An Methodology for Creating Integrated Nanotechnology Sophomore Course

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Abstract

We report a new course development to prepare future engineers with expertise in nanoscale science and technology. An increasingly competitive global economy requires engineers whose competence goes beyond technical specialization and encompasses the capability of working effectively on interdisciplinary or international teams. Although relatively modest in scope, this National Science Foundation (NSF) supported course represents the first step in establishing a sustainable program in nanoscale engineering at the University of Pittsburgh. To lay the foundation for this multi-year, multifaceted educational project, the following three methods were used; 1) development of an undergraduate elective in nanoscale science and engineering; 2) initiation of career education/outreach with secondary school students; and 3) provision of hands-on research experience. In considering options for enhancing the research experience for students, we recommend utilizing other resources within the School of Engineering (or other Units). One such resource is a workshop on professional-level presentation skills.

Introduction

Notechnology is a new arena for science and engineering with applications in a variety of fields including biomedicine and health care, communications, environmental sciences, energy, and space exploration. To meet the growing, worldwide need for engineers who are well trained in the scientific, social, and ethical aspects of nanotechnology, it is important to attract, educate, and retain talented young students [1]. Developing a pool of individuals interested in and committed to the field of nanoengineering entails counteracting misconceptions about nanotechnology that are promulgated through the entertainment media while engendering excitement about the truly innovative possibilities of this emerging technology.

In academia, nanotechnology is a multidisciplinary and rapidly developing field that seeks to understand new physical properties at length scales between atoms and bulk materials. A subcommittee of the National Science Foundation (NSF) on Nanoscale Science, Engineering and Technology (NSET) defines nanotechnology as [2]:

"Research and technology development at the atomic, molecular or macromolecular levels, in the length scale of approximately 1–100 nanometer range, to provide a fundamental understanding of phenomena and materials at the nanoscale and to create and use structures, devices and systems that have novel properties and functions because of their small and/or intermediate size."

This nanoscale definition derives from the importance of physical phenomena that are less obvious for larger objects including quantum mechanics, strong surface forces, and Brownian motion [2].

Because nanoscale science and engineering are broad in nature, many of the challenges in these fields require a multidisciplinary approach in research and development [1]. It is crucial, therefore, that engineering students gain the knowledge and skills necessary for integrating nanoscale science with engineering fundamentals in order to produce useful technology in the future. Additionally, the demand for integrating nanotechnology into the engineering and science curriculum has emerged from the exploration of community colleges and universities. Thus, Schools of Engineering are challenged to prepare undergraduate students who are capable of working in multidisciplinary teams, conducting research, and providing leadership in the emerging world of nanotechnology in engineering [3].

In keeping with these considerations, the project described in this article aims to:

1) Introduce second-year students to the fundamental principles of nanoscale science, engineering, and technology;

2) Provide an intensive research experience for a select number of undergraduate students under the mentorship of nationally and internationally recognized nanoengineering faculty; and
3) Introduce high school students to nanoscale science, engineering, and technology as a potential career path.

A threefold strategy was used to accomplish these goals. First, a three-credit undergraduate elective course in nanoscale science and engineering was developed and incorporated into the second-year curriculum of the Swanson School of Engineering of University of Pittsburgh. The elective course titled Nanotechnology and NanoEngineering addresses this gap in the curriculum, serves as an initial introduction to this growing area of engineering, and aims to encourage students to pursue more in-depth, specialized study. The course is open to engineering students at the 1600 sophomore level and above, 180 chemistry students, and 75 physics students in the School of Arts and Sciences, as well as students in other professional schools including medicine. Because the course has been incorporated into the fall semester of the sophomore-level curriculum, successful completion of all freshman-level courses is a prerequisite for engineering students who register for the course.

The strategy used to accomplish the second project goal was the provision of an intensive, paid summer research experience for a select number of students who successfully completed the elective course. The literature on engineering education suggests that students with hands-on research experience are better equipped to make informed judgments about technical matters and to communicate and work in teams to solve complex problems [4], [5]. Although the scope of funding for the project limited the number of students who would be able to engage in an actual research work, an experimental, research-focused learning activity was incorporated into the elective course. Working in teams of three, all students were required to conceptualize and develop a proposal for a research project that could potentially be conducted using the facilities of the Petersen Institute of NanoScience and Engineering (PINSE) under the supervision of a PINSE faculty member. The purpose of this experimental learning activity was to simulate the nature of professional work they are likely to encounter when they pursue engineering careers in industry or academia. By working on a project team, students had an opportunity to develop domain expertise, gain an understanding and appreciation for the research process and its practice, and acquire team, communication, problem-solving, and higher-level thinking skills [4], [5].

The strategy for addressing the third project goal was based on the premise that nanoscience and technology is such a new area of study, it is unlikely that many K-12 students and high school science teachers will have much understanding of this emerging field. Further, a student's understanding may be based on misconceptions of nanotechnology fostered by the entertainment media through portrayals of killing nanobots in cartoons and movies like Spiderman and The Hulk. In order to gain deeper understanding of the ways in which high school students think about nanotechnology and to promote a more accurate understanding of the field, the project included an outreach initiative. Unlike some areas of the country where elementary and secondary school students have limited opportunities for participation in science enrichment programs, southwestern Pennsylvania is fortunate to have a number of programs ranging from Governor's Schools for gifted, rising senior students to weekend and summer camps for elementary and middle school children. Within this resource-rich environment, it was more cost effective to incorporate information about nanoscale science, engineering, and technology into an existing program than to create a new program. Predicated on the assumption that students with an inclination to study science will be receptive to learning about exciting career possibilities in nanoscale science, engineering, and technology, a relationship was established with the Pennsylvania Junior Academy of Science (PJAS). The PJAS is "a statewide organization of junior and senior high school students designed to stimulate and promote interest in science among its members through the development of research projects and investigations" [6]. The research focus of PJAS was particularly appealing to the course instructor who focused on establishing a relationship with the western region of the PJAS.

Conclusion

Taken together, the undergraduate elective, summer research experience, and outreach workshop have successfully established a foundation for building a sustainable, research-intensive, multidisciplinary educational program in nanoscale science, engineering and technology. Efforts to accomplish this longer-range goal will take the following factors into consideration.

First, the students' positive response to hands-on activities is prompting a reevaluation of the balance between informational lectures and interactive learning experiences. As is fairly common with many introductory courses, there is far more content to be presented than is manageable in a three-credit course. Instructors often find it necessary to make difficult tradeoffs between presenting information on a broad range of fundamental concepts and principles and providing opportunities for interactive, hands-on learning.

Second, student understanding of ethical and social issues related to nanotechnology is considered an important instructional goal for engineering education. However, it is difficult to cultivate a meaningful grasp of ethical concepts and principles in a single class session. Despite the fact that many students claimed to have had previous instruction in ethics—in high school and/or engineering school—none demonstrated much insight into the ethical issues embedded in the scenarios presented for class discussion. Particularly troubling was the lack of time to help students apply ethical principles more critically to their analysis of the scenarios. Rather than a one-time session, consideration is being given to using the course Web site to integrate information about ethics throughout the semester.

Third, if the course is to have a multidisciplinary student enrollment, then more effort needs to be expended in announcing and promoting the course across the School of Engineering as well as other professional schools and the College of Arts and Sciences. Working with the registrar's office to cross-list the course in the university's course schedule is one step in this process. Although it would be ideal to have students from other professional schools participate in the course, this may be unlikely because the rigid sequence of required courses gives students little leeway for taking electives outside of their field of study. Another approach for recruiting students is to promote the course among other two- and four-year colleges.

In considering options for enhancing the research experience for students, the instructor recommends utilizing other resources within the School of Engineering. One such resource is a workshop on professional-level presentation skills. Although attendance at this workshop could potentially be included as a required course assignment, for now it will be incorporated as a recommendation. Making the workshop an option is based on concern for the overall course load carried by second-year students.

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