Assessing the Effectiveness of a Nanotechnology Educational Module Using the "Nanotechnology Awareness Instrument"

M. J. Klopfstein, Oklahoma State University
Ms. Lisa Cota, Oklahoma State University
Prof. Don A. Lucca, Oklahoma State University
Dr. Xiaoliang Jin, Oklahoma State University

Xiaoliang Jin received his Ph.D. degree in Mechanical Engineering from the University of British Columbia, Canada, in 2012. Now he is an Assistant Professor at Oklahoma State University, USA. His research interests include precision manufacturing processes, mechanics and dynamics of micro-machining, vibration assisted machining, and precision control.

Prof. Prabhakar R Pagilla, Texas A&M University

Prabhakar Pagilla is a TEES Endowed Professor in the Department of Mechanical Engineering at Texas A&M University. He received his PhD in Mechanical Engineering from the University of California, Berkeley in 1996. His formal background and expertise are in the general areas of dynamic systems and control with applications in manufacturing and robotics. His research interests lie in modeling and control of roll-to-roll manufacturing systems; control of large-scale complex systems; robotics/mechatronics; and adaptive and robust control of nonlinear dynamic systems.

©American Society for Engineering Education, 2016

Assessing the Effectiveness of a Nanotechnology Educational Module using the "Nanotechnology Awareness Instrument"

Abstract

The effectiveness of the introduction of an educational module to an Introduction to Engineering class was investigated. A lecture introducing nanotechnology was given to the students, and the students participated in a question-and-answer period following the lecture. The "Nanotechnology Awareness Instrument" of Dyehouse et al.[1] was used to assess students' motivation for, awareness of, and exposure to nanotechnology. The survey contained thirty multiple choice questions divided into sections covering nanotechnology awareness, motivation, and exposure. The survey was given to the students prior to the lecture and again five weeks after the lecture. An Ordinal Pattern Analysis in Observation Oriented Modeling was used to evaluate differences in student scores on the Nanotechnology Awareness Instrument after the lecture as compared to their scores before the lecture. It was found that students' awareness and exposure increased after the lecture, however, their motivation did not increase.

Introduction

Even though nanotechnology has been a topic of research interest for a number of years, it is still being introduced into undergraduate curricula. In some curricula, an entire course or sequence of courses is devoted to nanotechnology, and in others, nanotechnology modules are introduced into existing courses. There exists very little quantitative data concerning the effectiveness of the introduced course or module. Although there have been a number of surveys for the general public about their knowledge and attitudes toward nanotechnology (e.g., Kim et al.[2], Sechi et al.[3]), there have been very few surveys designed to assess undergraduate students' knowledge and attitudes toward nanotechnology before and after the introduction of a module or course. Dyehouse et al.[1] developed a survey called the "Nanotechnology Awareness Instrument" which covers the areas of nanotechnology awareness, motivation and exposure and used it to assess students before and after an educational module was presented to them. The authors use the term "awareness", however, "knowledge" may be a better description of the quality surveyed. See the Appendix for the complete survey. In this paper we present the results on students' knowledge, motivation and exposure to nanotechnology before and after a brief lecture on nanotechnology.

Experimental

A 40 minute lecture was presented to two sections of an "Introduction to Engineering" class. The first section contained approximately 140 students, and the other section contained approximately 40 students. The course is required of all engineering students and is a pre-requisite for many courses. The majority of the students were first-year students, and females made up approximately 30% of the class. The lecture provided a general introduction to nanotechnology including a discussion of length scale, the increase in surface area to volume ratio as length scale decreases, and common household items that use nanotechnology. Following the lecture there was a 10 minute question and answer session that allowed the students an opportunity to ask any questions about nanotechnology. The survey was given prior to the lecture and again five weeks after the lecture.

Results and Discussion

Table 1 shows an overview of student response to the survey questions. The second and third columns give the percent of students that agree (strongly agree and agree) and disagree (strongly disagree and disagree) with the statements both before and after the lecture. The students who answered neutral are not shown in the table, but the percentages are calculated based on all students who answered the question. The total number of respondents was approximately 120 – 150 students depending on the question. For the Awareness questions, the trend was an increase in the percent of students who agreed and a decrease in the percent who disagreed with the statements. For the Motivation questions, there is not a clear trend in the responses. For the Exposure questions and the Awareness questions, an increase in the percent of students who agreed and a decrease in the percent of students who disagreed was observed.

Table 1 Student responses to survey. Agree is the sum of "Strongly Agree" and "Agree" and Disagree is the sum of "Disagree" or "Strongly Disagree". The number of responses was about 120 - 150.

Survey Question	Agree (%) Before, After	Disagree (%) Before, After
Awareness, I can:		
Name a nano-scaled object.	28, 65	57, 20
Describe one way nanotechnology directly impacts my life.	30, 60	47, 17
Name a field of study that currently conducts nanotechnology research.	31, 62	50, 17
Describe one way nanotechnology may benefit society/humankind.	52, 76	32, 8
Name an application of nanotechnology.	33, 61	44, 18
Describe a process to manufacture objects at the nanoscale.	6, 30	81, 42
Name an instrument used to make measurements at the nanoscale.	14, 30	73, 44
Describe one way nanotechnology may directly impact my life in the future.	40, 65	38, 12
Motivation, I plan to:		
Formally teach nanotechnology concepts (e.g., as a teaching assistant).	6, 6	79, 77
Investigate the implications of nanotechnology.	22, 24	44, 45
Informally/casually teach someone something about nanotechnology.	18, 30	47, 40
Seek information about internships or Co-op experiences with companies engaged in nanotechnology.	20, 17	41, 47
Read a news story or popular magazine article about nanotechnology.	48, 48	22, 24
Give a presentation related to nanotechnology to an audience I perceive as having more experience with nanotechnology than I.	7, 7	72, 77
Read a research journal article about nanotechnology.	31, 25	38, 35

Enroll in a course about nanotechnology.	29, 22	41, 42
Attend a non-course related seminar about nanotechnology.	23, 25	44, 45
Visit an industry or business that specializes in nanotechnology.	32, 34	31, 30
Give a presentation related to nanotechnology to an audience I perceive as having less experience with nanotechnology than I.	18, 8	61, 64
Watch a program about nanotechnology.	42, 46	29, 20
Apply or interview for a nanotechnology related work or research experience.	18, 16	52, 50
Investigate fields of study in which I can learn more about nanotechnology.	28, 23	43, 49
Obtain a work experience or undergraduate research opportunity related to nanotechnology.	23, 19	50, 50
Exposure, I have:		
Heard the term nanotechnology.	57, 76	22, 7
Read [something] about nanotechnology.	26, 46	52, 27
Watched a program about nanotechnology.	18, 27	64, 52
Had one [or more] instructors/teachers talk about nanotechnology in class.	18, 54	71, 26
Participated in an activity involving nanotechnology [lab, project….].	3, 7	92, 80
Taken a class about nanotechnology.	1, 7	93, 84

Before further analysis of the data, any survey that had a missing response for any question was discarded. Also, since the intended analysis involved comparison of the scores on the survey given after the lecture to scores obtained prior to the lecture, only those students who responded to both surveys were included in the analysis. This reduced the number of surveys to 100. For these surveys, the answers were first converted to a numerical scale with “Strongly Agree” or “A Great Deal” equal to 5 and “Strongly Disagree” or “Not at All/Never” being equal to 1. Intermediate values were given values of 4 through 2. Rather than looking at each question individually, the sum of each of the three sections was calculated for each student survey. The scores were grouped into four bins with the point value times the number of questions being the dividing line. For example, the awareness section had 8 questions so the bins were: 8 – 15.5, 16 – 23.5, 24 – 31.5, 32 – 40.

“Observation Oriented Modeling” [4] (OOM) was used to further analyze patterns in the data. One of the main advantages of OOM as compared to traditional statistical methodology is that it does not require any assumptions about the distribution of the data; therefore, it can be used with both parametric and nonparametric data. Additionally, there is no estimation of population parameters in OOM; the statistics in OOM reflect solely the data collected. In an OOM analysis, the researcher provides a hypothesized pattern for the data, and the analysis checks the obtained data against that pattern. The resulting statistic, called a Percent Correctly Classified (PCC) index, is the percentage of the data which fits the hypothesized pattern. For this paper, the hypothesized pattern was an increase in students’ scores on the Awareness, Motivation or Exposure subscales after the lecture as compared to their scores before the lecture.

Table 2 shows the results for this model. The column labeled “Percent Correctly Classified

(PCC)” gives the percent of students whose score increased after the lecture. For the sections on Awareness and Exposure, a large percent (87% and 75%, respectively) of students showed an increase in their scores in these areas. For the Motivation section, however, only 45% of the students showed an increase in their score. The second column in Table 2 gives the “*c*-value” which is the “chance value” and is determined as follows: the scores after the lecture are randomized, akin to shuffling a deck of cards, and the number of observations that showed an increase in the scores as compared to before the lecture is recorded. This procedure is repeated 1000 times, in this case, and the *c*-value is determined as the quotient of those trials where the random score was greater than or equal to the number observed divided by the total number of trials. Using the Motivation subscale PCC value of 45% as an example, in 1000 randomized trials approximately 740 of the 1000 had a PCC greater than or equal to 45%; thus the *c*-value is 0.74. This means that there was not a unique, well-defined pattern to the Motivation subscale scores; in other words, the pattern of these scores is quite random. It should be noted that the *c*-value is not the *p*-value found in traditional statistics: unlike the *p*-value in traditional statistics, there is no “cut-off” *c*-value in OOM at which point the results are unacceptable; the PCC index is more important, as it is a measure of the extent to which the data fits the researcher’s hypothesis. The fact that only 45% of the students saw an increase in Motivation scores after the lecture as compared to before the lecture indicates that this particular hypothesized pattern does not fit the actual scores on this particular subscale well. The other 55% of the students had motivation scores that either remained the same or decreased after the lecture; the fact that the *c*-value is so low indicates that, overall, there is not a clear pattern to the motivation scores. Conversely, the randomization tests for the Awareness and Exposure subscales indicated that the pattern of the scores there was very unique: for both of those subscales, none of the randomized trials had a PCC greater than or equal to the original observed PCCs. So, not only did the majority of the students see an increase in their awareness of and exposure to nanotechnology after the lecture, but the pattern of the scores did not occur randomly.

When the Nanotechnology Awareness Instrument was originally published, Dyehouse et al.[1] did not find statistically significant differences between pre-intervention and post-intervention survey scores for four of the five items on the motivation subscale; on the fifth item (motivation for reading about nanotechnology), they reported the students scored significantly lower after the intervention ($p < 0.001$). The fact that just under half of the students in the current study were more motivated to learn about nanotechnology after a single 40-minute lecture is noteworthy.

Table 2 Results of observation oriented modeling. The model was that the students score increased after the introductory lecture on nanotechnology.

Item	Percent Correctly Classified (PCC)	c-value from 1000 random trials
Awareness	87	< 0.001
Motivation	45	0.74
Exposure	75	< 0.001

Summary

The effects of a brief introductory lecture on nanotechnology on students' awareness, motivation and exposure to nanotechnology was investigated using the "Nanotechnology Awareness Instrument". Using an Ordinal Pattern Analysis, it was found that both awareness and exposure to nanotechnology increased after the lecture however there was not a clear trend in students' motivation. It may be that students require more than a single 40-minute lecture to become motivated to learn about a subject; however, the fact that 45% of the students in this study did report being more motivated to learn about nanotechnology suggests that even a short lecture can have a meaningful effect.

Acknowledgment

The support by NSF through Grant No. EEC- 1446097 is greatly acknowledged.

References
[1] Dyehouse, M. A., Heidi, A. D.-D., Bennett, D. E., Imbrie, P. K., "Development of an Instrument to Measure Undergraduates' Nanotechnology Awareness, Exposure, Motivation, and Knowledge", Journal of Science Education and Technology, v. 17, pg. 500- 510, 2008.
[2] Kim, Y.-R., Lee, E. J., Park, S. H., Kwon, H. J., An, S. S. A., Son, S. W., Seo, Y. R., Pie, J.-E., Yoon, M., Kim, J. H., Kim, M.-K., "Interactive Survey of Consumer Awareness of Nanotechnologies and Nanoparticles in Consumer Products in South Korea", Int. Journal of Nanomedicine, v. 9, sup. 2, pg. 11 – 20, 2014.
[3] Sechi, G., Bedognetti, D., Sgarrella, F., Eperen, L. V., Marincola, F. M., "The Perception of Nanotechnology and Nanomedicine: A Worldwide Social Media Survey", Nanomedicine, v. 9, iss. 10, pg. 1475 – 1486, 2014.
[4] Grice, J. W., "Observation Oriented Modeling: Analysis of Cause in the Behavioral Sciences", Academic Press, NY, NY, 2011.
[5] Observation Oriented Modeling Software, http://www.idiogrid.com/OOM/, software is available for free download.

Appendix

Survey given to students before and after nanotechnology lecture. Taken from the "Nanotechnology Awareness Instrument"[1].

For the following items, please indicate the extent to which you agree or disagree using the following scale: (A) strongly agree, (B) agree, (C) neutral, (D) disagree, or (E) strongly disagree.

What is your awareness of nanotechnology? I can:

1) Name a nanoscale-sized object.
2) Describe one way nanotechnology directly impacts my life.
3) Name a field of study that currently conducts nanotechnology research.
4) Describe one way nanotechnology may benefit society/humankind.
5) Name an application of nanotechnology.
6) Describe a process to manufacture objects at the nanoscale.
7) Name an instrument used to make measurements at the nanoscale.

8) Describe one way nanotechnology may directly impact my life in the future.

What is your motivation to investigate nanotechnology? I plan to:

9) Formally teach nanotechnology concepts (e.g., as a teaching assistant).
10) Investigate the implications of nanotechnology.
11) Informally/casually teach someone something about nanotechnology.
12) Seek information about internships or Co-op experiences with companies engaged in nanotechnology.
13) Read a news story or popular magazine article about nanotechnology.
14) Give a presentation related to nanotechnology to an audience I perceive as having more experience with nanotechnology than I.
15) Read a research journal article about nanotechnology.
16) Enroll in a course about nanotechnology.
17) Attend a non-course related seminar about nanotechnology.
18) Visit an industry or business that specializes in nanotechnology.
19) Give a presentation related to nanotechnology to an audience I perceive as having less experience with nanotechnology than I.
20) Watch a program about nanotechnology.
21) Apply or interview for a nanotechnology related work or research experience.
22) Investigate fields of study in which I can learn more about nanotechnology.
23) Obtain a work experience or undergraduate research opportunity related to nanotechnology.

For the following items, please indicate the extent to which you have participated in each activity using the following scale: (A) a great deal, (B) a fair amount, (C) sometimes/occasionally, (D) very little, (E) not at all/never.

What is your exposure to nanotechnology? I have:

24) Heard the term nanotechnology.
25) Read [something] about nanotechnology.
26) Watched a program about nanotechnology.
27) Had one [or more] instructors/teachers talk about nanotechnology in class.
28) Participated in an activity involving nanotechnology [lab, project….].
29) Taken a class about nanotechnology.

30) When you hear the term nanotechnology, what length scale “typically” comes to mind?

(1) 10^9 m
(2) 10^6 m
(3) 10^3 m
(4) 10^1 m
(5) 10^{-1} m
(6) 10^{-3} m
(7) 10^{-6} m
(8) 10^{-9} m
(9) None of the above