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Abstract

The OSHA Susan Harwood Grant addressing Nano-Safety training for workers was critical to build a path for future training/education courses in Nano-Safety. The duration of the grant was one year 2010-2011 to facilitate training and to assess the outcomes of the participants'' knowledge. Two trainers went to four sites to conduct courses addressing Engineered Nanomaterials (ENM) occupational health and safety emphasizing human exposure. A survey was distributed to the participants at the end of the course to assess the quality of the course as well as the quality of the instructors. Overwhelming approximately 95%, the participants were satisfied with the course and training. A pretest was given to the participants to assess their knowledge of Nano-Safety and a post test was given after the training course. To test the hypothesis to determine if the training was effective, a Paired Samples t-test was used. The findings indicated a statistically significant difference between the group mean scores from the pretest to the posttest. In essence, the participants improved drastically from the pretest to the posttest scores as a result of the training. However, there are cautions were addressing these results as the sole indicator of the participants' success.

Keywords: Nanotechnology safety, safety training, OSHA, safety professionals

Introduction

Nanotechnology is emerging as the next frontier of cutting-edge science and engineering. Nanotechnology has provided researchers and industry a new avenue to developed products that may revolutionize the world as we view it. By 2015, National Nanotechnology Initiative has estimated that economic global impact could reach around $1 trillion dollars (Wedin, 2006). Also, industry has a monumental challenge of preparing a workforce to think and develop below the 100 nanometer (nm) boundary. Working with materials on the nano scale requires specialized training, and technical background is needed to manufacture Engineered Nanomaterials (ENMs) (Trybula, Fazarro, & Kornegay, 2009).

Researchers, technicians, manufacturing engineers, and production workers will be needed for a nanotechnology workforce (NNI, 2009). Dr. Mihail Roco, NSF Senior Advisor on Nanotechnology, is a strong advocate of nano workforce education. Roco stresses the training of people is vital for long-term success in the field of nanotechnology (Roco, 2001). By 2015, there will be approximately two million workers globally in nanotechnology (Roco, 2003). However, Roco's prediction may not encompass the United States as having the majority of nanotechnology workers.

There are workers producing carbon nanotubes in various applications (e.g. conductive plastics, and aeronautical applications) (Nanocyl, 2009). The workforce in these types of companies, such as Bayer, and Nanocomp Technologies that produce ENMs are estimated to contain at least 620 workers, which while small, is estimated to grow at an annual pace of 15-17% and represents only one of many different classes of nanomaterials (Task Force ACOEM, 2011).

A report identified sixty-one U.S.-based companies that manufacture or handle carbon-based nanomaterials, in particular carbon nanotubes Nanoparticle (Task Force ACOEM, 2011). This report is disturbing in the fact that sixty-one companies may have inadequate safety procedures for workers handling EMNs and most importantly, workers may not have the proper training to identify potential hazards, which may be very dangerous to welfare of workers and outside the confines of the workplace. According to studies, some carbon nanotubes (the most research and produced in industry, from a technological and toxicological viewpoint) have produced asbestos-like symptoms in rodents (Takagi & et. al, 2008). See figure 1 for illustration of a nanocarbon tube. Moreover, work is needed to research physical and chemical properties of nanomaterials and how the properties relate to unwanted health effects.

Figure 1. Carbon Nanotubes at 20 Nanometer (nm)

Figure 1. Source: Dominick E. Fazarro-Nanotechnology Course Resources II: Pattering, Characterization & Applications at NACK Center at Penn State Oct 5-9, 2011

Properties of nanomaterials cannot be generalized to determine one health and safety effects (Fazarro & Trybula, 2011). As new EMNs emerge, there is increased uncertainty of how they will behave (Shatkin and et. al, 2010). Research of the properties of EMNs will be on-going; however, there is need of transfer information to knowledge process to properly training U.S. nanotechnology workers in safety.

There are a growing number of two-year post-secondary institutions that facilitate direct training for industries that produce ENMs, such as Texas State Technical College, Dakota County Technical College, North Seattle Community College, and North Dakota State College of Science. However, these programs emphasize utilizing equipment not specifically training workers to safely handle ENMs. Although there are courses in the two-year programs that address safety, none do so at the depth to be fully functional to adequately know how to maintain a safe working environment involving nanotechnology.

A number of government organizations, such as CDC, NIOSH, NIST, FDA, and ICON are aggressively establishing a foundation to define fundamentals of nanotechnology safety content. In 2011, the following government organizations were funded these amounts to address the research needs to maintain a safe workplace: The US Food and Drug Administration (FDA) requested $15 million; The National Institute for Occupational Safety and Health (NIOSH) requested $16.5 million; and National Institute for Standards and Technology (NIST) doubled their nanotechnology safety research from $3.6 to $7.3 million (Maynard, 2010). According to Fazarro & Trybula (2011), "This effort to push nanotechnology safety research is novel; however, there is a need for a parallel effort to implement education and training" (IEEE, para 4). Maintaining worker's health and avoiding litigation would be a beneficial by-product of avoiding accidents that can result to public-mistrust. So, what should be done to prepare this growing workforce to meet the needs of industry? NIOSH is continuing to work on new approaches and strategies to ensure the protection of workers from hazardous nanomaterials and provide guidance to controlling exposure and evaluation of how to minimize hazards (NIOSH, 2016).

In this grant, the lead University (Rice University), Texas State University, and the University of Texas at Tyler collaborated to receive funding for the country's first OSHA grant addressing the training needs of safely handling nanomaterials in the workplace. The grant addressed the critical and urgent need for rigorous, science-based, and comprehensive training materials to directly address the safe handling of nanomaterials. Originally, two versions of the training were envisioned. After the initial development, it became apparent that a four-hour version would not be able to cover the critical material adequately. The purpose of this article is to illustrate the findings/assessment of the program funded by OSHA-Susan Harwood.

Curriculum Development

The development of the training package is derived from the brightest minds in nanotechnology safety as represented by organizations such as the Center for Biological and Environmental Nanotechnology (CBEN)-Rice University, The Lippy Group, Texas State University, The University of Texas-Health and Science Center at Houston, and the International Chemical Workers Union. There was an internal and external advisory board to ensure the topics were taught and input was provided for program improvement.

The training program consisted of establishing eight-hour course to cover ENM occupational health and safety to emphasize human exposure. Seven topics were used to develop the modules (see Figure 2). Two trainers went to four locations to conduct the training. (See Figure 3 for illustration of training.) To validate the curriculum to address how workers safely handle ENMs, a research study was created to ascertain if learning outcomes were achieved and participants' perspectives on the program.

Figure 2. Seven Modules Developed for Training Program

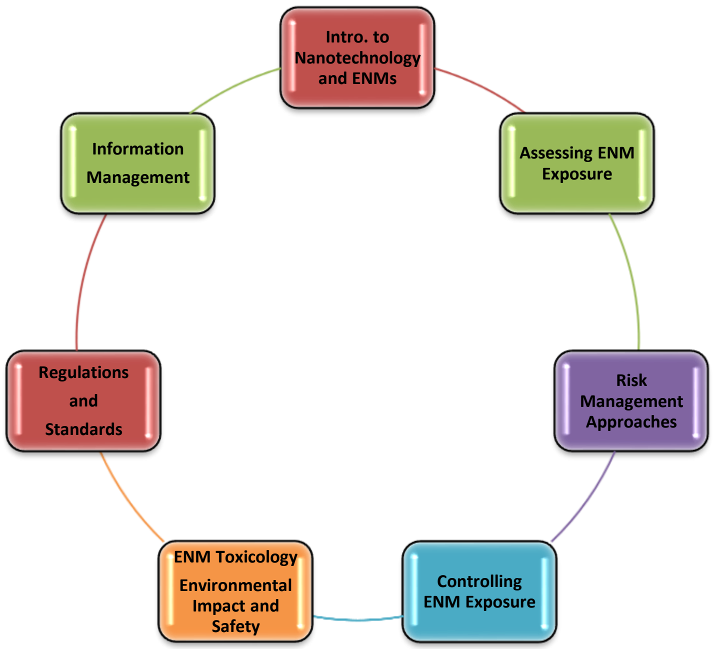

Figure 2. Seven modules used for training program funded by OSHA-Susan Harwood

Figure 3. Training Conducted at Site

Figure 3. Dr. Kristen Kulinowski conducts class at Mission College, CA.

Purpose of Study

The purpose of this study was twofold: 1) Determine if the participants successfully completed the seven topics and 2) determine the participants' perspectives of the program. To ascertain the success of the program, research questions and hypothesis statements were developed.

Research Questions

1. What were the participants' (Cohort 2011) perspectives on the Nanotechnology Safety Training?

2. Was there a difference between the participants' (Cohort 2011) means scores on the pretest and posttest?

The hypotheses statements are below are at a .05 alpha level for research question 1. The alpha level of .05 is commonly used in education because of the likelihoods of making a Type I and Type II errors.

Hypothesis Statement

1. H_o: There is no difference in the between the participants' means scores of the pretest and posttest.

   H_a: There is a difference in the between the participants' means scores of the pretest and posttest.

Methodology

Research Design

The research design for hypothesis statement 1 employs a minimal control, one-group, pretest-posttest design (Campbell & Stanley, 1966). Even though, there can be a significant result from the design, there are disadvantages. For example, there is no assurance that the treatment (training material) will be the only major factor in participants' learning. See figure 4 for research design layout.

Figure 4. One-Group Pretest-Posttest Design

Pretest	Treatment	Posttest
O_1	X	O_2

Figure 4. Adapted from D.T. Campbell, & J.C. Stanley (1966). *Experimental and quasi-experimental designs for research*. Chicago, IL: Rand McNally & Co.

Research question two uses a survey research (descriptive) design to obtain the participants' perspectives. According to Isaac and Michael (1997), this research method is used "to describe systematically a situation or area of interest factually and accurately" (p. 46).

Statistical Analyses Used

The study utilized descriptive analysis and Paired Samples t-test. The rationale for the descriptive analysis was to collect the frequency of the participants' perception based on the 4-Point Likert Scale. The paired samples t-test was used to determine if there was an increase in the group-mean scores from the pretest to posttest.

Population of Participants

The nanotechnology safety training targeted small to medium-sized ENM fabrication plants, processing companies, and research facilities. There are many small- to medium-sized companies that have no or few dedicated safety professional on staff; instead, such companies may task an engineer or scientist (if anyone at all) with health and safety duties as an adjunct to that staff member's primary responsibilities. A worker who must fulfill such a dual role needs to be able to find and apply reliable information about the safe handling of ENMs so that he or she can disseminate this critical information to all workers within a facility. Even when a trained safety professional is on staff, the worker will likely have had little prior experience specifically with ENMs and would benefit from learning how to apply their existing professional knowledge to this new class of materials.

Flyers were used for each site to invite workers to get training. There were two trainers traveling to sites all over the country, including Puerto Rico. Tables 1a and 1b illustrates the training sites and number of attendees for 2011.

Table 1a.

Training Locations

Training Location	City-State/Territory
Mission College	Santa Clara, CA
Univ. of Cincinnati	Univ. of Cincinnati
Labor College	Silver Spring, MD
University of Puerto Rico	Puerto Rico

Table 1b.

Number of Participants by Training Location

Training Location	No. of Attendees
Mission College	11

Univ. of Cincinnati	37
Labor College	25
University of Puerto Rico	30

[#] *n*=103

There was a wide range of participants, differentiated by job title along with their level of education, who attended the training sessions for 2011. See Tables 2a and 2b.

Table 2a.

Number of Participants by Job Title

Job Title	No. of Attendees*
Environmental Health	3
Injury and Prevention Control	1
Occupational Safety	25
Occupational Health Nursing	1
Occupational Medicine	4
Industrial Hygiene	23
Other	51

* Note: The number of attendees from the table 2a does not reflect the number of attendees in table 1b. There were some people who dropped out or left early

Table 2b.

Number of Participants by Level of Education

Education Level	No. of Attendees*
High School	5
Some College	13
Associate Degree	2
Bachelor of Arts or Science	30
MS/MA/MPH	7
Doctorate	44

* Note: The number of attendees from the table 2a does not reflect the number of attendees in table 1b. There were some people who dropped out or left early

Instruments for Study

The instruments for the study were a pretest, posttest, and end of the course survey. The pretest consisted of 14 questions (5 true/false), and 9 short written answer questions. The posttest contained the same amount of questions; however, the questions were reworded and ordered differently. The end of the course survey contained 3 sections (demographic, rate the instructors, and course experience) for a total of 15 questions. There were fourteen statements with a 4-point Likert Scale (Excellent, Good, Fair, and Poor).

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Data Collection Procedures

The data from the pretests, posttests, and end of the course evaluations were collected at the end of the training sessions for each site. Data was collected and stored on Excel spreadsheets. Steps were taken to ensure the pretests and posttests score were matched by participant. The data was imported to Statistical Package for the Social Sciences (SPSS) to generate results.

Results

Survey Results

The results are displayed in this section for the research questions SPSS-Crosstab function was used to generate frequencies by the 4-point Likert Scale for each statement that was answered by the participants. The research question stated, "*What were the participants' (Cohort 2011) perspectives on the Nanotechnology Safety Training?"*

To prevent data overload for readers, data displayed for the article, directly addressed the research question. Tables 3-5 addressed the quality of the course by each training site. The survey question in Table 3 illustrated all training sites perceived the content suited for their requirement was good and excellent.

Table 3.

Was the content suited your requirements?

Training Site	Likert Scale				
	Fair	Good	Excellent	Not Answered	Total
Santa Clara	1	5	4	1	11
University of Cincinnati	3	18	16	0	37
Labor College	4	17	4	0	25
Univ. of Puerto Rico	4	12	14	0	30

n=103

Training sites (Univ. of Cincinnati, Labor College, and Univ. of Puerto Rico) had large responses for good and excellent. See Table 4.

Table 4.

Were the topics covered in sufficient detail?

Training Site	Likert Scale				Total
	Fair	Good	Excellent	Not Answered	
Santa Clara	0	8	3	0	11
University of Cincinnati	5	16	15	1	37
Labor College	0	13	12	0	25
Univ. of Puerto Rico	3	14	13	0	30

n=103

All training sites rated the training course good to excellent in terms of the trainers covering the material in sufficient detail. See Table 5.

Table 5.

Overall rating of the course

Training Site	Likert Scale				Total
	Fair	Good	Excellent	Not Answered	
Santa Clara	0	6	5	0	11
University of Cincinnati	1	16	20	0	37
Labor College	1	10	12	2	25
Univ. of Puerto Rico	1	13	16	0	30

n=103

The next tables address the quality of the instructors and materials by each training site. See Tables 6-11. All training sites for table 6 below, participants thought the instructors did a good to excellent job providing real world experience to safely handling nanoscaled materials.

Table 6.

Instructors have the ability to provide real world experience

Training Site	Likert Scale			Total
	Fair	Good	Excellent	
Santa Clara	0	5	6	11
University of Cincinnati	5	15	17	37
Labor College	2	3	20	25
Univ. of Puerto Rico	1	10	19	30

n=103

The participants at the training sites rated good to excellent for instructors' knowledge of nanotechnology safety. See Table 7.

Table 7.

Instructors have knowledge of the subject matter

Training Site	Likert Scale		
	Good	Excellent	Total
Santa Clara	2	9	11
University of Cincinnati	7	30	37
Labor College	2	23	25
Univ. of Puerto Rico	7	23	30

n=103

In table 8, participants who completed the survey rated the instructors' abilities to present the material as good to excellent. See Table 8.

Table 8.

Instructors' presentation abilities were

Training Site	Likert Scale				Total
	Fair	Good	Excellent	Not Answered	
Santa Clara	0	1	9	1	11
University of Cincinnati	1	14	22	0	37
Labor College	0	8	17	0	25
Univ. of Puerto Rico	1	4	25	0	30

n=103

The majority of participants at the training sites rated the instructors as excellent for delivering the training materials. See Table 9.

Table 9.

Overall rating of the instructors

Training Site	Likert Scale			Total
	Fair	Good	Excellent	
Santa Clara	0	1	10	11
University of Cincinnati	1	7	29	37
Labor College	0	4	21	25
Univ. of Puerto Rico	0	5	25	30

n=103

The participants thought the materials, handouts, and activities were useful for the training course. See Table 10.

Table 10.

Materials, handouts, and activities useful

Training Site	Likert Scale			Total
	Fair	Good	Excellent	
Santa Clara	0	7	4	11
University of Cincinnati	4	13	20	37
Labor College	1	12	12	25
Univ. of Puerto Rico	1	13	16	30

n=103

All participants rated the quality of the overall materials from good to excellent. See Table 11.

Table 11.

Overall quality of the training materials

Training Site	Likert Scale				Total
	Fair	Good	Excellent	Not Answered	
Santa Clara	0	6	5	0	11
University of Cincinnati	0	16	19	2	37
Labor College	0	13	12	0	25
Univ. of Puerto Rico	1	8	20	1	30

Tables 12-14 illustrate the importance of having Nano-Safety certification at the worksite. All participants who answered the survey question agreed that they would consider being certified.

Table 12.

After this training, would you consider becoming certified in Nano-Safety? *n*=97*

Training Site	Decision Type			Total
	Yes	No	Do Not Know	
Santa Clara	9	0	1	10
University of Cincinnati	20	15	1	36
Labor College	10	11	0	21
Univ. of Puerto Rico	26	4	0	30

*Note: Six participants did not answer

Three out of four training sites agreed that a certification would be valuable to the participant and to the employer. See Table 13.

Table 13.

Would a certification in nanotechnology safety be valuable to you and your employer? n=96*

Training Site	Decision Type			Total
	yes	no	Do not know	
Santa Clara	10	0	0	10
University of Cincinnati	18	15	3	36
Labor College	17	8	0	25
Univ. of Puerto Rico	25	0	0	25

*Note: Seven participants did not answer

All four of the training sites agreed that certification in the Nano-Safety is important to the field. Ten participants from Labor College agreed strongly to obtain a certification is important. See Table 14.

Table 14.

Certification in nanotechnology safety is important to the field n=96*

Training Site	Likert Scale					Total
	strongly disagree	disagree	neutral	agree	strongly agree	
Santa Clara	0	0	1	7	2	10
University of Cincinnati	1	2	8	16	8	35
Labor College	0	0	0	11	10	21
Univ. of Puerto Rico	0	0	0	30	0	30

*Note: Seven participants did not answer

Course Effectiveness

To determine course effectiveness of the training, a paired-samples t-test was used. The paired-samples t-test requires a sample size of 30+ (Pallant, 2005) which was adequate for answering the hypothesis statement. The material taught at each training site was identical and grouped as *Cohort 2011* to achieve the necessary sample size. Ninety-eight participants completed the pretest and posttest to complete the required time of training. Determining significance for each training site was not possible due to the unequal sizes of the enrollment. To verify the SPSS output was valid, assumptions were checked to determine if there were any violations. There were no violations in the assumptions.

The Paired-Samples t-test was conducted to determine the course effectiveness-if there was an increase of the mean group score of the participants from the pretest to posttest based on the training material taught. There was a statistically significant increase in the posttest scores from the pretest (M=7.939, SD=5.9327) to the posttest [M=15.571, SD=4.7883, t (98)= -13.482, $p<.0005$]. Therefore, the null hypothesis was rejected and the alternative accepted.

Conclusion and Discussion

The study concluded with positive results for the training program. According to the posttest scores, there was a significant improvement in the participants'' knowledge of nano safety. Even though the participants started at different levels from the pretest, the variation of improvement on the posttest was about even across the training sites. Testing the hypotheses to whether there was a significant change in the pretest and posttest group mean score was based on the effectiveness of the training. The study revealed a statistically significance difference in the pretest and posttest group mean score, meaning that the training material was effective and contributed to the improvement in the posttest scores. The authors would suggest that readers approach findings with caution. The significance of the study is only generalized to the four training sites. One must conclude that there were uncontrollable external variables (i.e. monetary incentives, and self-motivation) which may have contributed to the increase of the mean group score of the posttest (Fazarro & et. al, 2009).

In Tables 13 and 14, the participants felt that nanotechnology safety training is important for the viability of companies who manufacture ENMs. Thus, certification according to Table 12 will be important to the participants. Who will develop a comprehensive certification? Agencies like NIOSH, OSHA, or profession organizations like IEEE, and others could pave the way to developing a certification.

In addition to the positive results of the training conducted at the sites, there are other future possibilities to continue to go beyond the training grant. In the 21st century, there will be continuing advances in nanomaterials. Educating the future workforce at post-secondary institutions in the safety of nanomaterials will be important to the longevity of nanotechnology and global competitiveness. The importance of teaching nanotechnology safety at post-secondary institutions will depend on the willingness of faculty in STEM departments to strategically insert nanotechnology safety content in various science, engineering, and technology courses. To this effect, graduates will have some learned content that will allow them to conduct and implement safety practices.

The funded grant on training workers in nanotechnology safety was ground breaking and a catalyst to make educators and government agencies aware of the importance of nanotechnology safety training. As more ENMs are created, industry must be more cognizant of the training needs of the workers. Constant improvement of training materials from research and industry practice will be vital to the field of nanotechnology. A well-trained workforce in safely handling nanoscale materials will lessen the likelihood of catastrophes and decrease public skepticism. Training materials on Nano-Safety is available to the public on the OSHA website U.S. Department of Labor-OSHA https://www.osha.gov/dte/grant_materials/fy10/sh-21008-10.html .

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