

Introducing Nano and Society Issues into the Undergraduate and Graduate Classrooms

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Abstract - Nanotechnology has recently emerged as an exciting new arena of scientific research and technological innovation. At the same time, concerned citizens, prominent technology leaders, nanotechnology boosters, science fiction authors, policy officials, and environmental organizations have raised important questions about the technology's potential social, ethical, and environmental implications. We have developed teaching modules as well as full courses that offer students from engineering as well as other disciplines from across campus an opportunity to engage in discussions about the interaction between new technologies and modern society. Our nanotechnology and society educational materials range from short teaching modules exploring the impact of a new technology on different social groups using a role-playing exercise, to complete courses at the undergraduate and graduate levels that focus on theories and approaches to understanding the social dimensions of technology, applied to the case study of nanotechnology. The courses have drawn students from a wide range of disciplines, including the life, physical, and social sciences, humanities, and engineering.

Index Terms – Interdisciplinary education, Nanotechnology, Societal implications, Undergraduate and graduate education.

INTRODUCTION

Nanoscale science and engineering (NSE) has recently emerged as an exciting new arena of scientific research and technological innovation. At the same time, concerned citizens, prominent technology leaders, nanotechnology boosters, science fiction authors, policy officials, and environmental organizations have raised important questions about the technology's potential social, ethical, and environmental implications. Individuals, including scientists, engineers, and members of the general public, must consider the interactions between nanotechnology and society.

Public officials and research funding agencies are increasingly acknowledging the societal, ethical, legal, and policy implications of NSE as an important aspect of nanotechnology research and education [1]-[3]. To be sure, recent hype and concern about “nanobots” and “grey goo” [4]-

[5] seem out of line with realistic assessments of nanotechnology, at least in the next few decades. However, there can be little doubt that the ability to create nanoscale materials and devices will generate new ways for people to understand nature, to act, and to interact, in turn raising complex and important questions about who will have access to these new capabilities, how they will be applied, by whom, and with what consequences for individual lives and the organization of social relationships [6].

It is incumbent on science and engineering educators to partner with social science and policy educators to bring the conversation about the connections between science, technology and society to undergraduate and graduate students across campus. At the outset of our project, we found that a curricular gap exists in nanoscale science and engineering education at the University of Wisconsin-Madison (UW), as well as elsewhere across the country. Nanotechnology education has primarily focused on the field's technical aspects, placing little emphasis on issues such as the social and ethical implications of design choices, public attitudes toward new technologies, nanotechnology and risk, or nanotechnology policy.

EPD 690: A GRADUATE SEMINAR IN NANO & SOCIETY

I. Background

In order to develop an effective undergraduate course in nanotechnology and society, we needed to begin by educating the educators – both at the faculty and the graduate student levels. To this end, we created a seminar for advanced graduate students in the sciences, engineering, humanities, and social sciences to explore questions about the connections between nanotechnology and societal issues and to reflect on the broader place of technology in modern societies. The instructors for this effort came from backgrounds in engineering, policy, and the humanities. Additionally, to develop, implement, and evaluate this program, we initiated a unique partnership between the UW Materials Research Science and Engineering Center (MRSEC) on Nanostructured Interfaces [7] and the Robert and Jean Holtz Center for

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Science and Technology Studies, a newly established focal point for research and teaching in the history, sociology, and philosophy of science, technology, and medicine at UW [8].

Our goal in developing the EPD 690 *Seminar in Nanotechnology and Society: Analytical & Pedagogical Approaches* course was to educate students at the graduate level and to create exciting undergraduate curriculum in nanotechnology and society for first-year students from liberal arts, science, and engineering fields. To do this, we focused on creating a curriculum that:

- Explores, in-depth, the social, ethical, legal, and policy implications of nanoscale science and engineering.
- Enables students in the sciences and engineering to learn about what happens when science and technology leave the laboratory and get taken up into society, to understand ethical issues in science and engineering research, and to communicate about such issues with others who do not have substantial technical training or skills.
- Exposes students in the humanities and social sciences to the ways in which social, political, economic, and cultural factors shape the design and organization of technological systems and, in turn, how these systems help to structure social interactions and human well-being.

- Prepares students in all fields to make informed choices as consumers and citizens about technology and provides them with greater literacy in the technological foundations of modern societies, as well as how choices about technology shape their own lives and the lives of others around the world.

II. Course Details

The graduate-level seminar was offered to graduate students for either one or three credits through an Engineering Professional Development course (EPD 690) titled *Seminar in Nanotechnology and Society: Analytical & Pedagogical Approaches*. Students who chose the one-credit option were expected to attend the seminar's first hour, read and discuss class materials, and write a one-page response essay each week. This part of the seminar, attended by 10 graduate students and post docs in the Fall 2004 semester, focused on theories and approaches to understanding the social dimensions of technology, applied to the case study of nanotechnology. A brief outline of the seminar is provided in Table I. More detailed course information is provided on the UW MRSEC website under "Nanotechnology Courses" [9] and in a book chapter [10].

TABLE I
OVERVIEW OF COURSE TOPICS AND DISCUSSION QUESTIONS USED IN
EPD 690 SEMINAR IN NANOTECHNOLOGY AND SOCIETY: ANALYTICAL & PEDAGOGICAL APPROACHES

Week	Topic	Classroom Discussion
1	Course Introduction	
2	What is Nanotechnology? Why Do We Care about Its Societal Dimensions?	
3	What is Progress?	What does Leo Marx's argument ("Does Improved Technology Mean Progress?") imply about current discussions of the societal benefits of nanotechnology? Can we think of ways in which nanotechnology innovations might not necessarily contribute to progress?
4	Technologies as Forms of Life	Find a news article describing an application of nanotechnology. Describe a form of life that might emerge involving this application, addressing who might see it as progressive and who might not.
5	Social Choices and Technological Change	Are there other examples that you can think of in which users are shaping current technologies? What does this mean for how we think about the societal aspects of nanoscience and nanotechnology?
6	The Politics of Technological Change	Is technology political? What does this imply for how we think about technological design?
7	The Military and New Technologies	What is the relationship between the military and new technologies? What interests does the military have in nanotechnology?
8	Technological Accidents	What is a "normal accident"? Do Charles Perow's concerns ("Normal Accident at Three Mile Island") apply to nanotechnology?
9	Technology, Risk, and Society	Why do experts and lay publics sometimes arrive at different reasoning regarding the risks of technologies?
10	Environment and Health Impacts	How should we approach questions of environment and health risks associated with nanotechnology?
11	Nano-Critics	What social groups care about nanotechnology? What reasons do they give for their concerns?
12	Government Assessments	
13	Science Fiction	Consider the advantages and disadvantages of science fiction as a medium for inquiring into and communicating about the societal aspects of nanotechnology.
14	Technology and the Future	Why is projecting into the future of technologies so hard? How important is it to try anyway? If it is important, how should we approach the uncertainties involved?

The three-credit option of EPD 690 focused on the development of teaching skills and the creation of a teaching portfolio, as is indicated in Table II. Students who chose this option attended a second hour of the seminar in addition to the first, and developed an annotated syllabus and teaching materials for an undergraduate seminar in nanotechnology and society that would integrate the technical and social

dimensions of NSE. As such, this portion of the course was designed for future educators who want to teach nanotechnology and society topics, either as stand-alone courses or as part of another course. This second part of the seminar introduced approaches, materials, and skills for teaching undergraduates how to think critically about the social aspects of technology.

TABLE II

TEACHING TOPICS COVERED IN EPD 690 SEMINAR IN NANOTECHNOLOGY AND SOCIETY: ANALYTICAL & PEDAGOGICAL APPROACHES

Week	Teaching topic
1	Course introduction
2	Leading discussions
3	Active learning
4	Selecting course materials
5	The inclusive classroom
6	Discussion of developing portfolios I
7	Classroom and writing problems
8	Informal writing assignments
9	Formal writing
10	Discussion of developing portfolios II
11	Grading writing
12	Asking for feedback
13	Course framework
14	The first day

Four graduate students completed the three-credit version of the course and developed their own annotated syllabi for a three-hour (per week) undergraduate nano and society seminar that discussed both technical and social dimensions of NSE. These students also created supporting materials, including course assignments (exams, formal writing assignments, quizzes, informal writing assignments, and/or problem sets), class lesson plans, and mid-term evaluation forms. The teaching assistants (TAs) for the undergraduate version of the seminar to be held in the spring used the second hour to help them to prepare for the up-coming semester and to develop their syllabi.

STS 201: UNDERGRADUATE SEMINAR IN NANO & SOCIETY

I. Background

During the Spring 2005 semester, two of the graduate students who developed syllabi in the EPD 690 course were employed as teaching fellows to teach their own undergraduate courses on nanotechnology and society. These courses meet as sections of a Science and Technology Studies course (STS 201), *Where Science Meets Society*. STS 201 is regularly taught as a small first-year seminar and satisfies either a humanities or social sciences requirement within the university's core liberal arts curriculum. It is well known by first-year advisors in the College of Letters and Science and the College of Engineering and has proven successful in drawing students from humanities, science, and engineering.

The undergraduate seminars were developed with the goals of:

- Introducing students to various social theories of technology, such as technological determinism and the social construction of technology.
- Exploring the wider social, historical, and cultural contexts in which nanoscale science and engineering are embedded.
- Examining, in an integrated fashion, the technical and social elements of nanotechnological systems.
- Providing students with skills and resources for learning about the technological infrastructures of modern societies

and the potential impacts of developments in nanotechnology.

- Investigating why people sometimes come to fear new technologies, including studies of technological utopias and dystopias, accidents, and concerns about loss of control.

Dr. Charlie Tahan was one of the graduate student TAs who taught an undergraduate STS 201 course in spring 2005. Tahan describes his seminar as “introduce[ing] the emerging and ill-defined field of nanotechnology to a diverse, nontechnical audience and explor[ing] nanotechnology's economic, historical, societal, political, and environmental implications and origins” [10]. Approximately 25 undergraduates ranging from first-years to seniors drew heavily from engineering, science, and business majors participated in the course.

More detailed course information about Tahan's course, as well as the other five courses that addressed nano and society, is provided on the UW MRSEC website under “Nanotechnology Courses” [7].

II. Assessment Results

Tahan heavily evaluated his seminar with several surveys given at intervals throughout the semester. He evaluated the students' knowledge gains by asking a variety of questions, including definitions and open-ended responses, and he solicited the students for feedback on the course by asking questions about its structure and content. A more detailed description is provided in a journal paper [11] and a book chapter [12].

In general, the pre- and post-assessments showed that the enrolled students found the course valuable and that many of the learning goals outlined in the syllabus were met. Over the course of the semester there was a general increase in comfort level across all topics surveyed. By the end of the semester, 95% of the class reported that they were “comfortable” or “very comfortable” with the subject of nanotechnology and society.

Additionally, clear improvements in understanding of NSE and N+S terms and concepts were achieved. In the pre-assessment, student definitions of “nanotechnology” used abstract terms as technology that was “tiny,” “microscopic,” or “advanced.” The most common answers were variations on “the study of small particles or very small technology,” with only one student citing 1×10^{-9} meters as a benchmark. The final exam provided a venue for post-assessment, where virtually all of the students were able to formulate a working definition of NSE on par with or surpassing the status quo definitions found in the research literature. The students were also aware of new phenomena that occur at the nanoscale, such as increased reactivity and quantum confinement effects, and were able to give three correct examples of specific nanotechnologies. Moreover, the students were able to formulate three meaningful questions about the societal

implications of NSE, a question that was left mostly blank on the pre-assessment.

EPD 160: NANO AND SOCIETY IN AN INTRODUCTORY ENGINEERING COURSE

While stand-alone courses obviously offer the greatest opportunity for engaging with nano and society issues in-depth, it is equally important to incorporate nano and society issues into traditional engineering courses. During the Fall 2004 training and syllabus development process of EPD 690, the graduate student teaching fellows developed modules on nanotechnology and society teaching to test in existing courses. One such module was implemented in a freshman-level *Introduction to Engineering* course (EPD 160) where the topic of technology and society is traditionally introduced. After an introductory lecture providing an overview of nanotechnology, the undergraduate students were divided into teams, assigned a NanoCommunity, presented with the idea of a new ultra-strong nanocomposite, and asked to brainstorm potential applications of this technology for their assigned NanoCommunity. After the brainstorming activity, each team presented its top idea. The range of the students' community-relevant ideas clearly illustrated the interaction between technology development and societal needs. After these brief presentations, students spent a few more minutes with their teams to discuss the future ramifications of their top idea, both positive and negative. The class concluded with a short lecture on policy issues that arise with the development of a new technology. One student commented in a course journal that the activity "reminds us that we are working for and with people. Sometimes I think we get [so] caught up in calculations and budgeting that we forget that our actions will affect others."

CONCLUSIONS

This curriculum development effort has resulted in both graduate and undergraduate-level interdisciplinary seminars that address the issues surrounding nanotechnology and society, and in seven tested syllabi for leading such seminars. These courses have attracted students from diverse fields, including social sciences, life and physical sciences, engineering, and humanities. Both the undergraduate and graduate students who participated in the seminar completed assessments and displayed a greater and more sophisticated appreciation for the social aspects of nanotechnology after the course. In addition, the undergraduates in particular demonstrated an increased knowledge of nanoscale science and engineering.

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