research-focused doctoral programs to prepare graduates for competitive and sustained programs of nursing research using scientific advances in emerging areas of science and technology. The purpose of this article is to describe the educational and scientific contexts for the Idea Festival, which will serve as the foundation for recommendations for incorporating emerging areas of science and technology into research-focused doctoral programs in nursing.

Keywords: Nursing research,Nursing science, Nursing scientist education, Research-focused doctorate

Introduction

The societal mandate for nursing as a profession includes practice and research (Donaldson and Crowley, 1978 and International Council of Nurses, 1999); research is critical to building the science that underpins nursing practice (e.g., Abdellah and Levine, 1965 and National Institute of Nursing Research, 2011). Priorities for nursing research reflect commitment of the discipline to the promotion of optimum health of populations amidst ever-changing demographic, epidemiologic, political, technical, and health care environments. Doctoral programs in nursing, both doctor of nursing practice (DNP) and doctor of philosophy (PhD) programs, are central to ensuring that nursing practice and nursing science keep pace with the increasingly complex and global environments for health and health care (Institute of Medicine, 2010). Research-focused doctoral programs offering the PhD degree are critical to preparing a sufficient cadre of nursing scientists to generate the new knowledge needed to advance the practice of nursing, improve the quality of health care, shape health policy, and positively impact the health of all people (American Association of Colleges of Nursing [AACN], 2006).

Nursing science concerns the "conditions necessary and sufficient for the promotion, maintenance, and restoration of health in human beings" (Donaldson, 2003 and Donaldson and Crowley, 1978). As such, nursing science is expansive, incorporating health and illness experiences of individuals, families, and communities over time and in ecological context. Research to build nursing science includes descriptive studies; design and evaluation of interventions for health promotion and disease prevention, mitigation of symptoms, and compassionate care at end of life; exploration of mechanisms driving health risks, symptom expression, and treatment responses; and assessment of nursing systems, quality of care, patient outcomes, and health policy (Henly, 2016). Nursing scientists conduct basic and bench research, clinical intervention trials, implementation studies, and comparative effectiveness research including cost analyses (Grady & McIlvane, 2016). Thus, nursing research spans the continuum of translational research, from problem identification (T0) to basic and bench science (T1), clinical intervention trials (T2), dissemination and implementation studies (T3), and comparative effectiveness research in real-world settings (T4; cf. Drolet and Lorenzi, 2011 and Khoury et al., 2007).

A significant challenge for PhD programs in nursing is to prepare graduates who understand the breadth of the discipline and possess the in-depth knowledge and skills in increasingly specialized areas needed to launch and sustain competitive careers as nursing scientists. This challenge becomes all the more urgent in light of shrinking research resources, rapid advances in science and technology impacting health care and health sciences research, and pressures to increase the numbers of doctorally prepared nursing faculty.

PhD Preparation

A hallmark of the research-focused doctoral degree is an individualized program of study that supports development of expertise in the core knowledge and research methods of the discipline and depth in a selected area of scientific investigation (AACN, 2010). The centerpiece of a PhD program of study is the dissertation, an independent research project completed under the guidance of the advisor that adds new knowledge to the discipline and prepares the graduate to embark on a scientific career. PhD degree programs in nursing are expected to have the environment, faculty, resources, and infrastructure to educate students to develop the science, steward the discipline, and educate the next generation of scholars (American Association of Colleges of Nursing, 2001 and American Association of Colleges of Nursing, 2010).

Doctoral education in nursing has proceeded against a backdrop of changes with the potential to impact quality of nursing scientist training. The number of research-focused doctoral programs in nursing in the United States increased from 20 in 1970 (AACN, 2001) to 132 in 2013 (www.aacn.nche.edu/research-data/doc.pdf). However, the capacity of the programs for training competitive nursing scientists is uneven (Anderson, 2000 and Kim et al., 2014) because of differences in training environments and resources and available research-productive faculty mentors (Potempa, Redman, & Anderson, 2008). Since 2004, many schools have offered research- and practice-focused doctoral programs (AACN, 2004); growth in DNP programs is outpacing that of PhD programs (e.g., increases of 26.2% and 3.2%, respectively, from 2013 to 2014; AACN, 2015). The impact of the rapid growth of practice-focused DNP degree programs on research-focused doctoral programs in terms of resources and faculty availability for training of nursing scientists is unclear (Dreher, Glasgow, Cornelius, & Bhattacharya, 2012).

Emerging areas of science and technological advances in data collection and capture, storage, retrieval, and analysis are creating new challenges for research-focused doctoral programs. In September 2013, AACN sponsored *A National Dialogue on the Future of Nursing Science and the Research-Focused Doctorate* to address implications of recent advances in biological sciences, big data, and technology for nursing research and PhD curricula (Kerr et al., 2013 and Tabak, 2013). In light of these advances in the content and methods of science, the relevance of the 2010 AACN Position Statement on the Research Doctorate was addressed in detail (Dunbar-Jacob, 2013). Attendees then met in small groups to discuss curricular content and educational processes needed to keep pace with scientific advances impacting health sciences research. Those in attendance recognized that no single research-focused doctoral program can offer training in all areas of science relevant to preparing graduates to launch a productive research career; participants suggested that programs identify content areas in which they have particular strength, such as genomics, health economics, or informatics. Discussion also focused on the processes of research training. There was general consensus that research training must include exposure to team science to prepare graduates to effectively engage with interdisciplinary colleagues to conduct cutting-edge nursing research and compete successfully for precious research resources.

As currently structured, many PhD programs in nursing may not have the capacity to prepare students to conduct cutting-edge research in line with emerging and priority areas of health sciences research. For example, Wyman and Henly (2015) recently examined the content of U.S. PhD degree programs in nursing as communicated on websites of programs on the 2010–2011 AACN list of PhD programs. Data were scraped from curriculum plans, course catalogues, PhD handbooks, and other documents posted on the websites in 2012 to determine the degree to which program elements listed in *Pathways to Excellence* (AACN, 2010) and emerging areas of science such as genomics, biophysical measurement, quantitative sciences, informatics, and big data were visible in the published documents. Virtually all programs required theory, statistics, and qualitative methods, but biological foundations for nursing science and emerging areas of science and technology were seldom visible. The findings suggested that nursing PhD programs are continuing to implement curricula better suited to the past, not the future of nursing science; descriptions of program curricula and training methods appeared insufficient for the incorporation of advances in biological sciences, biophysical and imaging technology, informatics technology and computing, mathematical/statistical modeling, and engineering for point-of-care technologies into nursing science. Findings emphasized the need for continued, in-depth dialogue about the science content of research-focused doctoral programs in nursing, particularly those aiming to prepare students to launch and sustain competitive programs of research in emerging areas of science that will serve as the foundation for future nursing practice in the digital age, the omics era, and a globalized and increasingly cost-conscious world.

Emerging and Priority Areas of Science

The Idea Festival Advisory Committee (IFAC) for Nursing Science Education was convened by the Council for the Advancement of Nursing Science (CANS) to stimulate dialogue about linking PhD education with a renewed vision for preparation of the next generation of nursing scientists that incorporates emerging and priority areas (Henly et al., 2015). The IFAC arose from the following circumstances:

1. The strategic plan for the NINR released in 2011 included greater emphasis on identifying biological and genomic mechanisms; integrating biological and behavioral sciences; and using technology to advance science related to health promotion and disease prevention, symptoms and symptom management, and end-of-life care.
2. National Institutes of Health (NIH) Common Fund programs (commonfund.nih.gov/) aimed at advancing innovative, interdisciplinary directions for research across the institutes and centers of the NIH included many areas related to nursing science, including genomics, proteomics, metabolomics (hereafter referred to as omics), the microbiome, behavior change, measurement of patient-reported outcomes, and knowledge discovery based on big data.
3. The *Bio2010* initiative (Committee on Undergraduate Biology Education to Prepare Research Scientists for the 21st Century, 2003) prompted changes in the curriculum of undergraduate biology students in the physics, chemistry, mathematics, and research experiences, significantly increasing preparation for scientific careers at the first level and positioning students for

success across many areas of science related to the NIH mission, including nursing science.

4. Health care reform is creating greater demand for more rapid translation of research findings into practice and greater emphasis on the cost-effectiveness of care.
5. The content of presentations at plenary sessions and cutting-edge symposia from recent CANS State of the Science and Special Topics Conferences reiterated the urgency to include these topics in PhD/research-focused doctoral programs.

In light of these events, the IFAC considered the status of the following emerging and priority areas of science and the implications for educational preparation of future nursing scientists: (a) omics and the microbiome; (b) behavior, behavior change, and biobehavioral science; (c) e-science, informatics, and big data; (d) quantitative science; (e) translational science, (f) patient-reported outcomes; and (g) health economics. Key points from these initial discussions on the emerging and priority areas of science impacting nursing science and health care research are summarized later. CANS IFAC recommendations for PhD programs incorporating the emerging and priority areas are presented in Henly et al. (2015).

Biological Science: Omics and the Microbiome

Nursing has long been a biopsychosocial perspective for the development of nursing science and the delivery of nursing care (Bond and Heitkemper, 2001, Cowan et al., 1993, Hinshaw et al., 1991, National Institute of Nursing Research, 2011 and Rudy and Grady, 2005). However, integration of biological sciences into nursing science and PhD curricula has been limited (Wyman & Henly, 2015). Current challenges involve an ever-expanding substantive knowledge base in the life sciences, technological advances in laboratory and field methods in biology-based disciplines, debut of new research designs (Conley, 2016), and advancements in mathematical modeling of complex biological data (Bergevin, 2010 and Marsteller, 2010). Even though mapping and sequencing of the entire human genome was announced in April 2003 (International Human Genome Sequencing Consortium, 2004), few faculty in schools of nursing have the expertise to teach genomics (Jenkins & Calzone, 2012) or biosciences generally (Smales, 2010).

The explosion of genomics knowledge since 2004 has created entire new fields of study, including transcriptomics, proteomics, metabolomics, epigenetics, and metagenomics, often collectively referred to as "omics" sciences. A blueprint for genomic nursing science maps the NINR strategic plan onto topical areas for genomic nursing research in areas ranging from biologic plausibility studies, risk assessment and communication, pharmacogenomics, genomic bioinformatics, and cross-generational sharing of genomic data; the blueprint emphasizes the need to train future nursing scientists in genomics (Genomic Nursing State of the Science Advisory Panel et al., 2013).

The Human Microbiome Project aims to characterize the microbial communities found on the human body, including nasal passages, oral cavities, skin, gastrointestinal tract, and urogenital tract, and to analyze the roles of these microbial communities in human health and disease (commonfund.nih.gov/hmp/index). Early research suggests that the microbiome can influence risk for diverse health and illness conditions including obesity, immune disorders, cardiovascular disease, and negative mood (Forsythe et al., 2012 and Khanna and Tosh, 2014). Consideration of the microbiome can add to understanding of bacterial colonization and wound repair mechanisms (Scales & Huffnagle, 2013).

Knowledge of these scientific advancements in the life sciences is needed to conduct cutting-edge nursing research in health promotion, risk reduction, symptom science, and end-of-life care. Explication of biological mechanisms or biological factors determining why and how a given intervention achieves a desired outcome will greatly accelerate the development of nursing as a biopsychosocial science for the health of all populations.

Health Behavior, Behavior Change, and Biobehavioral Nursing Science

Understanding health risks and improving health behaviors has been a mainstay of nursing science. For example, understanding the stress, coping, and adaptation process is a central concern, and much of what we know has been learned using data obtained from questionnaires or interviews. But development of health behaviors and health risks over the life course (Halfon and Hochstein, 2002 and Krieger, 2005) and behavior change and adaptation are processes that unfold over time; advancing knowledge about these critical health processes requires information obtained from repeated measures or longitudinal studies. Yet, few studies in nursing are based on longitudinal data (Henly, Wyman, & Findorff, 2011) or take advantage of models for longitudinal data that are now standard in the behavioral sciences (e.g., Hedeker and Gibbons, 2006, Singer and Willett, 2003 and Skrondal and Rabe-Hesketh, 2004). Instead, time-based frameworks are forced illogically onto cross-sectional data. More recent advances in computational methods make it possible to translate theories and data for intensive longitudinal processes (e.g., Walls & Schafer, 2006) into models that incorporate relationships between changing rates of change (e.g., Deboeck & Bergeman, 2013) or display graphic models for social and biological networks over time (e.g., Nicosia et al., 2012) needed to understand time-based behavioral processes in health and illness.

The way we think about behavior and behavior change, self-monitoring, and self-management of health and illness is being completely changed by the ability to collect moment-to-moment data using high technology devices (e.g., Lanza, Piper, & Shiffman, 2014). Exploration of biological mechanisms of cognitive and behavioral interventions like mindfulness or affirmation as well as identification of links among neuronal activity and behavior (http://www.nih.gov/science/brain/), hormonal activity and behaviour, and the interplay among them are being supported by advances in neuroscience and imaging (e.g., Bozak and Martin, 2014 and Wetherill and Tapert, 2013). New understanding of how adverse early life events and social environments impact the development of health risk and health behaviors are possible with new genetic and epigenomic models (e.g., Letourneau et al., 2014 and Shonkoff et al., 2012). Reduction of the incidence of chronic illnesses (heart disease, cancer, and type 2 diabetes) linked to health risk behaviors (smoking, poor diet, and physical activity) at the individual, aggregate, and community level may result from translation of personalized, precision interventions informed by genomic science (McBride et al., 2010).

New experimental designs such as sequential, multiple assignment, randomized trials (Murphy, Collins, & Rush, 2007) and multiphase optimization strategies research designs capitalize on the availability of intensive, technology-enabled data collection (Collins et al., 2011). Idiographic, person-centered theory supported by study of change over time (Henly et al., 2011 and Molenaar, 2004) serves as the basis for understanding these data. Taken together, these advances have real potential to extend current understanding of health-related behaviors and behavior change that will enable the identification of effective, personalized interventions for the prevention and management of weight, cardiovascular disease, diabetes, injuries, and other chronic conditions.

Emergence of E-science, Informatics, and Big Data

Around the turn of the millennium, the digital revolution gave rise to large-scale scientific enterprises characterized by the use of very large (colossal) data collections, computing resources, and high-performance visualization, now referred to as e-science (Herland et al., 2014 and Taylor, n.d.). The methods of data capture, storage and retrieval, and analytics and visualization are unfamiliar to most nursing scientists. The goals of big data–based e-science (description, integration, and prediction; Berger and Berger, 2004 and Fayyad et al., 1996) may seem counterintuitive to the traditions of theory building research (Nicholl, 1986, Risjord, 2010 and Stevenson and Woods, 1986) because data mining is seldom hypothesis driven. However, knowledge accumulation is theory building. The vastness and variety of nursing-related data and the purposes to which they might be put are virtually unimaginable; the challenges in doing so are likely similar to those facing the life sciences including a lack of comprehensive standards for data, lack of incentives for data sharing, and lack of infrastructure and support for the enterprise (Thessen & Patterson, 2013).

Digitized big data relevant to nursing science include but are not limited to (a) personal health data like activity, eating patterns, and sleep generated by individuals and families going about their everyday lives; (b) clinical data like encounter notes, nursing flow sheets, laboratory reports, medication records, images, and even nurse call light clicks and response times; (c) data sets arising from use of standardized documentation systems such as the Nursing Minimum Data Set, Nursing Intervention Classification/Nursing Outcome Classification, and Omaha System (http://www.nursing.umn.edu/icnp/index.htm); (d) cost and claims data; (e) omics-related databases such as the International HapMap Project (http://hapmap.ncbi.nlm.nih.gov/; see also Bakken et al., 2008 and Mitchell, 2012); and (f) the collection of the many small, structured data sets obtained by individual investigators. Few faculty in nursing (or the other health sciences) have the background and skills needed to access and integrate these diverse data sets to generate actionable knowledge; yet, this is exactly what is needed to advance nursing science for the 21st century (NIH, n. d.). In e-science as in practice, a person (patient, participant)-centric focus, uptake of technology, and the enterprise environment combine to create the foundation for nursing as a learning discipline that seamlessly connects translation of research findings into practice and practice into new knowledge (Androwich, 2013 and National Research Council, 2007).

On the horizon, health information technology will link health care directly to contemporary life, allowing research and the point of care to be wherever participants and patients are in real time (Brennan, 2014 and Ozkaynak et al., 2013). It will support healthy living with persuasive technologies using interactive computer systems to change people's attitudes and/or behaviors (Chatterjee & Price, 2009). Case-based machine learning can be used to develop prognostic models for individual outcomes in critical care and population outcomes in public health (e.g., Schmidt & Gierl, 2005). In aging care, technology is already being used to support independent living (Tak, Benefield, & Mahoney, 2011). The use of bioinformatics for discovery is at the heart of the initiative for Clinical and Translational Science Awards (Zerhouni, 2007). Initiatives like the Physiome Project and the Virtual Physiological Human (http://physiomeproject.org/) aim to describe how body systems from molecules to organs work as a whole in health and illness, enabling a realistic vision of how these big data, computation-based perspectives, and health-information technology can inform nursing science and enhance nursing practice (Schallom, Thimmesch, & Pierce, 2011).

Quantitative Sciences

Mathematics is the universal language of science. Ever since personal computers appeared in the early 1980s, vast, accessible, and inexpensive computational resources have accelerated the development of quantitative methods and the uptake of new methods in research at speeds never before seen. Approaches to the management of missing data, the wide range of statistically justified latent variable models (http://www.fa100.info), mixed-effects models for multilevel and longitudinal processes, models for intensive longitudinal data, and item response theory are examples. Yang (2010) described bioinformatics as a multidisciplinary, interdisciplinary, and cross-disciplinary big data field used to understand biological systems, explore mechanisms of biological systems, and verify biological hypotheses that also includes the use of simulations to explore theoretical plausibility of hypotheses. The methods of bioinformatics are essential to the development of omics sciences, including problems in nursing science (Baumgartel et al., 2011). As noted in the background materials for the NIH Big Data to Knowledge (BD2K) initiative, data mining and data visualization are essential to the search for the discovery of meaningful patterns across the biopsychosocial domains of the health sciences including nursing (http://bd2k.nih.gov/#sthash.iXzZ4met.dpbs). Fruitful use of big data approaches requires awareness of their existence and working knowledge of the mathematics that lie at the foundations followed by instruction in the techniques and guidance in their application for knowledge discovery (Matney, Brewster, Sward, Cloyes, & Staggers, 2011) in nursing.

Translation Science

Launched in 2004, the NIH Roadmap challenged the research community to re-engineer the clinical research enterprise to translate evidence-based treatments into service delivery settings and sectors in local communities (Zerhouni, 2003). Nursing has a rich history in translation science as shown by the seminal work on research use (Horsley et al., 1983, Kirchhoff, 2004 and Titler, 2004). However, the strategies and interventions to translate research findings into practice were not clearly elucidated in these initiatives, thus calling for the systematic study of what translation interventions work, in what circumstances, and the mechanisms by which they are effective. Translation science (also called implementation science) is the field of research that focuses on testing implementation interventions to improve uptake and the use of evidence to improve patient outcomes and population health and explicate what implementation strategies work for whom, in what settings, and why (Titler, Wilson, Resnick, & Shever, 2013).

The term translation research means different things to different people Therefore, all PhD students and nursing scientists must understand (a) the terminology used in translation science; (b) the phases of translation research from bench to clinical trials to implementation of research findings; and (c) based on the state of the science in a specified area, the necessity to move the science along the translation continuum. Full integration of research, education, and care within academic health centers and the development of provider/researcher teams within integrated practice units are new ways to enhance translation (Broome, 2014).

Patient-Reported Outcomes Research

Patient perspectives, long valued in nursing research, are integral to assessing health status, intervention effects, and quality of care. However, attempts to compare findings from studies using diverse "legacy" self-report instrumentation for patient-reported outcomes (PROs) that produced scores with varying measurement properties highlighted the need for common data elements against which PROs could be compared across research settings and populations. These concerns were especially critical for meta-analytic studies. To overcome these limitations, the NIH Common Fund sponsored the development of the Patient-Reported Outcomes Measurement Information System. The Patient-Reported Outcomes Measurement Information System developers used a theory-based domain framework for health that incorporated physical, mental, and social subdomains familiar to nursing scientists. Item response theory was used to create banks of items with known parameters to increase precision and standardization of PRO measurement across diseases and situations for adults and children (www.nihpromis.org/science/publications). The most informative items can be combined to obtain scores with minimal error and minimal patient burden in research and clinical settings in which electronic devices are available (Bevans, Ross, & Cella, 2014).

Patient-centered outcomes research (PCOR) is designed to help consumers better assess treatment options, increase patient participation in health care decisions, and, ultimately, improve patient care outcomes, all of which are consistent with the nursing perspective (Barksdale, Newhouse, & Miller, 2014). The Patient-Centered Outcomes Research Institute established crosscutting methodology standards to ensure that funded research yields valid, trustworthy, and useful information (http://www.pcori.org/assets/2013/11/PCORI-Methodology-Report.pdf). Innovative study designs and analytic methods for patient-centered outcomes research, comparative effectiveness research, and community-based participation research are yielding valid new knowledge to address the complexity of health and health care outcomes in real-world settings.

Health Economics

Because health care decisions are complex and health care including nursing services is expensive, decisions made in clinical settings have substantial consequences and involve trade-offs that need to be weighed (Uchida-Nakakoji & Stone, 2016). Cost-effectiveness research addresses the health care value of clinical interventions. Testing the cost-effectiveness of interventions across populations, settings, or over time requires specific analytic skills and innovative computation models that control for bias and endogeneity arising from omitted variables, measurement error, or simultaneity. Nursing scientists should be aware of the implications of opportunity costs and financial incentives that may affect the uptake of an intervention or care delivery model in everyday practice. Health services researchers often use big data to understand the comparative clinical effectiveness and cost-effectiveness of health care interventions with the goal of innovating health care delivery models/systems. This requires a working knowledge of health care organization and financing, health policy concepts of access, cost, resource allocation, and their effect on patient care. Nursing scientists must be able to communicate and collaborate with health services researchers and economists to pose innovative and important comparative and cost-effective research questions and explicate the value of nursing care to improving health promotion and/or disease prevention across the continuum of health care.

Summary

Recent rapid developments in the life sciences, the digital revolution, and the emergence of e-science and predictive analytics have altered our understanding of human life, health, and health behavior of individuals and populations across generations and environments worldwide. These scientific advances demand that nurse educators consider how the science and methods of other health science disciplines can inform the development of nursing science (American Association of Colleges of Nursing, 2010 and Henly, 2013) and how nursing science can inform these related fields. Research-focused doctoral programs in nursing must prepare graduates who understand the breadth of the discipline and possess the specialized knowledge and skills needed to launch their research career. PhD programs are being challenged by rapid growth of new knowledge and methods in related disciplines and shrinking resources to support research by nursing scientists. Meeting these challenges will require faculty in research-focused doctoral programs to reconsider the foundational science content and specialized research training needed to prepare PhD graduates for sustained, competitive careers in nursing science impacted by emerging areas of science and technology.

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