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Educating Nursing Scientists: Integrating Genetics and Genomics into PhD Curricula

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ABSTRACT

Nursing science is a diverse field of study, the scope of which has broadened to more fully incorporate genetics and genomics. In recent years, these topics have become focus areas for many nursing researchers. However, recent evidence suggests that doctoral level nursing students and nursing faculty may be underprepared to conduct independent research using genomic approaches. Furthermore, genetics and genomics are severely underrepresented in doctoral level nursing curricula across the United States. This article suggests a thorough, yet manageable three-part curriculum designed to educate doctoral level nursing students on genetics, genomics, and their use in nursing science. Recommendations are then given for the integration of the curriculum into existing nursing PhD programs.

Introduction

Nursing science is a uniquely diverse field of study, encompassing all manner of health science research, from qualitative ethnographic studies to quantitative bio-behavioral studies. The scope of nursing science has broadened and evolved over the years to more fully incorporate genetics, basic sciences, and the “bench-to-bedside” focus on translational research. The call for nurses to participate in interdisciplinary collaboration and conduct genetic research themselves, however, is not new. The National Institute of Nursing Research (NINR) has long realized the enormous potential of integrating genomics into nursing science and has encouraged it since the early 2000's (Grady & Collins, 2003). Similarly, a professional nursing organization, the International Society of Nurses in Genetics (ISONG), has advocated for integration of genetics and genomics into nursing practice and research. The NINR has led the charge for nurses in bio-behavioral research, listing precision medicine, genomics, and proteomics as main focus areas. Indeed, nurses have since contributed greatly to the existing wealth of genomic literature over the past decade and beyond (Calzone et al., 2010).

Perhaps as a result of this aspect of the on-going evolution of nursing research, many nurse scientists have sought training in genomics, transcriptomics, proteomics, and other forms of basic science to better prepare themselves for such projects. Focused training in genomics is available, including the Summer Genetics Institute (SGI) at NINR. Frameworks and guidelines for nursing research and education in genomics have also been developed recently, including the Blueprint for Genomic Nursing Science and The Essential Genetic and Genomic Competencies (Genomic Nursing State of the Science Advisory et al., 2013; Greco, Tinley, & Seibert, 2011). A summary of the research themes and competencies suggested for nursing research in these documents is listed in the table below (see Table 1).

Despite the establishment of national guidelines for genetic and genomic competencies, evidence suggests that competency levels in genomic knowledge of nurses and nursing faculty remain low (Calzone et al., 2012; Jenkins & Calzone, 2012; Read & Ward, 2016). Furthermore, genetics and genomics are dramatically under-represented in nursing PhD programs across the United States (Wyman & Henly, 2015). A wealth of opportunities exists for nurse scientists to conduct high-impact research in this ever-evolving field, but they must be leveraged through precise, intentional, and meaningful integration of ‘omics’-based tools in research designs. If nursing science is to continue to rise to the challenge of conducting bio-behavioral research using ‘omics’-based approaches, nurse scientists must be adequately trained to do so. The purpose of this article is to synthesize current recommendations for the integration of ‘omics’ training into nursing science and distill them into a manageable three-semester long training program that could be integrated into existing nursing PhD curricula.

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Table 1
A summary of genomic research themes and competencies as described by the Blueprint for Genomic Nursing Science and the Essential Genetic and Genomic Competencies documents (Genomic Nursing State of the Science Advisory et al., 2013; Read & Ward, 2016).

Source document	Suggested genomic research themes and competencies
Blueprint for Genomic Nursing Science	Suggested research themes focused on the client - Health promotion and disease prevention through genetic risk assessment - Effective communication of risk information to clients - Psychosocial and ethical implications of genetic information for clients and families - Symptom management and client self-management in the context of genetic disease Suggested research themes focused on context - Capacity building in genomics for current and future nurses - Advancing integration of genetic nursing into practice through education and preparation
Essential Genetic and Genomic Competencies	Suggested competencies - Participate in the application and translation of genetic and genomic research and education - Identify genetic and genomic healthcare methods and outcomes that can be influenced by nursing - Collaborate with relevant disciplines in the conduct, dissemination, and/or translation of genomic inquiry and research

Genomics: Underrepresented in Nursing

It is widely agreed that genomics play an integral role in the health of those we study and is thus fundamental to our research efforts (Calzone et al., 2010; Genomic Nursing State of the Science Advisory et al., 2013; Read & Ward, 2016). As such, genetics and genomics are fields in which nursing scientists must have at least a basic level of familiarity. Many organizations such as the National Institutes of Health (NIH), ISONG, the American Academy of Nursing, and the American Association of Colleges of Nursing (AACN) have made concerted efforts to address the widening gap between the evolution of trends in nursing science and the preparedness of nursing scientists to address them. The Summer Genetics Institute (SGI) offered by NINR is a one-month intensive training program, featuring both lectures and laboratory sessions, that is designed to provide attendees with a foundation and basic level of familiarity in molecular genetics. The SGI is a well-designed and executed program, but admission is competitive and will not be available to all students. If nursing scientists are to gain the level of expertise in genomic methods required to properly conduct such research or meaningfully incorporate these methodologies, more avenues must exist for training of an adequate length and depth.

As of 2015, a review of 120 nursing PhD programs across the United States found that nearly all incorporated coursework on statistics, quantitative design, theory development, and qualitative methods, with many of those subjects requiring more than one semester of study (Wyman & Henly, 2015). These areas of study, originally designated as indicators of quality in research-focused doctoral nursing programs by the AACN, are essential in the education of a well-rounded nurse scientist and should indeed be well represented in nursing PhD programs. However, since recommendations for nursing PhD core curricula were published 30 years ago, the AACN has updated them multiple times to now include "priority" areas such as informatics, physiology, biophysical measurement/instrumentation, and genetics/genomics ("Indicators of quality in doctoral programs in nursing. American Association of Colleges of Nursing", 1997; American Association of Colleges of Nursing, 2002). Nevertheless, most nursing PhD programs have yet to revise their curricula to reflect 1) the markers of excellence recently updated by AACN and 2) the priority areas of focus as described by NINR. In fact, according to Wyman & Henly's, 2015 report, genetics/genomics were represented in fewer than 8% of the 120 nursing PhD programs they examined (Wyman & Henly, 2015).

Given the diversity and breadth of nursing science, it is unreasonable to expect every nursing scientist to have interest in genetics, let alone achieve advanced expertise. Nevertheless, the relatively few avenues in place for nursing PhD students to gain even a basic level of familiarity in genetics remains a challenge. Considering the ubiquity of genomic theory and concepts both within nursing and without, it is essential that all nurse scientists have at least a basic level of competency in genetics and genomics. This level of competency can be achieved by completion of a basic genomics course, an example of which is represented by the first semester course in Table 2 below. A 'mid-level' competency in genetics would be most beneficial to students interested in pursuing collaborations with geneticists or other basic scientists and could be achieved by completion of an intermediate genetics course, represented by the second semester course in Table 2.

Table 2
A three-semester long sample curriculum in genetics/genomics including the suggested topics to be covered in each course.

Semester	Course to be completed	Topics to be covered
1	Introduction to genomics (Basic genetics course)	1. Review of cell biology 2. Cell structure and function 3. Cell cycle, mitosis, and meiosis 4. "Central Dogma" a. DNA structure and function b. RNA structure and function c. Basic protein structure and function 5. Introduction to DNA variation 6. Mendelian theory, heredity 7. Understanding genetic and genomic research designs and reports 8. Introduction to incorporating genetics/genomics into nursing research designs
2	Molecular and cytogenetics (Intermediate genetics course)	1. Chromosomal structure and function 2. Nondisjunction 3. Copy number variants and human disease 4. Karyotyping and interpretation 5. Sanger sequencing and interpretation 6. Whole exome sequencing and interpretation 7. Whole genome sequencing and interpretation
3	Lab: "Omics" research methods (Advanced genetics course)	1. Review of related concepts 2. Laboratory safety 3. Laboratory basics: buffers, chemicals, reagents 4. Skills: measuring, pipetting 5. Sample collection, handling, and storage 6. DNA and RNA extraction, isolation, purification, and spectrophotometric analysis 7. Gel electrophoresis: DNA gels and blots 8. Polymerase Chain Reaction (PCR): quantitative and end-point 9. Enzyme Linked Immuno-sorbent Assays (ELISA) and proteomic measurement

Finally, for those students interested in conducting research utilizing 'omics'-based tools, an advanced competency level in genomic research design and methodology would be required. This level of competency can be achieved by completion of an advanced genetics course, an example of which is the third semester course in Table 2. Nursing doctoral students with such interest would be best served by completing a laboratory-based, hands-on course in genomic methods such as this in addition to their first two semesters of classroom instruction.

Genomic Nursing Training Program

Proposed below is a sample curriculum designed to confer nursing PhD students one of the three levels of competency in genomic research theory, design, and methodology listed above: basic, mid-level, or advanced. Students who complete the first semester course will achieve the basic level, students who complete semesters one and two will achieve mid-level competency, and those who choose to complete all three will achieve advanced level competency. These sample courses are designed to be completed during the course of PhD study. This curriculum, in total, is a three-semester long intensive training plan, featuring both lecture and laboratory-based instruction. For clarity, the proposed sample curriculum is split into Tables 2 and 3 below. Table 2 describes the order of the courses and topics they cover, while Table 3 describes the competencies students will achieve by completing each one.

The training program proposed in Tables 2 and 3 is lengthy and intensive, but will provide doctoral nursing students with a level of competency in genomic research design and methodology beyond the foundation which can be provided by a shorter training plan. Furthermore, these courses are designed to be completed in sequential order, meaning that students could take one, two, or all three, depending on their interests and research goals. For example, students who plan to be part of a research team that includes genetic approaches may find that a mid-level competency achieved by completing semesters one and two would suffice. Meanwhile, those students who wish to lead their own independent genetics-based projects would require an advanced competency level, achieved by completion of all three courses. However, given the importance of genetics and genomics both within nursing and without, we recommend all nursing PhD students be prepared with a basic competency level, achievable by completion of the first course in the sequence above. Students completing some or all of the curriculum presented here would benefit from having received that training early in their course of doctoral study. Consequently, these students may find the most benefit in completing this curriculum prior to proposing their doctoral research.

Integration into Current Nursing PhD Programs

Integration of the training program described above into current nursing PhD programs is not without barriers. A 2012 study by Jenkins et al. indicated that current nursing faculty report a limited capacity to integrate genomic content into their curricula (Jenkins & Calzone, 2012). Most of those faculty self-reported their genetic/genomic knowledge as "low" (Jenkins & Calzone, 2012). A 2016 report by Read

Table 3
Description of basic, mid-level, and advanced competency levels obtained by completion of each course, and specific competencies that define each level.

Course to be completed	Competency level with completion	Specific competencies to be achieved
Introduction to genomics (Basic genetics course)	Basic	- Explain and discuss cellular machinery including structure and function - Understand and explain the cell cycle including all phases of mitosis and meiosis and the purpose of each - Explain and discuss the "central dogma" of genetics including the structure and function of DNA, RNA, and protein and how each is formed - Explain and provide examples of DNA variation in the population - Understand and discuss mendelian inheritance, the basic modes of heredity, and be able to identify each in a pedigree - Identify and understand genomic concepts, designs, and methods in current literature including genome-wide association studies (GWAS) and candidate gene analyses - Demonstrate ability to incorporate basic genetic concepts into nursing research designs by writing specific aims of a bio-behavioral research project
Molecular and cytogenetics (Intermediate genetics course)	Mid-level	- Explain the structure and function of chromosomes and how they are manipulated during mitosis and meiosis - Understand and discuss nondisjunction, including the circumstances under which it can happen and its consequences - Discuss how variants in copy number can arise, specifically how they can lead to human disease, and what diseases they can cause - Understand and discuss the various methods of testing for genetic disease including karyotyping, Sanger and next generation sequencing, whole exome and whole genome sequencing. Understanding of these tests includes when they may be ordered, interpretation of their results, and what results may mean for the patient.
Lab: "Omics" research and laboratory methods (Advanced genetics course)	Advanced	- Before attempting laboratory procedures, students will demonstrate the competencies listed in the above two courses - Explain and discuss basic laboratory safety including personal protective equipment and safety procedures. This will be separate from any institutional laboratory safety requirements. - Demonstrate understanding and ability to make precise laboratory measurements in common denominations and convert between them - Demonstrate ability to make common laboratory buffers, chemicals and reagents from protocols - Practice collection, handling, preparation, and storage of tissue and blood samples and verbalize understanding of different preparation and storage methods - Understand, explain, and demonstrate ability to extract, isolate, and purity DNA, RNA, and protein from tissue and blood - Demonstrate theoretical understanding of and ability to perform gel electrophoresis including both DNA and protein gels - Understand the differences between quantitative and end-point PCR, when each should be used, and demonstrate ability to perform each protocol - Understand and discuss principles of ELISA and other common proteomic measurement techniques and demonstrate ability to measure proteins using ELISA-based techniques

et al. used the emerging Genomic Nursing Concept Inventory (GNCI) to evaluate knowledge levels of current nursing faculty on genetics/genomics. Of the 495 faculty who completed the evaluation, the mean score was 48% correct, scoring lowest in the 'genome basics' section at 33% correct (Read & Ward, 2016). Furthermore, 37% of those faculty who completed the GNCI reported having lectured in genetic/genomic content (Read & Ward, 2016). These data indicate that current nursing faculty may be underprepared to adequately teach the material proposed in the training plan above.

Many options are nonetheless available to effectively teach this material, such as interdisciplinary collaboration with departments of genomic sciences. Additionally, given the evolution of nursing science to more fully include genetics and genomics, schools of nursing offering research-based doctoral programs could consider hiring faculty with expertise in those areas. For schools of nursing with no such faculty, inter-departmental relationships are important and need not be unidirectional. Many basic science research departments have few, if any, faculty trained in working with human subjects. Furthermore, few disciplines have the training and expertise of nursing in psychosocial research design, measurement, and evaluation. Opportunities for collaboration could take the form of a genetics professor teaching 'omics' to nursing students, while a nursing professor teaches ethics and human subjects regulations to genetics students. Extra-curricular opportunities may also arise from development of such working relationships. For example, a nursing PhD student seeking expertise in measurement of gene expression might complete a summer practicum in the laboratory of a genetics researcher who is an expert in gene expression, providing a valuable learning opportunity for the nursing student and laboratory assistance for the genetics researcher. In these ways, interdepartmental collaboration between nursing and genomics or other basic sciences can be mutually beneficial.

Integral to the training sequence presented here is hands-on instruction in a molecular genetics laboratory. As most nursing PhD programs in the United States do not feature formal education in genetics/genomics, it is unreasonable to expect them to house physical space for a laboratory (Wyman & Henly, 2015). Furthermore, each school of nursing offering a research-based doctoral program has its own areas of strength, not all of which include basic science or laboratory-based research. As such, these schools may not be equipped to offer a laboratory-based training course, such as the one described above. However, it is essential in the ever-evolving milieu of health science research, that every nurse scientist have at least a basic level of competency in genetics and genomics. Schools of nursing that do not claim strength in these areas should still prepare students with basic understanding of these important concepts.

There are some research-based doctoral nursing programs located at universities that do not feature a department of genetics or genome sciences. At such universities, it may be difficult to find faculty who are adequately prepared to teach courses such as those suggested here. Furthermore, given the diversity of nursing science as field, it is unreasonable to expect every nursing scientist to have interest in genetics and genomics. We recognize that achieving what we have defined as a basic competency level in genetics may be difficult for students without interest in these areas or for those studying at universities with no avenues for inter-departmental collaboration in genetics. For these students, we recommend attaining some level of familiarity in these important concepts by pursing one of the other options available for genetic/genomic training such as the SGI at NINR.

Conclusions

Though recognized as focus areas by NINR and other professional organizations, Genetics and genomics are vastly underrepresented in nursing PhD programs across the united states (Wyman & Henly, 2015). Genetics and genomics play an integral and inseparable role in the health of those we study (Calzone et al., 2010; Henly et al., 2015; Read & Ward, 2016). As of 2014, 12 of the top 15 causes of death in the United States, including the top three (heart disease, cancer, and stroke) include a genetic component (Kochanek, Murphy, Xu, & Tejada-Vera, 2016). As the most trusted health-care professionals in the country, it is our responsibility to earn that trust by ensuring we have experts in the most relevant scientific fields. The curricular component presented here is designed to provide PhD students in nursing with the knowledge and foundation required to conduct genomic research as a member of a research team or an independent investigator. Integration of training programs such as this in research-focused doctoral nursing programs will prepare future nurse-scientists to rise to the challenges set forth by NINR and continue to move forward in realizing the enormous potential of genetics and genomics in bio-behavioral research.

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