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Building Genetic Competence through Partnerships and Interactive Models

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Abstract

Background—Nurses are increasingly using genetic-directed therapies in routine care, but evidence indicates that nurse educators lack knowledge about basic genetic concepts and related clinical implications. Educators are the key to preparing future nurses for effective practice in the genomic era, and creative approaches are needed for faculty development.

Method—Nurse educators in academic and clinical settings partnered with science educators who use sophisticated DNA, RNA, and protein models to explore ways to teach abstract genetic concepts.

Results—Hands-on learning enabled the workshop participants to understand how transcription of gene mutations leads to the translation of defective proteins responsible for specific diseases. Participants found using the models helped clarified complex concepts that occur at the cellular level.

Conclusion—Partnerships with science educators can address gaps in nurse educators' knowledge about genetics and introduce creative teaching strategies.

As genetic information and molecular medicine revolutionize the healthcare environment, nurse educators must find ways to impart the relevant information to the current and next generation of caregivers. Evidence suggests that many nurses and nurse faculty lack knowledge of the basic principles of genetics and its clinical implications. However, novel strategies and collaborations with science educators and other healthcare professionals can address those gaps in creative ways. The purpose of this paper is to describe successful

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partnerships among nurse educators in academic and clinical settings with science educators who use sophisticated DNA, RNA, and protein models to teach abstract genetic concepts.

Background

There is a pressing need for all nurses to become literate in the field of genetics in today's world in which the 10 leading causes of mortality have a genetic component. Clinical nurses increasingly are using genetic-directed therapies in routine care. An expanding number of diseases are treatable with a gene therapy procedure similar to a blood transfusion; after the cells are infused, they replicate and alter the DNA or RNA transcript used to synthesize proteins and thereby correct the disease. For example, nurses in some centers administer stem cells modified to contain the missing gene needed to correct the underlying defect for a limited number of monogenetic, life threatening diseases such as X-linked severe combined immuneodeficiency, adrenoleukodystrophy (ADL), chronic granulomatous disease, and Wiscott-Aldrich syndrome.

Nurse leaders in genetics confirm that, “faculty are key to preparing future professional nurses to bridge the gaps for individuals, families, and communities as they traverse this complex personalized healthcare environment guided by knowledge of their genomic uniqueness” (Jenkins, Bednash, & Malone, 2010, p.1). However, recent evidence has revealed that nursing school faculty lack confidence in their ability to apply and disseminate genetic information. In a study of 167 nurses, 86% of whom were nursing faculty and 82% of whom had masters or doctoral degrees, Jenkins & Calzone (2012) found that 71% rated their personal genetic knowledge as low or very low. Read & Ward (2016) found 70% of 495 nursing faculty surveyed rated their proficiency with genetic content as fair or poor. This lack of confidence is compounded by an actual knowledge deficit in recent studies that measured competence on genetic concepts. De Sevo (2013) developed a 15-item instrument to measure genetic knowledge relevant for nursing, on which nursing faculty achieved a mean score of 53% correct on questions about basic genetic definitions, inheritance patterns, referral actions, pedigree development, cultural issues, and insurance issues. Read & Ward (2016) used the Genomic Nursing Concept Inventory (Ward, 2011) to assess faculty knowledge of the genetic concepts most critical to nursing practice. Faculty achieved a mean score of 48% correct overall but scored only 33% correct on 12 items relating to genome basics.

The mean age of nursing faculty in the United States with a master's or doctoral degree is greater than 51 years (American Associate of Colleges of Nursing, 2015). Therefore, the majority of nursing faculty attended college prior to the beginning of the Human Genome Project in 1990 and may not have learned basic genetic concepts as part of their initial education. Recent articles provide practical information about educating the next generation of nurses on genetics (Lea, Skirton, Read, & Williams, 2011), recommend strategies to prepare faculty to integrate genetics into educational programs (Tonkin, Calzone, Jenkins, Lea, & Prows, 2011; Williams, et. al. 2011), and offer ways to integrate genetics into undergraduate nursing education (Daack-Hirsch, Dieter, & Quinn Griffin, 2011; Kirk, Calzone, Arimori, & Tonkin 2011; Quevedo Garcia, Greco, & Loescher, 2011). However, little attention has been given to identifying educational resources that specifically focus on

basic genetics concepts. This gap in faculty knowledge must be addressed to ensure that students receive a fully integrated education in genetics. Because nursing students in clinical courses often learn their craft from practicing nurse preceptors, cutting-edge content would ideally be taught through an academic/service partnership model that uses the expertise of nursing as well as science educators.

Forming Partnerships Between Nursing and Science Educators

As part of an ongoing effort to update the genetic knowledge of nursing faculty in the baccalaureate and master of nursing programs at the authors' institutions, a collaborative team was forged with the outreach program of the Center for Environmental Health Sciences (CEHS), at the Massachusetts Institute of Technology (MIT). The CEHS has a world-renowned reputation for genetic research. The team included research scientists, science educators, and nurses from the MIT Clinical Research Center. One of the goals of the CEHS outreach program is to develop educational tools to explain the importance of gene-environment interactions and their effect on health and disease.

During a period of 7 years, CEHS led numerous 2-day cell biology workshops for health professionals, providing them with continuing education credit. These workshop programs used MIT's unique molecular models, guest lecturers, and visits to local research laboratories. The MIT team also instructed students in genetics classes, provided faculty workshops, and presented a genetics workshop for National Institutes of Health (NIH) Collaborative Pediatric Critical Care Research Network (CPCCRN) meeting in Washington D.C. In addition, the team presented hands-on workshops as well as poster and podium talks held by several professional organizations such as the International Association of Clinical Research Nurses and the American Public Health Association Learning Institute. To meet the needs of the contemporary nursing workforce, the MIT team continuously sought the advice of the broader nursing community. The MIT team also conducted focus groups and analyzed assessments from all workshops.

During these workshops, the MIT team used an interactive educational kit they had developed that included models for teaching key genetic concepts. Their prior experience teaching nurses and nurse educators about the difficult, three-dimensional molecular biology concepts and relating them to clinical care made for an interesting, interactive faculty development program at the authors' school of nursing. The use of the models is described below.

Using Models to Address Knowledge Gaps

Virtual simulations may be popular, but physical models are a particularly effective form of hands-on active learning (Lipson, 2007). The molecular models created by Vandiver (Figure) are innovative because they require participants to reenact the multistep molecular processes. A knowledge retention study has shown that as much as 90% of knowledge is retained when a concrete experience is used, compared to 20% being retained when only an abstract conceptualization is used (Stice, 1987). Learning has also been shown to be especially enhanced by active experiences when the spatial and physical concepts are difficult to

visualize and understand abstractly (Asokanthan, 1997). Molecular processes are difficult to visualize because the molecules affect each other through chemical interactions.

The molecules of DNA and RNA nucleotides, amino acids, and tRNA prototypes were constructed from LEGO® bricks glued together to form the monomers of each type of molecule. These monomers were designed to be linked and unlinked, as that happens repeatedly during cellular processes. For example, the DNA nucleotide models will form DNA strands by linking the phosphate and sugar components of adjoining nucleotides, consistent with the actual replication process in cells. The bases of the DNA models differ in size, representing their chemical structures, and each base has a designated color for easy recognition. Base pairing of nucleotides is accomplished through a ball-and-socket connection that allows the DNA models to twist and demonstrate the double helix structure. The connections between the base pairs allow the two DNA strands to separate easily, representing the weak hydrogen bonds between the base pairs, and allowing for easy separation of the two DNA strands for various cellular processes.

The central dogma of biology (DNA to RNA to protein) can be experienced as a completely hands-on process with the models. Transfer of information from the original DNA sequence to an RNA copy is accomplished through unzipping and base pairing. It is an engaging first step. The RNA copy is then decoded into a series of individual amino acids. These amino acids are connected end to end, creating a protein chain. The amino acid models also have shapes representative of their atomic structures. Chains of amino acids can be created in various lengths and in various orders, and these chains can be folded into myriad shapes depending on the properties of the amino acids.

The Figure shows a top-down view of a cell membrane. Four simplified protein chains form a functional channel protein as represented by the amino acid model. The orientation of the chains in the membrane's lipid bilayer is used to introduce the protein structure-function relationship. All four chains coiled into helices contribute to an interior passageway for ions such as K^+ or Cl^-. The key to the protein's functionality is the sequence of the amino acids in each chain. The helical structures position the hydrophobic (yellow) amino acids on the exterior of the protein, thereby creating a hydrophilic interior, which can expedite the transport of ions across the membrane barrier. One amino acid in this channel protein is changed from hydrophobic to hydrophilic to show how a single amino acid change can drastically change the function of a protein. This change from a hydrophobic to hydrophilic amino acid prevents the proper functioning of the channel protein and creates a possible disease state, much like cystic fibrosis. Another clinically relevant example of a single amino acid change is the heritable basis of a patient's metabolism of warfarin. This can be illustrated in a lesson where a particular gene variant in the liver causes one amino acid to be replaced by a more effective amino acid, thus impacting warfarin dosing.

The MIT DNA and protein models create elegant solutions to three major learning issues. First, molecules themselves are moving entities; their constant association, dissociation, creation, and destruction make cell processes difficult to follow. These cell processes are not easily conveyed by lecture presentations, which provide learners with a two-dimensional, passive learning experience. In contrast, the MIT models are ideally suited for the task of

providing an active learning experience. Learners must make and execute decisions during every part of the lesson. In addition, the visual and tactile feedback helps learners construct the procedural concepts in a memorable way for recall.

Second, cellular detail is often is poorly connected to nursing practice. The lessons for the MIT models were designed to illustrate real-world medical examples that connect the molecular understanding of the disease to treatments in practice. For example, participants can build a cell membrane channel protein and discover what effects a DNA mutation might have on the structure and function of the protein. That knowledge then is linked through discussion to cystic fibrosis, a disease caused by decreased or absent function of a channel protein. The models help reconcile Mendelian genetics with the molecular story.

Third, cognitive and psychological barriers exist toward learning genetics. The models make the content more approachable and less intimidating. Hands-on models lower the fear of failure and make the learning process more like a puzzle or game. The involvement in learning happens during the building, and participants work in teams of two to help each other and reinforce their new knowledge.

Early Evaluation Data

The study was reviewed by MIT's Committee on the Use of Humans as Experimental Subjects and received exempt status given the nature of the research activities. The data gathered from workshops with practicing nurses generated pre- and post-scores that demonstrated statistically significant improvement in knowledge following instruction with the molecular models. Scores were significantly higher on a DNA and protein posttest (M = 11.10, SD = 1.99) than on the pretest (M = 4.95, SD = 2.89), t (38) = 13.48, $p \leq 0.0001$. Self-rating scores improved significantly as well. In a long-term impact survey (more than 3 months after the workshop) nurses stated specific examples of translating these complex concepts directly to clinical care. Nurses reported gains in their scientific literacy. Statements included “Articles that I read make so much more sense to me now,” and, “In reviewing new research protocols, I have a better understanding of the mechanism by which the drug's action is being researched.” Practicing nurses also described an increased ability to communicate public health information. One nurse stated, “I have been able to explain the changes occurring in the flu viruses to people who do not understand the importance of vaccination.”

Participants in a nursing faculty workshop had highly positive feedback about the interactive nature and clinical relevance of the program. By the end of the workshop, they were able to construct a model of a simple gene and its resultant membrane channel protein, describe the processes of transcription and translation, and explain how a mutation could produce a non-functional molecule that leads to a disease. They found the modeling of basic genetic components using the MIT manipulatives to be a useful clarification of complex concepts that occur at the cellular level.

Moving Forward

The team at MIT is developing additional lessons that will illustrate the role that molecules play in the medical diagnostic and treatment program in nursing practice. The team is also producing new model sets that can be distributed on a wider scale.

Conclusion

Nursing faculty are charged with the responsibility of transforming students into professionals who demonstrate genetic competence in practice. Likewise, there is a need to enhance genetic knowledge and competencies among today's practicing nurses, who often play a major role in the clinical education of nursing students. Given the complex nature of genetic information, the knowledge deficit among faculty and nurse educators about basic genetics, and the apprehension that many educators feel about their ability to teach the content effectively, multiple methodologies should be used. Partnering with science and clinical educators can provide academic nursing faculty with opportunities that expand possibilities and introduce creative teaching strategies.

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Figure.

This photograph shows a top-down / bird's eye view of a cell membrane in which a functional channel protein with the model is represented by four amino acid chains in four helices that span the lipid bilayer. This is a simplification. The real protein has 10 helical turns in each of the chains. This simplification however permits the shortened membrane protein to be assembled by learners starting from a gene and using the molecular processes of transcription and translation. The membrane pore is functional because the hydrophilic amino acids in the chain are folded into the interior of the protein and expedite the passage of ions across the membrane barrier.