2016

# Nanotechnology: An Educational Program for Nurses

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| Date of Submission: | April, 22, 2016 |

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Abstract

*Background*: Nurses are constantly exposed to occupational and environmental issues with the potential to impact their health and safety. A relatively new technology with promising benefits for medicine, yet with potential health and environmental risks is Nanotechnology. *Purpose:* The aim of this project was to implement an educational program to increase nurses' knowledge and awareness about Nanotechnology, its potential benefits and risks in healthcare. The single educational intervention was delivered in person, using PowerPoint presentation designed by the DNP student. The program provided definitions of Nanotechnology and Nanomedicine, it discussed nanoparticles and its application in medical and household products, addressed the benefits, potential health and safety risks, and nursing implications. *Results*: A pre- and posttest format design was utilized to examine the effect of the educational program on participants' knowledge about Nanotechnology. The results from the knowledge surveys showed an increase of 77.1% in knowledge about Nanotechnology among the participants. Qualitative comments reflected the positive response towards the educational program. *Conclusions*: These findings have implications for nursing practice including providing educational opportunities for nurses so they are better equipped to identify medical products containing nanoparticles, to practice safely and to educate patients about treatments using such products.

***Keywords***: nursing, Nanotechnology, Nanomedicine, nanoparticles, hazards exposures, healthcare, safety, and education.

## Introduction and Background

It is well known that nurses are at high risk for work-related injury and exposure to hazardous substances. The nursing profession is also impacted by new technology that are changing the way patient care is being delivered. Among the emerging technologies with the potential for healthcare impact is Nanotechnology. Nanotechnology is based on small-scale science dealing with structures that are typically between 1 and 100 nm in size (1 nm = 10−9 m) (Giacobbe, Monica, & Geraci, 2009). According to Allhoff, et al. (2007) if a nanometer were somehow magnified to appear as long as the nose on your face, then a red blood cell would appear the size of the Empire State Building, a human hair would be about two or three miles wide, one of your fingers would span the continental United States, and a normal person would be about as tall as six or seven planet Earths piled atop one another.

Nanotechnology offers the promise of vast improvements to industrial processes and new value-added products, but it also raises concerns about potential health hazards to workers, the environment and consumers (Goyette & Journeay, 2014). For instance, "nano-sized particles may be more likely to reach the bloodstream and pass through the bloodbrain barrier than larger particles of the same composition and thus may represent a unique health hazard" (Centers for Diseases Control and Prevention [CDC], 2011). Further, products containing nanoparticles such as antibacterial products utilizing nanoparticles of Titanium Dioxide (TiO2) or Silver, for example, are already been used and possibly affecting individuals handling it. "Some toxicological studies show that animals exposed to titanium dioxide (TiO2) and carbon nanotubes (CNTs) have displayed pulmonary inflammation, and perhaps the most troubling finding is that CNTs can cause asbestos-like pathology in mice" (National Institute for Occupational Safety and Health [NIOSH], 2013).

Nanotechnology is a reality. Nanotechnology-enabled medical products (NEMPs) in imaging, diagnosis, and therapy applications are already on the market, with a reported 22 nano-enabled medical products approved by the US Food and Drug Administration (FDA) and 87 Phase I and Phase II clinical trials of NEMPs initiated in 2011 (Murashoy & Howard, 2015). For instance, in cancer treatment the nanoenabled drugs approved by the FDA Abraxane®, which is used to treat breast cancer, and Doxil® for ovarian cancer (Goyette & Journeay, 2014).

Healthy People (2020) recognizes the promising benefits and potential environmental and health impact of Nanotechnology (U. S. Department of Health & Human Services [HHS], 2015). There are specific implications for education of health care consumers and clinicians about the safe and ethical use of nanomaterials, a requirement for new policies and regulations, potential radical role changes for both consumers and clinicians, and new demands in the practice of informatics (Staggers et al., 2008). Nurses can avoid workplace injuries and illnesses related to nanoparticle exposure by staying ahead of the curve through education and training.

## Problem Statement

Risk of illness related to exposure to hazardous substances, including nanoparticles among nurses is indicated by the incidence of injuries being 125.1 per 10,000 full-time workers among registered nurses (RNs) (Bureau of Labor Statistics, 2012). Workplace environmental factors, such as hazardous materials are considerate risk factors for some of wok-related injury among nurses (Perhats et al., 2012; Vecchio, Scuffham, Hilton, & Whiteford, 2011). It has been known that these risks are related to nurses' lack of awareness about the presence of hazardous substances, its potential adverse health effects and failure to utilize proper precautions (Trinkoff et al., 2008).

## Review of the Literature

A comprehensive literature review was conducted in the following databases: Cumulative Index to Nursing and Allied Health Literature (CINAHL), and PubMed to obtain relevant articles on Nanotechnology from 2007 to 2015. The search terms were nursing, Nanotechnology, Nanomedicine, nanoparticles, hazards exposures, healthcare, safety, and education. Nineteen articles were used for this literature review. Inclusion criteria consisted of articles that addressed health and safety of nurses and healthcare workers, and nanotechnology use in healthcare, English written articles from peer-reviewed scholarly journals. Exclusion criteria consisted of non-English articles, nanotechnology related to professions, and article not related to healthcare.

The CINAHL search yields four hundred and five articles. Among those, thirteen articles were included in this review. All thirteen abstracts were reviewed prior to inclusion. The PubMed search yields sixty-one articles. Among those, six articles were included in this review. All five abstracts were reviewed prior to inclusion. The other articles were excluded due to the lack of applicability.

A total of nineteen articles were synthesized for literature review. Other articles were included for discussion purposes throughout the paper. The articles included varied from original research to expert opinions. The review was organized under three headings: 1) Nanotechnology benefits, 2) Nanotechnology risks, and 3) management of nano-associated occupational hazards in healthcare. The Johns Hopkins Nursing Evidence-Based Practice Research Evidence Appraisal tool (Dearholt, & Dang, 2012) was utilized for evaluating the evidence. Please refer to appendix A for literature review matrix and evidence evaluation.

**Nanotechnology Benefits**

Four of the nineteen articles had the primary focus on the benefits of Nanotechnology in healthcare. More specifically, the articles addressed topics from current and potential usage of nanotechnology in health care delivery and to address public health issues.

Bell, Schwartz, Boyer, Koithan, and Brooks (2013) through a literature review, concluded that nanoparticles' large ratio of surface-area-to-volume confers increased reactivity and adsorptive capacity, with unique electromagnetic, chemical, biological, and quantum properties has the potential to better address infectious diseases. Nanomedicine using traditional agents from alternative systems of medicine can facilitate progress in integrative public health approaches to infectious diseases (Bell et al., 2013)

One study addressed how Nanomedicine, through nano-enable drugs, has the potential to address many of the pressing challenges in global health, such as HIV/AIDS and cancer in the near future, with many studies showing how nanotechnology can be used to increase the efficacy and safety of treatment compared with conventional approaches (Tsai et al., 2014).

Two studies addressed the usage of nanotechnology in malaria control (Najer et al., 2014; Rathee, Dalal, Kumar, & Ruhil, 2015). Nanotechnology has the potential to offer solutions currently under investigation, such as nanomimics, flow strip chip for diagnosis of malaria infection using nano/microfluidic technologies, nanosomal smartphone-like malaria detection/Nanosomal DNA analyser to detect malaria DNA strain, vapor nanobubbles that detects low levels of malaria infection through the skin in seconds with a laser scanner, and nanocarriers for drug delivery (Najer et al., 2014; Rathee, Dalal, Kumar, & Ruhil, 2015).

**Nanotechnology Risks**

Ten of the nineteen articles had the primary focus on the risks of Nanotechnology in healthcare. Exposure to nanoparticles can impose health risk for those handling it. Nanomaterials have different chemical, physical and biological characteristics than larger materials of the same chemical composition creating the potential danger for human and environmental health (Hoet, Legiest, Geys, & Nemery, 2009). The nanoparticles able to penetrate the epidermal layer may cause allergic reactions, due to the release of substances with notorious sensitizing potential, such as metals (e.g., nickel, cobalt, palladium), which can induce an allergic contact dermatitis or respiratory symptoms (Larese, Mauro, Adami, Bovenzi, & Crosera, 2015). There is also concerns regarding nanoparticles' persistence in the body. Traditional molecular therapeutics are generally processed by the body and the metabolites are excreted soon after administration, but some nanoparticles have demonstrated persistent in vivo deposits for months or years (Etheridge et al., 2013)

Petrick, Rosenblat, Paland, and Aviram (2014) found that exposure to nanoparticles (NPs) of silicon dioxide (SiO2) can play a major role in the development of cardiovascular diseases when the NP cross tissue and cellular barriers and also find their way into the circulatory system. Several studies with single-walled carbon nanotubes (SWNTs) administered to the lung of mice by oropharyngeal aspiration and by inhalation reported inflammation, granuloma formation and fibrosis in the lung, and multiwalled carbon nanotubes (MWCNT) were found to cause asbestos-like effects of the mesothelium following intracavitary injection of high doses in rodents (Oberdörster, 2010). According to Song, Liu, Feng, Wei, and Shao (2015) several in vivo and in vitro studies have demonstrated that TiO2 nanoparticles, for their nanoscale, possessed toxic properties on the brain.

Occupational cohorts are likely to have earlier and higher exposures than the general populations/consumers, and that may occur through inhalation, ingestion, and dermal absorption (Ling et al., 2011). According to Murashov and Howard (2015) the more NEMPs are used in patient care, the greater the potential exposure to NEMP s among all types of health care industry workers and the potential for harmful exposures. Liou et al. (2012) explored the potential health effects of nanoparticles exposure on occupational cohort of 227 workers in 14 nanomaterial handling plants in Taiwan. The study revealed depression of antioxidant enzymes, and increased expression of cardiovascular markers were found among workers handling nanomaterials (Liou et al., 2012). Journeay and Goldman (2014) reported a case of throat irritation, nasal congestion, facial flushing and skin reaction due to nickel nanoparticles in a laboratory worker.

**Management of Nano-associated Occupational Hazards in Healthcare**

Five of the nineteen articles had the primary focus on management and safety recommendations on nano-associated occupational hazards. Gilden (2010) addressed the need for nurses, and nurse administrators specifically, to first self-educate on the health risks and exposure potentials associated with chemicals used to and clean/sanitize various parts of the facility in order to learn about practices to reduce exposure to toxic chemicals. Specifically to Nanotechnology, Staggers et al. (2008) suggests that clinicians would need education about nanomaterials with special emphasis on the safe use of the new products.

Yokel and Macphil (2011) suggested that given the notable lack of information, current recommendations to minimize exposure and hazards related to nanoparticles are largely based on common sense, knowledge by analogy to ultrafine material toxicity, and general health and safety recommendations.

Ramachandran, Howard, Maynard, and Philbert (2012) suggested that the rapid developments in nanomedicine research raise concerns relating to the protection of researchers, lab workers, health care workers as well as family members involved in clinical trials involving nanotherapeutics. Goyette and Journeay (2014) suggest that occupational health nurses may find themselves at the forefront of managing workers' exposures and illness related to nanoparticles, and a heightened sense of awareness regarding the presence of nanoparticles materials in the workplace, current safety strategies, as well as potential worker exposures.

**Summary of Reviews**

Among the articles reviewed, healthcare interventions involving the utilizations of nanotechnology were discussed. Promising interventions benefitting healthcare ranged from treatment and prevention of infectious diseases to cancer and HIV treatment (Bell et al., 2013; Najer et al., 2014; Rathee, Dalal, Kumar, & Ruhil, 2015). Risks and toxicity of nanoparticles is a topic that continues to gain attention. Nanoparticle exposure and risk for adverse health effects were addressed by the reviewed articles. More specifically, risks for the development of cardiovascular disease (Liou et al., 2012; Petrick et al., 2014) respiratory complications (Larese et al., 2015; Ling et al., 2011; Oberdörster, 2010), and dermatological reactions (Journeay & Goldman, 2014; Larese et al., 2015). Song et al., (2015) addressed neurotoxicity due to exposure to titanium dioxide nanoparticles. Further, the articles also addressed management of occupational nanoparticle exposure and how prudent safety actions should be taken. Specifically, the need for provider education on nanotechnology and safety were addressed (Staggers et al., 2008). In addition, current safety measures used for ultrafine materials should be use due to the lack of information on nanoparticle's toxicity were discussed (Yokel & Macphil, 2011). Lastly,

Goyette and Journeay (2014) addressed the important role that occupational health nurses may have in the management of illnesses related to nanoparticle exposure.

### Nursing Implications

Nurses have a privileged position to advocate for safety policies, and the ethical use of nanotechnology for patients as well as for themselves. Patients, clinicians, public health agencies, the healthcare industry, consumers, and society all need advocates for the safe and ethical use of nanomaterials (Staggers et al., 2008). Further, nurses can advocate for the inclusion of nanotechnology content in the nursing education curricula in order to prepare the next generation of nurses. According to Bryant, Chuoke, Inocencio, and Arrieta (2009) healthcare professionals will have to re-educate themselves and adapt to these changes in drug delivery systems, and will need to understand the drug metabolism and pharmacokinetics of nanomedicines in order to achieve appropriate therapeutic dosing. Nurses can play a key role in research, in particular as it relates to the impact of nanotechnology in nursing knowledge and practice. Ultimately, nurses' contributions can influence the development of safety policies for nanotechnology.

## Theoretical Framework

The Kurt Lewin Change Theory (1951) was chosen to guide the educational presentation about Nanotechnology. Lewin's (1951) theory involves three steps: unfreezing, changing and refreezing, and recognizes change as a constant factor of life ensuing from a dynamic balance of driving and opposing forces" (Zaccagnini, & White, 2011). The process of change entails creating the perception that a change is needed, then moving toward the new, desired level of behavior and finally, solidifying that new behavior as the norm. Lewin (1951) theory can lead to a better understanding of how change affects the organization, identify barriers for successful

implementation and is useful for identifying opposing forces that act on human behavior during change, therefore overcoming resistance and leading to acceptance of new technologies by nurses (Bozak, 2003).

In order to apply this theory, it is pertinent that the driving and restraining forces must be analyzed before implementing a planned change (Kritsonis, 2005). The Lewin's Change Theory (1951) stages guided the actualization of the educational capstone project. In the "Unfreezing Stage", an assessment of the current educational strategies used by ABC Nurses Association to educate its nurses was done. In addition, the driving forces for the change from well know health topics towards learning about an unfamiliar topic and the likely resisting forces against were identified. During this stage, nurses were engaged in order to have a better understanding of how this educational intervention was helpful for the delivery of Nanotechnology content, and how it was benefit nursing practice. In the "Changing Stage" is where the actual educational project was implemented. In this case, in-person presentation about Nanotechnology, with YouTube video embeded in the PowerPoint was provided to nurses. In this stage, the nurses were also reminded of the reasons for the change and how it was going to benefit them once fully implemented. In the "Refreezing Stage" is where the change in topics was made to ABC Nurses Association's educational offered programs was accepted and refrozen as the new norm. Lastly, the application of Lewin's Change Theory (1951) provided a structured approach that can help nurses to overcome challenges related to change needed to improve nurse's educational needs. For more information about Lewin's Change Theory (1951), please refer to appendix B.

## Project Design

The project utilized a comparison of the single group of nurses seeking continuing education credits using a pre- and posttest format design. Individual consent was obtained

(Appendix C). The DNP student administered a pretest knowledge survey (Appendix D) before conducting the educational intervention. Then two posttests were administered: (a) knowledge survey (Appendix E), (b) process/program evaluation questionnaire (Appendix F).

### Goals, Objectives and Expected Outcomes

**Goal.** The overall goal was to increase the nurses' knowledge about Nanotechnology, its potential benefits and risks associated with Nanotechnology, types of nanoparticles and its applications in medicine and everyday products, exposure routes and precautionary methods, and nursing implications.

**Objectives.** The objectives of this capstone project were: 1) to implement the evidence-based educational program about Nanotechnology, using a PowerPoint presentation, 2) to evaluate the effect of the educational program on nurses' knowledge improvement about Nanotechnology, 3) to examine the nurses' perception of the implementation process.

**Expected Outcomes.** The expected outcomes for the project were the following: (a) 80% of the participants would respond correctly to the posttest knowledge survey (b) there will be an increase in mean knowledge scores between pre-, and post-intervention, and (c) 80% of the participants would satisfy with the delivery of an educational intervention (process/program evaluation questionnaire)

## Project Methods

### Participants

The educational intervention was offered in a partnership with the ABC Nurses Association, for nurses seeking continuing education credits. There were a total of seven participants from several clinical specialties.

**Measurements and Data Collection**

Demographic information was obtained from participants at the time of sign up (Appendix G). An assessment of patients' prior knowledge in relation to Nanotechnology was obtained using a pre knowledge survey (Appendix D) before initiating the intervention. The survey was developed by the DNP student and consisted of 6 questions related to previous experience with Nanotechnology, applications of Nanotechnology in medicine, environment, household and other products, routes of exposure and health impacts. A post knowledge survey using the same questions as in the pretest, was utilized to determine change in knowledge after the educational intervention. At the completion of the educational sessions, a process/program evaluation questionnaire consisting of eight questions, was administered to measure the participants' satisfaction outcomes and to assess the feasibility and acceptability of the Nanotechnology education program and to provide the opportunity for recommendations and suggestions.

Once the surveys were collected, the responses were analyzed utilizing descriptive statistics (frequency and percent), to see knowledge improvement before and after the educational intervention. Each of the six questions in the knowledge survey was scored in a correct percentage basis, with 100% being the highest (perfect) score, and 0% being the lowest. Then the percentage scores from the pre-tests were compared with the post-tests scores. Analyses were conducted using IBM SPSS version 23. Only participants who completed the demographic data, pre-test, and post-test results were used in this analysis (N=7).

**Implementation**

The program was advertised in the ABC Nurses Association's continuing education catalog, website, and Facebook page. Participants were able to register online, by phone, and in-

person. The implementation process began with registration. Individual consent was obtained prior to the educational intervention (Appendix C). Participants received the program's folder. The program's folder contents (Appendix H) consisted of: the presentation schedule, program description handout, ABC Nurses Association's program evaluation form, notebook, PowerPoint printout, a NIOSH handout "Nanotechnology & Workplace Safety and Health", another handout "Nanomaterials in Construction and Other Jobs", two journal articles providing information on Nanotechnology and Occupational health, and on Nanotoxicology.

Following the participants were instructed to complete the demographic questionnaire, and pre- knowledge survey anonymously. Subsequently, the DNP student's preceptor welcomed the participants and introduced the DNP student and the program. Then the DNP student started to present the content of the program.

Using a PowerPoint presentation, the single educational intervention was conducted in the conference room in the participating institution on February 16, 2016, at 5:00pm, and lasted two hours. The information contained in the PowerPoint included the following:

1. Nanotechnology background and definition of various types of nanoparticles
2. Nanotechnology applications in medicine and other products, advantages and disadvantages
3. Occupational health concerns with potential nanoparticle exposure routes
4. Discussion on precautionary approach that can be utilized when working with substances containing nanoparticles for both patient and worker protection.
5. Future nursing implications

The participants were allowed to ask questions during the presentation, as well as at the end of the program. After the end of the presentation, questions from participants were answered,

the DNP thanked the ABC Nurses Association's staff and preceptor for the opportunity, and the participants for their time. The DNP student then guided the participants to complete the post knowledge survey and the process/program evaluation questionnaire. Once participants finished, the DNP student delivered their credit education unit document. The DNP student plans to lead a social media follow-up to engage the participants to address questions related to Nanotechnology.

### Ethics and Human Subjects Protection

This project was an educational program with the goal to assess nurses' knowledge about nanotechnology and its implications for health and safety. The participants were members of the ABC Nurses Association. Each individual participant's pre- and posttest results were anonymous, and the results were reported only as a percentage, to compare before and after the educational intervention. An Institutional Review Board (IRB) approval was not needed for this DNP QI project. The DNP student has completed the Collaborative Institutional Training Initiative (CITI) program. Health Insurance Portability and Accountability Act (HIPPA) policies was not be breeched since no actual patient data was reviewed.

## Results

### Participant' Demographic Characteristics

There were a total of seven participants. As illustrated in Appendix I, all participants (n=7) were female (100 %). For the age of participants, 14.3% (n=1) of the participants were between 31-40 years of age, 14.3% (n=1) were between 41-50 years of age, and 71.4% (n=5) were 61 years old or older. For years working in nursing, 14.3% (n=1) worked 0-10 years, 28.6% (n=2) 21-30 years, 14.3% (n=1) 31-40 years, 28.6% (n=2) 41-50 years, and 14.3% (n=1) 50 years or higher. The participants' primary clinical specialty included mental health, public health, adult health, occupational health, critical care, gerontology, and perioperative.

**Prior Experience with Nanotechnology**

In the pre-test 28.6 % of the participants' responded "yes", and 71.4% responded "no'. For the definitions, 0% of participants defined Nanotechnology, Nanomedicine or nanoparticles. This question was not present in the post-test.

**Pre and/ Post- Intervention knowledge Survey Results**

Percentage scores for each of the pre- and post-intervention knowledge surveys are presented in the table in Appendix J.

**Knowledge Survey Question # 1. Are you familiar with nanotechnology research and develop?** In the pre-test 71.4% of the participants reported "they were not familiar with nanotechnology at all", and 28.6% reported "very little". In the post-test 100% of the participants reported to be "somewhat" familiar with Nanotechnology (Appendix K).

**Knowledge Survey Question # 2. Name three nanotechnology applications in medicine.** In the pre-test 14.3% of the participants named three nanotechnology applications in medicine. In the post-test, 85.7% answered the question correctly. There was a 71.4% increase.

**Knowledge Survey Question # 3. Name three nanotechnology applications in environment?** In the pre-test, no participants named three nanotechnology applications in the environment. In the post-test, 71.4% answered the question correctly. There was a 71.4% increase.

**Knowledge Survey Question # 4. Name three household or other products that contain nanoparticles?** In the pre-test, no participants named three household or other products

that contain nanoparticles. In the post-test, 100% of the participants answered the question correctly. There was a 100% increase.

**Knowledge Survey Question # 5. Name three routes of exposure of nanoparticles?** In the pre-test 14.3% of the participants named three routes of exposure of nanoparticles correctly. In the post-test, 100% answered the question correctly. There was an 85.7% increase.

**Knowledge Survey Question # 6. Name three potential health problems nanoparticles might cause?** In the pre-test, no participants named three household or other products that contain nanoparticles. In the post-test, 57.1% answered the question correctly. There was a 57.1% increase.

The results from the educational intervention with the nurses showed a 77.1% increase in the post knowledge survey, therefore satisfying expected outcome (b) an increase in mean knowledge scores between pre-, and post-intervention. The expected outcome (a) 80% of the participants would respond correctly to the posttest knowledge was not fully met. Only three post knowledge survey questions that were answered correctly, 80% or above. For the question *named three nanotechnology applications in medicine*, 85.7% answered the question correctly. For the question *named three household or other products that contain nanoparticles*, for the question *name three routes of exposure of nanoparticles*, 100% answered the question correctly.

## Process and Program Evaluation Results

Only 42.9% (n=3) of the participants partially completed the process/program evaluation questionnaire. 42.9% responded “yes” for the program being presented at a convenient time, convenient location, and for the room being conductive to learning. For the question *what did*

*you learn from this educational intervention?* 42.9% of the participants provided responses about related to "what Nanotechnology is about, different types of nanoparticles, applications, and impact of Nanotechnology in healthcare and in nursing". For the question *what recommendations do you have for improvement? 28.6%* (n=2) of the participants requested that "the presentation to continue to be offered". 14.3% of the participants responded that to the question *what recommendations do you have to facilitate provider engagement?*. For the question *what learning opportunities would you like related to this topic?* 28.6% (n=2) of the participants emphasized the "need to learn more about specific products containing nanoparticles and to find ways to ban them", and that they would "like to learn more about the application of Nanotechnology to prevent dementia and Alzheimer's disease". For the question *In your opinion, a Nanotechnology lecture, is necessary to increase nurses' awareness about potential benefits and risks related to the use of this technology in healthcare? If so, why?* 42.9% (n=3) of the participants agreed that a "Nanotechnology lecture is necessary to increase the knowledge about Nanotechnology, its risks, its presence in the environment, exposure potential, as well as safety as it relates to medications containing nanoparticles".

The expected outcome (c) 80% of the participants being satisfied with the delivery of the educational intervention (process/program evaluation questionnaire) was not met, only 42.9% of the participants completed the process/program evaluation questionnaire.

**Facilitators and Barriers**

ABC Nurses Association was an important resource as it relates to the access to its members and the capability to create, and disseminate educational content that is appropriate and beneficial for nurses and ultimately patients. Further, the collaboration network between ABC Nurses Association and other nurses association offered the opportunity to engage other

facilitators for the educational intervention. It is important to acknowledge the barriers that impacted the implementation of the capstone project, such as the weather, participation rate, scheduling conflicts, work commitments, transportation issues, and lack of interest.

## Discussion

The results from the educational intervention with nurses showed an increase in knowledge about Nanotechnology after the education. As the pre knowledge survey scores and anecdotal reports demonstrated, there has been a general lack of knowledge about Nanotechnology among nurses in healthcare. Without Nanotechnology information being available, nurses may continue to be unaware about the application of Nanotechnology in healthcare, leading to potential health and safety issues. The study findings indicate an important role of Nanotechnology education program to improve safety for both nurses and patients.

This program utilized many examples of Nanotechnology applications in medical and other products, while educating participants about routes of exposure, potential benefits and risks to health, as well as nursing implications. To achieve quality healthcare outcomes, it is imperative that nurses are aware of new technologies, such as Nanotechnology impacting nursing practice. The study participants' had increased scores in the post knowledge survey; this research translation suggests that an educational intervention is effective in increasing the knowledge in Nanotechnology among nurses. While the effectiveness of this program may not be generalizable because of a small convenient sample used in the study, it opens a discussion on the potential of tailoring educational interventions to the needs of nurses. The overall goal was to increase the nurses' knowledge about Nanotechnology, its potential benefits and risks associated with Nanotechnology, types of nanoparticles and its applications in medicine and everyday products, exposure routes and precautionary methods, and nursing implications was met.

The Nanotechnology educational intervention program was well accepted by the participants. A number of the comments made by the participants about the program were overwhelmingly positive. The participants reported that they "enjoyed the topic covered" and expressed that they" learned a lot from the program, particularly information provided on products containing nanoparticles and the application of Nanotechnology in healthcare". The participants also mentioned that "the information on various routes of exposure and potential health impact was very valuable". The participants further mentioned that they "felt that the program was informative and innovative and more nurses should attend".

**Nursing Practice Implications**

The results from this educational capstone project have implications for nursing practice. The results shows that educating and training nurses can increase the knowledge about Nanotechnology, in particular as it relates to exposure prevention to nanoparticles, and to the health and safety of both nurses and patients. Nurses need to be aware of emerging technologies that can pose a new type of hazards, such as Nanotechnology. It is important for nurses to understand risk factors, the potential environmental hazards and precautionary strategies. This project is also evidence that there is still a need for increased education targeting nurses about Nanotechnology. Nurses are in a prime position to guide future educational projects and research involving Nanotechnology's application in healthcare. Well-informed nursing workforce will be better equipped to identify medical products containing nanoparticles, to practice safely and to educate patients about treatments using such products.

**Limitations**

The findings of this capstone project should be interpreted in light of several limitations. This project had limitations related to attendance. The educational program information was sent to ABC Nurses Association's members who were all invited to attend the educational intervention, but a small number of participants attended (n=7). A possible reason for the small sample was the inclement weather. The original date (February, 9th, 2016) for the program to be implemented had to be cancelled due to the effects of a snowstorm that took place during the overnight hours. On the alternative date (February 16th, 2016), there was a severe thunderstorm passing through the area at the time that the educational intervention was to going to be delivered. The DNP student had to implement this intervention in order to comply with the academic requirements of the semester. If the DNP student could have implemented the education later in the spring, perhaps more nurses could have attended the program. Other alternative would be offering a web-based program.

Another limitation was that participants' IDs were not collected because of ANCC CE program requirements, therefore the descriptive statistics were used instead of inferential statistics, such as a paired t-test. By utilizing descriptive statistics was a limitation because the results cannot not be generalizable, and the differences are not supported by statistical significance.

Other limitation was related to the process/program evaluation questionnaire. Although the process/program evaluation questionnaire was handed out upon entering and completion was encouraged, but only 30% of the participants completed them. Potential reasons are related to the process/program evaluation questionnaire was printed in the back of the last page of the

evaluation package, and limited time frame to complete all the forms. Recommendations to increase the return rate would be making the process/program evaluation questionnaire more visible, to provide more time for completion, and the availability of online surveys. Suggestions for future DNP students would be related to exploring alternative and more innovative program delivering methods, such as case scenario, or simulation approaches.

## Conclusion

Nurses, among other healthcare workers face work-related injuries and hazards exposures in the execution of their jobs. It is important for nurses to understand risk factors, the potential environmental hazards and precautionary strategies. It is also important for nurses to be aware of emerging technologies that can also pose a new type of hazards, such as Nanotechnology. This educational capstone project shows that educating and training nurses can increase the knowledge about Nanotechnology, potentially preventing exposures to nanoparticles, and ultimately impacting the health and safety for both nurses and patients. Nurses are in an important position to impact future projects and research about Nanotechnology's application in healthcare. Appropriate education programs targeting nurses about Nanotechnology can lead to a more informed nurse's population.

The findings of this project were shared with ABC Nurses Association's management following data analysis, and the results will be further disseminated to its members. The ABC Nurses Association is an opportune venue to teach nurses about health and safety implications of Nanotechnology to nurses. The DNP student is hopeful that ABC Nurses Association will continue to teach Nanotechnology content in their offered courses, as the Nanotechnology program was created for the organization with a CE component. This project will ultimately

become a permanent program at ABC Nurses Association resulting in a wider spread of the Nanotechnology knowledge.

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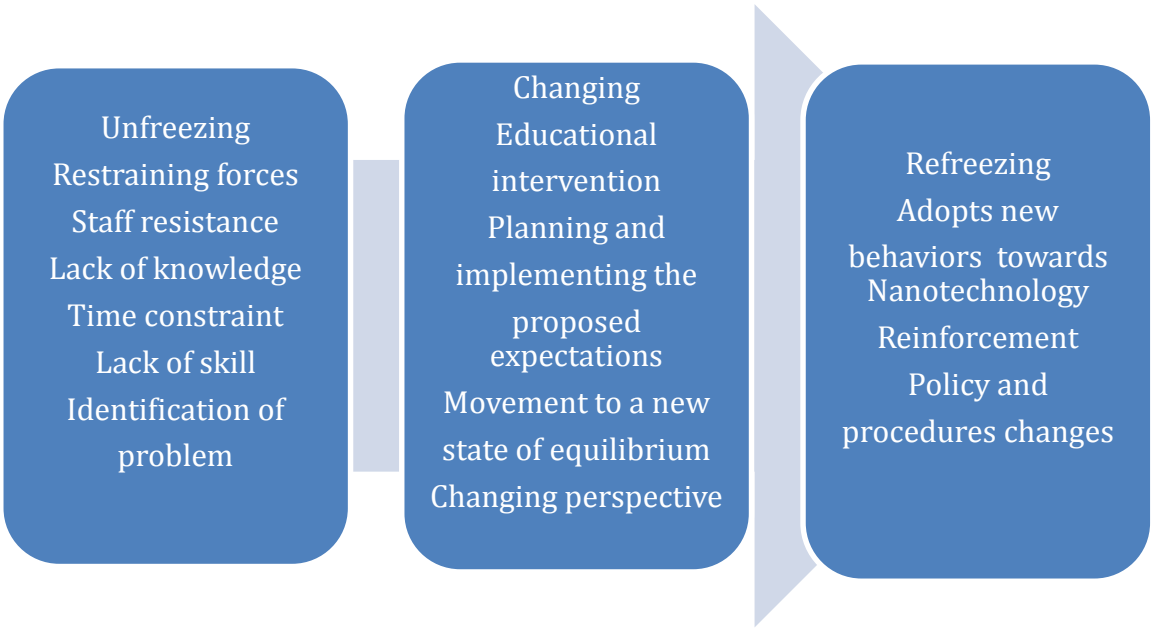
# Appendix A: Evidence Table

| Citation | Sample / Setting | Type/ Design | Outcomes/Results | Strengths of Evidence |
|---|---|---|---|---|
| Bell et al. (2013) | No subjects | Literature Review | Nanomedicine is integrative, blending modern technology with natural products to reduce toxicity and support immune function. Nanomedicine using traditional agents from alternative systems of medicine can facilitate progress in integrative public health approaches to infectious diseases. | Level 5/ Quality B |
| Etheridge et al. (2013) | No subjects | Literature Review | A detailed search of the literature, clinical trial data, and Web identified 247 applications and products that were confirmed or likely nanomedicine interventions (under our definition) and which were approved for use, under clinical study, or on the verge of clinical study. | Level 5/ Quality B |
| Giacobbe et al. (2009) | No subjects | Non-experimental design | Until sufficient knowledge has been acquired ,recognized protection strategies, which can be applied to potentially harmful substances, must be adopted, thereby reducing, as much as possible, potential exposure of workers to SWNTs and nano-TiO2. | Level 3/ Quality B |
| Goyette & Journeay (2014) | No subjects | Expert opinion | Nanotechnology is a reality with benefits, risks, safety and exposure management implications, as well as nurses' involvement. | Level 5/ Quality B |
| Hoet et al. (2009) | No subjects | Literature Review | The properties of nanomaterials are unique, benefits, risks and regulation on exposure and management are necessary. | Level 5/ Quality B |
| Journeay & Goldman (2014) | Female chemist | Case Report | In conclusion, a worker developed nickel sensitization when working with nanoparticle nickel powder in a setting without any special respiratory protection or control measures. | Level 5/Quality |
| Larese et al. (2015) | No subjects | Literature Review | Concluded that for some types of NPs both penetration and permeation through the skin have been shown, but for many NPs it is still uncertain. | Level 5/Quality B |
| Ling et al. (2011) | No subjects | Non-experimental design | The present risk management control strategy suggests that the most effective way to reduce airborne NPs is to incorporate the use of a ventilating system combined with N95 respirator protection. This will enable the concentrations of TiO2-NPs and CB-NPs to be reduced to acceptable exposure levels. | Level 3/ Quality B |
| Liou et al. (2012) | 227 workers. | Cross-sectional design | Depression of antioxidant enzymes and increased expression of cardiovascular markers were found among workers handling nanomaterials. | Level 3/ Quality B |
| Murashov & Howard (2015). | No subjects | Expert commentary | The more NEMPs are used in patient care, the greater the potential exposure to NEMPs among all types of health care industry workers. These exposures can potentially be harmful. | Level 5/ Quality B |
| Najer et al. (2014) | No subjects | Non-experimental design | Interrupting the parasite life cycle using nanomimics and then subsequently eliciting an immune response represents a promising alternative to current drug treatment and vaccination strategies | Level 3/ Quality B |
| Oberdörster (2010) | No subjects | Literature Review | Even without being able to perform a quantitative risk assessment for ENMs, due to the lack of sufficient data on exposure, biokinetics and organ toxicity, until we know better it should be made mandatory to prevent exposure by appropriate precautionary measures/regulations and practicing best industrial hygiene to avoid future horror scenarios from environmental or occupational exposures. | Level 5/ Quality B |
| Petrick et al. (2014) | No subjects | Literature Review | Found that exposure to nanoparticles (NPs) of silicon dioxide (SiO2) can play a major role in the development of cardiovascular diseases when the NP cross tissue and cellular barriers and also find their way into the circulatory system | Level 5/ Quality B |
| Ramachandran, et al. (2012) | No subjects | Expert opinion | The rapid developments in nanomedicine research raise significant questions relating to the protection of researchers, lab workers, and health care workers engaged in clinical trials involving nanotherapeutics. | Level 5/ Quality B |
| Rathee et al. (2015) | No subjects | Expert opinion | Nanotechnology has the potential to empower a local response to challenges such as the diagnosis and treatment and prevention of this deadly disease and we can see it's as a better approach to solve out the all problems. | Level 5/ Quality B |
| Staggers et al. (2008) | No subjects | Literature Review | Clinicians and healthcare providers must engage in educational activities related to nanotechnology in healthcare. | Level 5/ Quality B |
| Song et al., (2015) | No subjects | Literature Review | Several in vivo and in vitro studies have demonstrated that TiO2 NPs, for their nanoscale, possessed toxic properties on the brain. | Level 5/Quality B |
| Tsai et al. (2014) | No subjects | Expert opinion | Nanomedicine has the potential to address many of the pressing challenges in global health in the near future. | Level 5/ Quality B |
| Yokel & MacPhail (2011) | No subjects | Literature Review | Given the notable lack of information, current recommendations to minimize exposure and hazards are largely based on common sense, knowledge by analogy to ultrafine material toxicity, and general health and safety recommendations. | Level 5/ Quality B |

*Dearholt, S.L., & Dang, D. (2012). Johns Hopkins nursing evidence-based practice model and guidelines (2nd ed.). Sigma Theta Tau International, Indianapolis, Indiana.

## Appendix B: Lewin's Change Theory




### STAGES

Lewin's change theory consists of three distinct and vital stages:

**Unfreezing**

- Unfreezing is the process which involves finding a method of making it possible for people to let go of an old pattern that was counterproductive in some way.
- Unfreezing is necessary to overcome the strains of individual resistance and group conformity (Kritsonis, 2005).

**Changing**

- This stage involves a process of change in thoughts, feeling, behavior, or all three, that is in some way more liberating or more productive (Kritsonis, 2005).

**Refreezing**

- Refreezing is establishing the change as a new habit, so that it now becomes the "standard operating procedure."
- Without this stage of refreezing, it is easy to go back to the old ways (Kritsonis, 2005).

## Appendix C: Consent Form

Consent Form for Participation in a QI Study
University of Massachusetts Amherst

| | |
|---|---|
| Principal Investigator: | Patricia Goyette, RN, DNP(c) |
| Study Title: | Nanotechnology: Educational Program for Nurses |
| Sponsors: | XXX Nurses Association |

**1. Introduction to the study**

You are invited to participate in a QI (quality Improvement) study designed to provide an overview of Nanotechnology discussing the fundamental science of nanotechnology. The overall goal is to increase the nurses' knowledge about Nanotechnology, its potential benefits and risks associated with Nanotechnology, types of nanoparticles and its applications in medicine and everyday products, exposure routes and precautionary methods, and nursing implications.

**2. What will happen during the study?**

Participation in this study will involve completing a pre- and post-test surveys. You will receive 2-hours educational workshop provided by the PI, Patricia Goyette.

**3. Risks and Benefits:**

We believe there are no known risks associated with this study.

After you take part in this study, you may have a better understanding about use of nanotechnology in nursing care practice. We also hope that your participation in the study may bring a sense of satisfaction that you helped advanced the nursing science.

**4. How your privacy is protected**

All of your responses will be held in anonymous. All study records (including surveys you will fill out) will be kept in a locked cabinet in the PI's office. Access to these data will be limited to the researchers involved in this study. At the conclusion of this study, we may present our findings. Information will be presented in summary format and we will not use identifiable data in any research reports.

**5. Questions**

If you have any questions about this study, contact the investigator Patricia Goyette, **phone:** 617-381-1509, **email**:pgoyette@nursing.umass.edu

**6. Your rights**

Your participation in this study is voluntary. You are free to decline to participate, to end your participation at any time for any reason, or to refuse to answer any questions.

**7. Review Board approval**

The Institutional Review Board (IRB) at University of Massachusetts Amherst has approved this study. If you have any concerns about your rights as a participant in this study you may contact the Human Research Protection office via email (humansubjects@ora.umass.edu ); telephone (413-545-3428); or mail (Office of Research Affair,108 Research Administration Building, University of Massachusetts, 70 Butterfield Terrace, Amherst, MA 01003

**8. Please read the following statement and sign below if you agree**

I have read this form and decided that I will participate in the project described above. The general purposes and particulars of the study as well as possible harms and inconveniences have been explained to my satisfaction. I understand that I can stop being in the study at any time.

| _____ | _____ | |
|---|---|---|
| Participant Signature: | Print Name: | Date: |

By signing below I indicate that the participant has read and, to the best of my knowledge, understands the details contained in this document and has been given a copy.

| _____ | _____ | |
|---|---|---|
| Signature of Person Obtaining Consent | Print Name: | Date: |

## Appendix D: Pretest Knowledge Survey

Pretest____ Date_____ Member_____

Have you heard of Nanotechnology?

If yes, can you define Nanotechnology, Nanomedicine, or nanoparticles?

Are you familiar with nanotechnology research and development?

( ) To a Great Extent

( ) Somewhat

( ) Very Little

( ) Not at all

Name three nanotechnology applications in medicine?

Name three nanotechnology applications in environment?

Name three household or other products that contain nanoparticles?

Name three routes of exposure of nanoparticles?

Name three potential health problems nanoparticles might cause?

## Appendix E: Post-test Knowledge Survey

Posttest____ Date_____ Member_____

Are you familiar with nanotechnology research and development?

( ) To a Great Extent

( ) Somewhat

( ) Very Little

( ) Not at all

Name three nanotechnology applications in medicine?

Name three nanotechnology applications in environment?

Name three household or other products that contain nanoparticles?

Name three routes of exposure of nanoparticles?

Name three potential health problems nanoparticles might cause?

## Appendix F: Process/Program Evaluation Questionnaire

Date_____ Member_____

1. Was the program presented at a convenient time? Yes No
2. Was the program presented at a convenient location? Yes No
3. Was the room conducive to learning? Yes No
4. What did you learn from this educational intervention?

5. What recommendations do you have for improvement?

6. What recommendations do you have to facilitate provider engagement?

7. What other learning opportunities would you like related to this topic?

8. In your opinion, a Nanotechnology lecture, is necessary to increase nurses' awareness about potential benefits and risks related to the use of this technology in healthcare? If so, why?

## Appendix G: Demographic Questionnaire

Demographic Questionnaire

Please fill in the blank or check the appropriate boxes for each of the following questions.

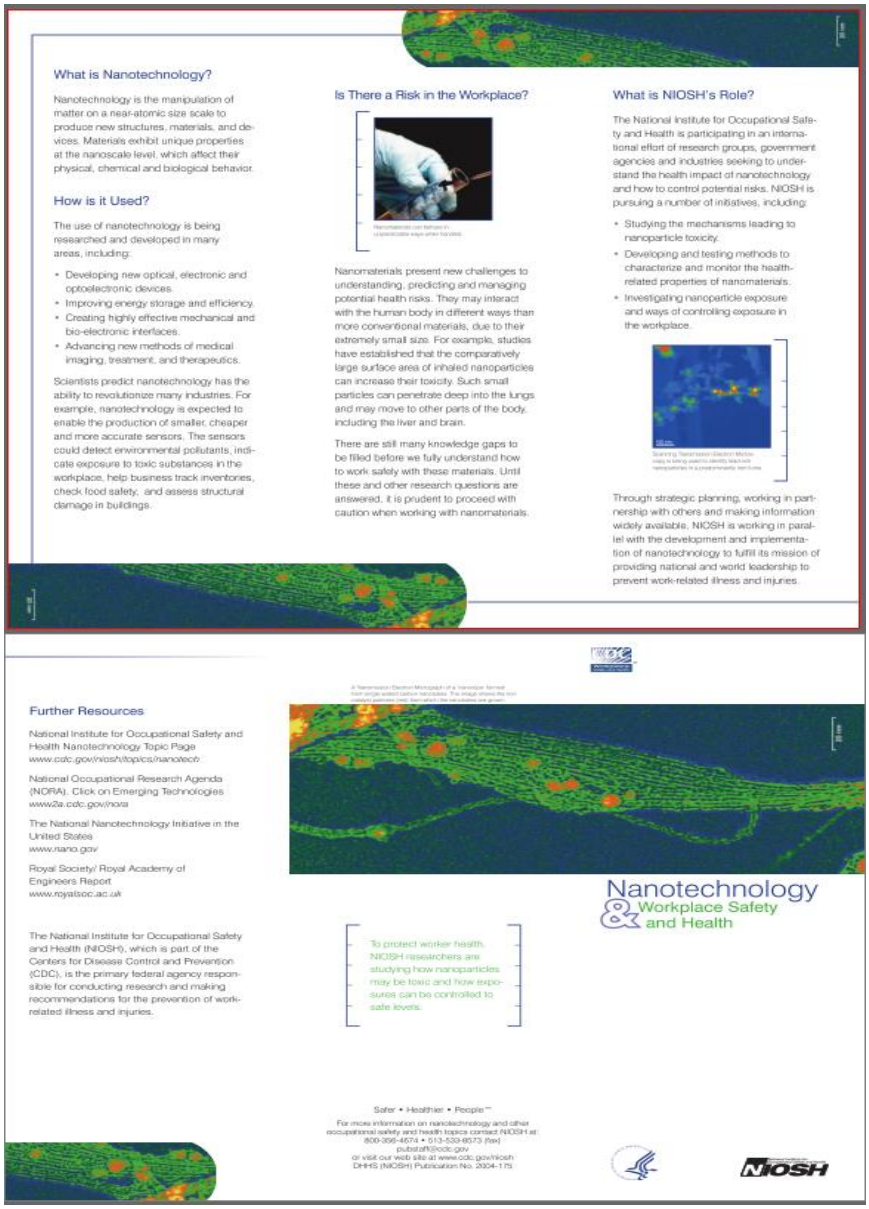
1. What is your age?_____yrs.

2. What is your gender? □ Female □ Male

3. How long have you been a RN? _____ yrs.

4. What is your primary clinical specialty?
□ adult health
□ cardiovascular
□ community
□ critical care
□ family health
□ general med/surg
□ gerontological
□ home health
□ neurology/neurosurgery
□ occupational health
□ oncology
□ parent/child health
□ perioperative
□ psych/mental health
□ pulmonary
□ other_____

## Appendix H: Program's Folder Contents



What is Nanotechnology?

Nanotechnology is the manipulation of matter on a near-atomic size scale to produce new structures, materials, and devices. Materials exhibit unique properties at the nanoscale level, which affect their physical, chemical and biological behavior.

How is it Used?

The use of nanotechnology is being researched and developed in many areas, including:

- Developing new optical, electronic and optoelectronic devices.
- Improving energy storage and efficiency.
- Creating highly effective mechanical and bio-electronic interfaces.
- Advancing new methods of medical imaging, treatment, and therapeutics.

Scientists predict nanotechnology has the ability to revolutionize many industries. For example, nanotechnology is expected to enable the production of smaller, cheaper and more accurate sensors. The sensors could detect environmental pollutants, indicate exposure to toxic substances in the workplace, help business track inventories, check food safety, and assess structural damage in buildings.

Is There a Risk in the Workplace?

Nanomaterials present new challenges to understanding, predicting and managing potential health risks. They may interact with the human body in different ways than more conventional materials, due to their extremely small size. For example, studies have established that the comparatively large surface area of inhaled nanoparticles can increase their toxicity. Such small particles can penetrate deep into the lungs and may move to other parts of the body, including the liver and brain.

There are still many knowledge gaps to be filled before we fully understand how to work safely with these materials. Until these and other research questions are answered, it is prudent to proceed with caution when working with nanomaterials.

What is NIOSH's Role?

The National Institute for Occupational Safety and Health is participating in an international effort of research groups, government agencies and industries seeking to understand the health impact of nanotechnology and how to control potential risks. NIOSH is pursuing a number of initiatives, including:

- Studying the mechanisms leading to nanoparticle toxicity.
- Developing and testing methods to characterize and monitor the health-related properties of nanomaterials.
- Investigating nanoparticle exposure and ways of controlling exposure in the workplace.

Through strategic planning, working in partnership with others and making information widely available, NIOSH is working in parallel with the development and implementation of nanotechnology to fulfill its mission of providing national and world leadership to prevent work-related illness and injuries.

Further Resources

National Institute for Occupational Safety and Health Nanotechnology Topic Page
www.cdc.gov/niosh/topics/nanotech

National Occupational Research Agenda (NORA), Click on Emerging Technologies
www2a.cdc.gov/nora

The National Nanotechnology Initiative in the United States
www.nano.gov

Royal Society/ Royal Academy of Engineers Report
www.royalsoc.ac.uk

The National Institute for Occupational Safety and Health (NIOSH), which is part of the Centers for Disease Control and Prevention (CDC), is the primary federal agency responsible for conducting research and making recommendations for the prevention of work-related illness and injuries.

Nanotechnology & Workplace Safety and Health

To protect worker health, NIOSH researchers are studying how nanoparticles may be toxic and how exposures can be controlled to safe levels.

Safer • Healthier • People™

For more information on nanotechnology and other occupational safety and health topics contact NIOSH at 800-356-4674 • 513-533-8573 (fax) pubstaff@cdc.gov or visit our web site at www.cdc.gov/niosh DHHS (NIOSH) Publication No. 2004-175

NIOSH

Goyette, P., & Journeay, W. S. (2014). Nanotechnology and Occupational Health. *OOHNA Journal*, 33(1), 40-45.

Nanomaterials in Construction and Other Jobs Handout –

http://us5.campaign-archive1.com/?u=4586a1ad0b7ecd671f7295e07&id=2a31387ab1&e=249fd54afa

Oberdörster, G. (2010). Safety assessment for nanotechnology and nanomedicine: concepts of nanotoxicology. *Journal of Internal Medicine*, 267(1), 89-105. doi:10.1111/j.1365-2796.2009.02187.x

Tinkle, S., McNeil, S. E., Mühlebach, S., Bawa, R., Borchard, G., Barenholz, Y., Tamarkin, L. and Desai, N. (2014), Nanomedicines: addressing the scientific and regulatory gap. Annals of the New York Academy of Sciences, 1313: 35–56. doi: 10.1111/nyas.12403

## Appendix I: Participant Demographics

| Participant Demographics | | | |
|---|---|---|---|
| | | **Frequency, n** | **Percent %** |
| **Age** | 31-40 | 1 | 14.3% |
| | 41-50 | 1 | 14.3% |
| | 61 or older | 5 | 71.4% |
| | Total | 7 | 100 % |
| | | | |
| **Gender** | Female | 7 | 100% |
| | Male | 0 | 0% |
| | Total | 7 | 100% |
| | | | |
| **Years working in Nursing** | 0 -10 | 1 | 14.3% |
| | 21- 30 | 2 | 28.6% |
| | 31 -40 | 1 | 14.3% |
| | 41- 50 | 2 | 28.6% |
| | 50 or higher | 1 | 14.3% |
| | Total | 7 | 100% |

## Appendix J: Results of Pre/Post-test Knowledge Surveys

| | Pre-test Knowledge Survey | | | Post-test Knowledge Survey | | |
|---|---|---|---|---|---|---|
| | | Frequency, n | Percent, % | Frequency, n | Percent, % | Difference % |
| **Have you heard about Nanotechnology ?** | Yes | 2 | 28.6% | | | |
| | No | 5 | 71.4% | | | |
| | Total | 7 | 100% | | | |
| **Are you familiar with nanotechnology research and development?** | To a Great Extent | 0 | 0% | 0 | 0% | 0% |
| | Somewhat | 0 | 0% | 7 | 100% | 100% |
| | Very Little | 5 | 71.4% | 0 | 0% | -71.4% |
| | Not at all | 2 | 28.6% | 0 | 0% | -28.6% |
| | # of correct answers | Frequency, n | Percent, % | Frequency, n | Percent, % | Difference % |
| **1. Name three nanotechnology applications in medicine?** | 0 | 3 | 42.9% | 0 | 0% | -42.9% |
| | 1 | 2 | 28.6% | 0 | 0% | -28.6% |
| | 2 | 1 | 14.3% | 1 | 14.3% | 0% |
| | 3 | 1 | 14.3% | 6 | 85.7% | 71.4% |
| | Total | 7 | 100% | 7 | 100% | |
| **2. Name three nanotechnology applications in environment?** | 0 | 5 | 71.4% | 1 | 14.3% | -57.1% |
| | 1 | 2 | 28.6% | 1 | 14.3% | -14.3% |
| | 2 | 0 | 0% | 0 | 0% | 0% |
| | 3 | 0 | 0% | 5 | 71.4% | 71.4% |
| | total | 7 | 100% | 7 | 100% | |
| **3. Name three household or other products that contain nanoparticles?** | 0 | 4 | 57.1% | 0 | 0% | -57.1% |
| | 1 | 1 | 14.3% | 0 | 0% | -14.3% |
| | 2 | 2 | 28.6% | 0 | 0% | -28.6% |
| | 3 | 0 | 0% | 7 | 100% | 100% |
| | total | 7 | 100% | 7 | 100% | |
| **4. Name three routes of exposure of nanoparticles?** | 0 | 4 | 57.1% | 0 | 0% | -57.1% |
| | 1 | 1 | 14.3% | 0 | 0% | -14.3% |
| | 2 | 1 | 14.3% | 0 | 0% | -14.3% |
| | 3 | 1 | 14.3% | 7 | 100% | 85.7% |
| | total | 7 | 100% | 7 | 100% | |
| **5. Name three potential health problems nanoparticles might cause?** | 0 | 6 | 85.7% | 0 | 0% | -85.7% |
| | 1 | 1 | 14.3% | 3 | 42.9% | 28.6% |
| | 2 | 0 | 0% | 0 | 0% | 0% |
| | 3 | 0 | 0% | 4 | 57.1% | 57.1% |
| | total | 7 | 100% | 7 | 100% | |

## Appendix K: Prior Experience with Nanotechnology Bar Graphs