NanoExposed! – Chemical Applications in Nanotechnology

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Abstract – As part of an NSF NUE grant, the introductory seminar course NanoExposed! was developed to introduce freshmen to basic concepts in nanotechnology. The goal was to introduce entering engineering and science student to nanoscience in a way that gets them excited about the field. The course was taught for the first time during the Spring 2011 semester and for the second time during the Fall 2011 semester. This paper focuses on the chemistry and chemical engineering portion of the course, but there is overlap with other fields. Specifically, some examples are given to explain the differences in properties between the bulk scale and the nanoscale. Other topics include fabricating nanoparticles or other nano-structures, "seeing" or characterizing nanomaterials, and applying nanotechnology in common commercial products. In addition to current uses, possible future uses are discussed. The focus is on course topics and resources used.

Keywords: nanotechnology, nanoscience, freshman seminar.

INTRODUCTION

In 2004, it was estimated that there could be as many as 7 million nanotechnology jobs globally by 2015 [1]. In spite of its importance to the national economy, little has been done to educate our students in this field at Mississippi State University. Many of the background courses in various fields including chemistry, physics, engineering, and biology already existed, but there weren't any courses dedicated to nanoscience and nanotechnology. Therefore, a team of faculty from biological sciences, chemical engineering, electrical engineering and mechanical engineering have developed the introductory 1 credit seminar course "NanoExposed!" that is aimed primarily at freshmen engineering and science majors. A nanotechnology certificate program is being developed at Mississippi State University that includes this introductory seminar course as well as more discipline specific courses. The goals of this course are to introduce science and engineering students to nanoscience and nanotechnology in an exciting way, and to make them aware of further opportunities of research and study through the nanotechnology certificate program.

A second reason for offering this course to any interested student is to educate more of the general public about nanotechnology. It has been noted that since the public is being and will be affected in the future by nanotechnology, they need to be educated so that they can make informed decisions [2]. Since this introductory class is open to students from any major, it has the potential to educate students in nontechnical as well as technical majors.

One facet of nanoscience that makes it so exciting is that fields of study that are quite different at the macroscale come together at the nanoscale. That is, many of the materials studied in various disciplines depend on the material structure at the nanoscale whether it is a virus or a carbon nanotube. Therefore, all of these disciplines share a common interest in manipulating matter at the nanoscale. Since it is a truly interdisciplinary science, this is reflected in teaching the introductory course by using a multidisciplinary team of four faculty members from biological sciences, chemical engineering, electrical engineering and mechanical engineering.

In this paper, the focus is on the chemical applications section of the course. Although discipline specific courses have a strong tendency to compartmentalize course content, the objective in this seminar is to help the students understand the multidisciplinary nature of nanotechnology. Therefore, this will be highlighted.

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Course Structure and Implementation

The course is taught as one 50 minute session per week for 15 weeks. The first two sessions are introductory lectures to explain the concepts of size. Then each of the four professors has 3 sessions to present topics in their discipline. The final session addresses health and ethics concerns. Since each faculty member has a different teaching style, the students are exposed to different educational approaches throughout the semester ranging from lectures to a visit to Institute for Imaging and Analysis Technology on campus to see electron microscopes. In the other segments of the course the mechanic engineering professor covers nanomechanics, the electrical engineering professor discusses nanoelectronics, and the biological sciences professor leads the visits to the electron microscope facility and covers topics such as nanobacteria.

The course was taught for the first time during the Spring 2011 semester and for the second time during the Fall 2011 semester. The first time it was taught it was open to students at any level and it was mainly populated by junior and senior chemical engineering students. Out of the 43 students in the class, there were also students for computer, electrical, and mechanical engineering. The second time it was taught there were 22 students in the class of which 17 were freshmen. The second time the course was taught it had students from aerospace engineering, biochemistry, biological engineering, biological sciences, chemical engineering, computer engineering, electrical engineering, geosciences, industrial engineering, and mechanical engineering. Since the course was designed for entering freshmen, there weren't any prerequisites for the course.

The chemical engineering section of the course discusses chemical applications including fabricating and characterizing nanomaterials.

Chemical Applications

Prior to the chemical applications modules, material was presented on what is considered to be nanoscale and examples are given of nanoscale materials. Nanotechnology generally refers to structures and processes occurring on a length scale ranging from 1 to 100 nm. Examples of nanomaterials include many natural materials such as chemical molecules (water molecule ~ 1 nm, buckyball ~ 1 nm) and biomaterials such as DNA (width ~2.5 nm) [2]; and manmade materials such as carbon nanotubes and nanowires.

In the modules that were developed a number of resources were used.

Chemical Module 1: Particle Size Effects

This module focused on the size effects of particles and compared properties of particles larger than a micron with the properties of nanoparticles. The topics and resources used are summarized in Table 1. The topics were chosen to highlight the differences between bulk materials and nanoparticles, to demonstrate the applications that are made possible by the special properties of nanoparticles, and to demonstrate the potential benefits to society. For example, the change in color with particle size is unique to nanoparticles. In addition, the effect of impurities on the color of colloidal gold is unique to nanoparticles. One benefit to society is the use of colloidal gold to detect melamine in contaminated milk. The decreased melting point of colloidal gold example showed what was different at the nanoscale and presented the practical application of printing devices on plastic or paper at lower temperatures.

Some of the resources used were developed by previous NSF grants at other institutions. Specifically, the Materials Research Science and Engineering Center (MRSEC) website at the University of Wisconsin Madison provides access to slides and videos of experiments. Additional material is also available on the Nanotechnology Center for Learning and Teaching (NCLT) website. Other images and information were from various other sources such as news articles. Video clips were used to better demonstrate some concepts.

Chemical Module 2: Seeing at the Nanoscale

This module focused on characterizing nanoparticles and nanostructures. The approach was to compare characterization of bulk materials with characterization of sub-micron materials so that students could understand some of the challenges of working at the nanoscale. Therefore the discussion began with optical light microscopes. The aim of this module was to help the students understand the limits of light microscopy and why new techniques were needed to characterize nanoparticles.

After presenting the limitations of light microscopy, class discussion was initiated by asking the students to name other things that we can't see with light and be discussing how these were characterized. One example is discussing how the bottom of the ocean was mapped. The students were also asked what the alternatives to light microscopy might be. The goal was to get the students to think about alternatives to light microscopy.

Table 1. Topics and resources used in Module 1.

Topics	**Resources**
Size and Opacity Application: nanoparticles in contact lens	[3] [4]
Determining whether colloidal dispersion or solution – Tyndall effect	
Size and color – CdSe nanoparticles	[5]
Synthesis of CdSe nanoparticles	[6]
Synthesis of colloidal gold • Gold chloride method • Laser ablation	 [7] [8]
Effects of impurities on colloidal gold • Citrate anions color change • Melamine detection in milk	 [9] [10, 11]
Melting point and particle size – gold Application: printing electronic devices	[12] [13]

The topics discussed in Module 2 are summarized in Table 2. Both the scanning electron microscope (SEM) and the transmission electron microscope (TEM) were discussed and compared with light microscopy. In addition, scanning probe microscopy (SPM) was discussed and mainly focused on scanning tunneling microscopes (STM) and atomic force microscopes (AFM). Although none of these were presented in great detail, an overview of the general concepts of operation, advantages, and limitations of each technique were presented.

Table 2. Topics and resources used in Module 2.

Topics	**Resources**
Scale and microscopy techniques	[14]
Light microscopy Empty magnification and depth of focus	 [15]
SEM and TEM	[16]
Scanning probe microscopy Scanning tunneling microscopy Atomic force microscopy	[17] [9, 17] [9, 17]

Chemical Module 3: Nanostructures

This module focused on nanostructures, particularly carbon based nanostructures. The different types of carbon nanostructures including graphene, buckminsterfullerene, and carbon nanotubes were compared; and the properties techniques for synthesizing carbon nanotubes (CNTs) were presented. Class discussion was initiated by asking the class what applications could CNTs have based on the known properties. This is followed by a discussion of possible applications in various fields. This includes a discussion of a water filter that uses a mesh with carbon nanotubes [21]. This example is chosen because it not only is an example of a practical use of CNTs, but it also demonstrates global and societal impact because this filter can be used to provide clean water in third world countries where clean water is scarce. The applications were updated in the Fall 2011 semester to include an example where CNTs were used in wind turbine blades to create a lighter stronger blade that will capture more energy [23]. Other applications included using CNTs as nanoscale test tubes for chemical reactions [19]. This is not an exhaustive list of the applications. Since other faculty would discuss mechanical and electrical aspects later, the focus here was on chemical applications.

Table 3. Topics and resources used in Module 3.

Topics	**Resources**
Carbon allotropes	[18]
• Fullerenes	[19]
Carbon nanotubes (CNTs)	[9]
• Growing CNTs	[20]
• Properties	[9]
• Applications	[19, 21-23]

ASSESSMENT

Formal course assessment is being performed by a faculty member in the Department of Counseling and Educational Psychology. Assessment has only been completed for one offering of this course. The plan is to compare the course assessment results for each time it is offered.

At MSU students complete course evaluations by giving ratings from 1 through 5 on a set of criteria, where 5 is the most desirable rating. In the spring semester of 2011, the course received a 4.2 and during the fall semester it received a 4.1 rating; these ratings indicate the class was well received.

CONCLUDING REMARKS

During both semesters the course was taught, students were engaged in the course and frequently asked questions during class. Some students were excited enough to send the instructors links to websites that described recent innovations in nanotechnology. Therefore, the class did meet the goal of getting more students interested in nanotechnology.

This class was developed as an introductory class for a nanotechnology certificate program. Regardless of each student's field of study, this course provided each student with a variety of applications across a broad spectrum of fields – nanobacteria to nanoelectronics. Students who take this course and one of the subsequent courses in the certificate program will be better prepared to address nanotechnology issues in their field. Specifically, in the chemical section of this course, students learned about nanoparticle preparation techniques, characterization methods, and applications.

This course is the first step in creating a multidisciplinary program in nanotechnology at MSU. The certificate program courses will allow students to tailor their studies to better prepare them for nanotechnology in their careers.

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