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## **AC 2012-3747: NANOEXPOSED! AN INTRODUCTION TO NANOTECHNOLOGY**

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Yaroslav Koshka, an Associate Professor in electrical and computer engineering at Mississippi State University, has 13 years experience in academia. Koshka's research interests include semiconductors and nano-electronic materials and devices (design, growth, fabrication, and advanced characterization techniques). Koshka's teaching interests include microelectronics, semiconductor materials and devices, semiconductor physics, and nanotechnology.

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Oliver Myers, an Assistant Professor in mechanical engineering at Mississippi State University, has three years experience in academia and 10 years of industrial experience. His research interests include multifunctional materials (piezoelectric, magnetostrictive, nanomaterials), composite materials, and novel manufacturing processes.

### **Dr. Giselle Thibaudeau, Mississippi State University**

Giselle Thibaudeau is the Director for Mississippi State University's Institute for Imaging & Analytical Technologies, a university wide core facility and research institute meeting missions in research, teaching and service. Her research support role is diverse and her specific research interests include biological inspiration of color.

### **Dr. Carlen Henington, Mississippi State University**

Carlen Henington is a nationally certified School Psychologist and is an Associate Professor in School Psychology at Mississippi State University. She completed her doctoral work at Texas A&M University and her internship at the Monroe Meyer Institute for Genetics and Rehabilitation at the University of Nebraska Medical Center, Omaha. She received the Texas A&M Educational Psychology Distinguished Dissertation Award in 1997, the Mississippi State University Golden Key National Honor Society Outstanding Faculty Member Award in 2000, the Mississippi State University Phi Delta Kappa Outstanding Teaching Award in 1998, and the College of Education Service Award in 2010. She has worked as a consultant to the Mississippi Department of Education to address disproportionality and has provided technical assistance to schools across the state. She has served as a program reviewer for the American Psychological Association and for the National Association for School Psychologists for more than eight years. Additional areas of research include evaluation of effective teaching and program administration at the post-secondary levels.

# **NanoExposed! – An Introduction to Nanotechnology**

## **Abstract**

In both industrial and academic research, interdisciplinary collaboration in nanotechnology has increased to address its applications to fields such as materials engineering and biomedical engineering. However, undergraduate nanotechnology instruction has not kept pace. While nanotechnology concepts are introduced in various courses, they tend to be discipline specific. As part of an NSF Nanoscience Undergraduate Education award (NUE) (cite) to Mississippi State University (MSU) a certificate program is being developed to address this deficiency. This paper focuses on the introductory course, NanoExposed! which was built into the Nanotechnology certificate program. This course is designed as a weekly seminar course that introduces students to basic concepts in nanotechnology.

The goals of the course NanoExposed! are to increase awareness of nanoscience in entering science and engineering students, to demonstrate the multidisciplinary nature of nanoscience, and to excite students about taking more advanced nanotechnology electives in the nanotechnology certificate program. This is an introductory survey course that presents practical applications of nanotechnology, fabrication and characterization of nanomaterials, and future possibilities. The course gives examples where nanoscale properties are different from bulk scale properties, and how these differences can be exploited for the development of commercial products.

The paper describes the implementation of the NanoExposed! course including course topics, activities, faculty involved as instructors, guest speaker(s), and resources used. Specific topics from different disciplines are given as examples. It also includes preliminary assessment results as well as student data such as the different majors enrolled in the course. The course was first taught during the Spring 2011 semester and taught again during the Fall 2011 semester.

## **Introduction**

Nanotechnology and nanoscience are expected to have significant effects on both the national and global economies. It is estimated that in 2008 the value of products incorporating nanotechnology was approximately \$200 billion globally and \$80 billion in the U.S., and it is estimated to reach \$3 trillion globally and \$1 trillion in the U.S. by 2020<sup>1</sup>.

Recognizing the potential impact on the region and the national economy, several MSU faculty realized that students had limited exposure to and opportunities for learning nanotechnology. Although fundamental topics in nanoscience were included in many existing courses in biology, chemistry, engineering, and physics, there were no courses focused specifically on nanoscience and nanotechnology nor were there courses that addressed the interdisciplinary nature of nanoscience and nanotechnology. To address these deficiencies, a team of faculty from biological sciences, chemical engineering, electrical engineering and mechanical engineering developed the introductory seminar course NanoExposed! primarily for freshmen. This course is part of a nanotechnology certificate program that is being developed in coordination with an existing materials research certificate program. While some of the subsequent nanotechnology courses in the certificate program are more discipline specific, this introductory course emphasizes the interdisciplinary nature of nanotechnology.

In addition to preparing students for careers where a basic knowledge of nanotechnology is required, it is also essential to educate the general public regarding nanotechnology. Society is already being affected by new developments in nanotechnology and will continue to be affected in the future. In deciding the future of nanotechnology, both the technical experts and the public will participate in the decision making. Therefore it is essential to educate the general public so that they can make informed decisions<sup>2</sup>. Although designed with science and engineering majors in mind, this introductory course is open to and is accommodating to all majors increasing an informed citizenry.

## Objectives

The objectives for the NanoExposed! course are to:

1. Introduce and increase excitement of science and engineering students to nanoscience and nanotechnology
2. Demonstrate the interdisciplinary nature of nanotechnology
3. Introduce nanotechnology to students who may not major in science or engineering
4. Make students aware of research and career opportunities through the nanotechnology certificate program.

## Course Description

The course was structured as one 50 minute session each week for 14 weeks and was taught during the Spring 2011 and Fall 2011 semesters. The introductory lecture discussed general concepts and focused on applications in nanotechnology. As shown in Table 1, the course was split into three week sequences that focused on nanochemical, nanomechanical, nanobiological, and nanoelectronic applications. The final session discussed literature on the possible risks and health effects from nanostructures. Since the course was designed for a general audience, no prerequisites were required. The student population each time NanoExposed! Has been taught to date were quite different. During the spring semester the majority of students (total of 42) were juniors and seniors in chemical engineering, but there were also students from computer, electrical, and mechanical engineering. During the fall semester 17 of the 22 students were freshmen and there was a greater diversity of majors including aerospace, biological, chemical, computer, electrical, industrial, and mechanical engineering, as well as biochemistry, biological sciences, and geosciences.

As shown in Table 1, the first class was an introduction to nanotechnology with a focus on practical applications. This was followed by 3 week blocks on nanoscience and nanotechnology in chemical engineering, mechanical engineering, biology, and electrical engineering. To meet the objective of demonstrating the interdisciplinary nature of nanotechnology, a team of faculty from the four disciplines taught the course where each instructor taught the section in their discipline. After exploring many possibilities in nanotechnology, the final class focused on the possible risks of nanotechnology including health risks, ethics and public perception of nanotechnology.

Various resources were used in teaching the course. For the first class, much of the material came from an existing presentation<sup>3</sup>. The goal was to excite students about nanotechnology by

providing them examples of how nanotechnology is already being used in everyday life. In addition, size comparisons were presented to help students gain an appreciation of scale - macro- to nanoscale.

Table 1. Course topics for NanoExposed!

Week	Topic
1	Introduction - What Is Nanotechnology? Significance, Motivation, Applications
2	Chemical applications: Size – How small is it?
3	Importance of size in chemical applications
4	Chemical applications
5	Nanomechanics and Golf Clubs
6	Nanomechanics: Modeling
7	Nanomechanics: Science Fiction vs. Science Fact
8	Seeing at the Nanoscale and Nanoscience in Biology
9	Seeing at the Nanoscale and Nanoscience in Biology
10	Geosciences and NanoBacteria
11	Nanoelectronics: Nanowire Fabrication
12	Nanoelectronics
13	Nanoelectronics
14	Health Effects, Ethics

In the chemical engineering lectures, presented by author Hill, the effect of size on the color of CdSe nanoparticles was presented. To explain the concept, publically available slides from an NSF funded project were used<sup>4</sup>, and a video was shown of the particles being grown<sup>5</sup>. Applications of colloidal gold included melamine detection in milk<sup>6,7</sup> and printing electronic devices<sup>8,9</sup>. Fundamental concepts were discussed such as how the change in melting point with size allowed the printing of electronic devices. How we see things at the nanoscale was presented and selected basic concepts of electron microscopy and scanning probe microscopy were introduced<sup>10,11</sup>. Also, selected properties of carbon nanostructures such as carbon nanotubes were presented<sup>12</sup>. The application of carbon nanotubes to solving the societal problem of clean water sources<sup>13</sup> was presented to provide students with one example of how nanotechnology can contribute to solving real world problems.

The mechanical engineering presentations, by co-author Myers, discussed current applications ranging from golf club shafts<sup>14</sup> to NEMS and MEMS devices<sup>15</sup>. Future applications of materials with desired properties were discussed. This included unobtainium which has been defined as: “A substance having the exact high test properties required for a piece of hardware or other item of use, but not obtainable either because it theoretically cannot exist or because technology is

insufficiently advanced to produce it."<sup>16</sup> Other topics included modeling a golf club shaft that contained nanoparticles and an emphasis was placed on some of the scale problems with modeling.

In the biology presentations, by co-author Thibaudeau, students visited the Institute for Imaging & Analytical Technologies, a university level core facility and research institute to see demonstrations of nanoscience/nanotechnology application potentials using scanning and transmission electron microscopies, confocal microscopy, and an atomic force microscopy. The live demonstrations allowed students the opportunity to obtain a better understanding of the value of state-of-the-art imaging and analysis technologies to research at the nanoscale. Students were amazed by the nano-sized bulldog (MSU mascot) printed with the nanolithography capabilities of the atomic force microscope. A guest lecturer from geosciences, who bridges the materials science and engineering with the biological research communities discussed efforts in nanobacteria research and some of the competing theories about whether or not nanobacteria actually exist.

In the nanoelectronics sessions, presented by co-author Koshka, both top-down and bottoms-up methods for preparing nanostructures were presented. Some examples were shown from the instructor's research. Characterization and application of nanoelectronic devices were discussed. The expected contribution of nanotechnology to Moore's Law was discussed.

Throughout the presentations various approaches were used to keep the students engaged. Some activities were hands-on activities to demonstrate concepts, and other activities were brief brainstorming activities where students were asked to answer questions. For example, each student was given a strip of paper of the same length and then asked to use a pencil to divide it in half. The students were asked to determine how many times they could halve the strip using a pencil and how many times they would have to mark the paper to obtain 1 nanometer. The exercise demonstrated the difficulty of using macroscale tools to work on the nanoscale.

Due to the interdisciplinary nature of the field, selected topics appeared in several discipline areas. Specifically, carbon nanotube fabrication was discussed in the chemical sessions, the use of carbon nanotubes as part of a composite material was presented in the mechanical sessions, and the use of carbon nanotubes in nanoelectronics was shown. This was done to reinforce the concept that the disciplines overlap at the nanoscale.

After providing many possibilities for nanotechnology in the future, during the last lecture possible risks were discussed. For example, the toxicity of many nanomaterials is unknown and it is likely in some cases that lethal dose for nanoparticles is different than the lethal dose for a bulk material. Also, the nanotechnology certificate program was introduced during the final session of the semester.

### **Preliminary Assessment**

Formal course assessment is being performed by co-author Hennington, a faculty member in the Department of Counseling and Educational Psychology. The data obtained will be used to modify the course offerings and determine efficacy of the course in providing students with knowledge and enhancing their attraction to the field of nanotechnology.

As this is an informational course with minimal hands-on opportunities, the outcomes for this course have been in the area of effect on students perceptions of the field of nanotechnology. To date, efforts related to research across the two semesters that the course has been offered include weekly evaluation of course perceptions of an introductory course in nanotechnology (i.e., knowledge, practicality, research, application) and student goals (i.e., career in field, independent research) for 64 undergraduates (42 juniors and seniors enrolled in the Chemical Engineering department during Spring 2011 and 22 predominately freshmen and sophomores enrolled in a variety of Engineering and Biological Sciences departments in fall 2011). Students provided weekly ratings of the topics presented in class and responded to a series of open-ended questions relevant to the weekly topic presentation. These responses were evaluated across time using single-subject design to track student interest and growth in knowledge across the semesters. A comparison of the two groups will also be conducted to determine differences between lower and upper level students.

In general, our research indicated that the freshman and sophomores, relative to the seniors, tended to find the course slightly better in providing information on the practicality of nanotechnology, the current research in nanotechnology, and industry-level applications of nanotechnology. However, the seniors, relative to lower level students, tended to find the course slightly more able to provide them with more foundational knowledge to use in their field, to better prepare them to independently study nanotechnology, and to have relevance to their professional goals. It is important to note that these differences were minimal.

Preliminary assessment data is also available from course evaluations that are used by the university. When students fill out these forms near the end of each course, they rate how strongly they agree or disagree with a set of statements by giving a rating ranging from 1 (strongly disagree) to 5 (strongly agree) for each statement. The average responses for three selected questions are shown in Table 2. There was no significant difference between the evaluations for the two semesters. Overall, the student evaluations were quite positive. Student responses to the first two questions indicate that the students responded favorable to the course being co-taught by four faculty members. The response to the final question indicates that the students thought they learned more about nanotechnology as a result of taking this class.

Table 2. Average student responses to selected course evaluation statements. Ratings range from 1 to 5 where 1 = Strongly Disagree and 5 = Strongly Agree.

<b>Statement</b>	<b>Spring 2011</b>	<b>Fall 2011</b>
1. The instructor conveyed the course content in an effective manner.	4.1	4.2
2. I would recommend this instructor to other students if they wanted to learn this subject.	4.2	4.3
3. I learned a great deal in this class.	4.3	4.2

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