Nanotechnology and Society: A discussion-based undergraduate course

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Nanotechnology has emerged as a broad and exciting, yet ill-defined, field of scientific research and technological innovation. Important questions have arisen about the technology's potential economic, social, and environmental implications by prominent technology leaders, nanotechnology boosters, science fiction authors, policy officials, and environmental organizations. We have developed an undergraduate course that offers an opportunity for students from a wide range of disciplines, including the natural and social sciences, humanities, and engineering, to learn about nanoscience and nanotechnology, to explore these questions, and to reflect on the broader place of technology in modern societies. The course is built around active learning methods and seeks to develop the students' critical thinking skills, written and verbal communication abilities, and general knowledge of nanoscience and nanoengineering concepts. Continuous assessment was used to gain information about the effectiveness of class discussions and enhancement of students' understanding of the interaction between nanotechnology and society.

I. INTRODUCTION

Nanotechnology is cool. Though not profound or provable, this truth has great allure to students and educators both. As public attention to nanoscale science and engineering (NSE) spotlights research ongoing in labs across the country, students are pulled toward careers in science, engineering, and related social sciences or businesses. Educators not only have a new field of endeavor and questions to explore but also another hook to gain the attention and interest of these creative learners and cohorts. Indeed, NSE raises many important questions that need addressing, especially at the intersection of technology and society. This is evident if one looks at government funding of the field in the USA, with apportioned money specifically for environmental and societal impact studies [1, 2]. The ability to create nanoscale materials and devices will generate new ways for people to understand and exploit nature, 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 and social relationships.

It is incumbent on science and engineering educators to partner with their counterparts in the social sciences and public policy to bring the conversation about the connections between technology and society to undergraduate students across campus. Before this project, a curricular gap existed in NSE 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, or nanotechnology policy.

A course on nanotechnology and its societal implications can serve multiple purposes. Recruitment, education, introduction to NSE from a beginner's perspective, and science and technology studies (STS) all fall in its scope. We describe here a nontechnical course for undergraduates that introduces a broad audience to NSE and STS in one venue. The course is open to all majors and satisfies a humanities requirement for undergraduate students. Though designated a 200-level class, the course was made open to all grade levels, from freshman to seniors. Discussion-based and requiring active student involvement, the course focuses on key readings, group discussion sessions, role-playing exercises, essay assignments and exams, and a semester-long research project with final presentation.

The course, *Nanotechnology and Society*, was taught in two manifestations in the spring of 2005. Two sections of a STS course, STS 201 - *Where Science Meets Society,* were designated for NSE and each was designed and lead by a graduate student specifically trained on NSE and STS in the previous semester. 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. This paper details the section [3] taught by co-author Tahan, a physics graduate student; the other section was taught by co-author Leung, a sociology graduate student. Both build on a similar core curriculum developed in the prior semester's training [4].

II. PREPARATION

In order to develop an effective undergraduate course in nanotechnology and society, we first needed to educate the educators. To this end, a seminar was created 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 (co-authors Zenner, Ellison, Crone, and Miller) came from backgrounds in engineering, policy, and the humanities. Additionally, to develop, implement, and evaluate this program, a unique partnership was initiated through a National Science Foundation funded Nanotechnology Undergraduate Education (NUE) grant between the Materials Research Science and Engineering Center (MRSEC) and the Robert and Jean Holtz Center for 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.

The 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 ten graduate students and post doctoral associates in the Fall 2004 semester, focused on theories and approaches to understanding the social dimensions of technology, applied to the case study of nanotechnology. More detailed course information is provided on the UW MRSEC website under "Nanotechnology Courses" [5] and in a conference proceeding [4].

The three-credit option of EPD 690 had an additional emphasis on the development of teaching skills and the creation of a teaching portfolio. 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. These students also lead the discussion in the first hour on a rotating basis, giving them an opportunity to test various active learning techniques such as think-pair-share, jigsaw, town-meeting formats, group discussion, blackboard exercises, etc. This second part of the seminar introduced approaches, materials, and skills for teaching undergraduates how to think critically about the social aspects of technology. Four graduate students completed the three-credit version of the course and developed their own syllabi, including the two who went on to teach their own courses in the spring. One of these courses is described here.

III. GOALS AND COURSE CONTENT

STS 201: Nanotechnology and Society sets broad goals in both its scope and content. As stated in the student syllabus, the objectives of this course are summarized

1. **Introduction to Nanotechnology and Society.** (Class 1, 2, 3, Essay 1) How do we define nanotechnology?
2. **Nanoscience/technology** (Class 4, 5, 10, 12, 14, 37-44)
    (a) Policy Reports and Reviews
    (b) Topics: New Effects at Nanoscale; Quantum vs. Classical; Nano-Manufacturing; Quantum Dots and Nanoparticles; Carbon; Medical Applications
    (c) Student research projects and presentations
3. **Nanotech in Culture** (Class 6, 8, 9, 22, 24, 46)
    (a) **Nanoproducts and Business.** What real nanoproducts are on the market now and what's nanohyped?
    (b) **Science Fiction.** How does science fiction bring science/technology to the public? (See Refs. [24–26])
    (c) **In the News.** How has nano seeped into the media?
4. **Revolutions and the History of Science and Technology.** (Class 31, 46, Essay 3) Is nanotech a new industrial revolution?
5. **Technology and Society** (Class 7, 9, 11, 13, 15, 16, 24, 32, 46, Essay 2)
    (a) **Progress.** Do technological innovations necessarily contribute to progress?
    (b) **Technology as Forms of Life.** How does technology affect the way we live?
    (c) **Social Choices.** How do the users shape the development of technology?
    (d) **The Politics of Technological Change.** Is technology political?
6. **How Government Drives Technology** (Class 23, 25, 46, Essay 4)
    (a) **Nanotechnology Funding Initiatives.** How much money is being put into nano?
    (b) **Funding Agencies.** What agencies handle nanotech funding?
    (c) **The Military and Technology.** How do the military's needs shape our world?
7. **Weighing the Risks** (Class 33, 34, 35, 36, 46, Essay 4)
    (a) **Risk Analysis.** How does society decide what kinds of risks are acceptable given the possible consequences of pursuing a certain technology or science?
    (b) **Nanotoxicology.** Is NSE explicitly more dangerous than micro?
    (c) **Accidents.** What is a normal accident?
8. **Thinking About the Future** (Class 30, 45, 47)
    (a) **Prophets, Worriers, and Hacks.** What do the minds of today (or at least those who get media attention) think about nanotech? (e.g. [27, 28])
    (b) **More Science Fiction.**
    (c) **Reflections.** What have we learned?

Table I: Approximate course outline for 47 classes (each 50 minutes). We list one possible question with each topic as an example. The course materials can be found online [3].

below.

1. Introduce the broad field of nanotechnology and the basic science and technology behind it.

2. Consider the societal implications of nanotech in the context of social, scientific, historical, political, environmental, philosophical, ethical, and cultural ideas applied from other fields and prior work.

3. Develop your questioning, thinking, idea producing, and communication skills, both written and verbal.

Since this was primarily a humanities course, the focus is on understanding the implications of technology and its interactions with society, specifically applied to NSE. From a deeper curriculum perspective, the goals include the following.

1. Introduce the various social theories of technology, such as technological determinism and the social construction of technology.

2. Explore the wider social, historical, and cultural contexts in which nanoscale science and engineering are embedded.

3. Examine the technical and social elements of nanotechnological systems.

4. Provide skills and resources for learning about the technological infrastructures of modern societies and the potential impacts of developments in nanotechnology.

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

An obvious question is how much science was included? Although this is not a technical course, the students were required to learn some of the basic science of the nanotechnologies discussed in class. It is best to illustrate the level with an example. Let's take the quintessential nanotechnology of nanocrystals, or quantum dots. The students were expected to learn some primitive semiconductor physics in order to understand why nanoscale semiconductor crystals exhibit new properties, such as changes in color emission, at certain size thresholds. The notion of a bandgap between core (valence) electron levels and free (conduction) levels was introduced with a discussion of light (photon) excitation. The students were expected to learn how the distance between the electron levels changes with decreasing size and why (quantum confinement effects). This understanding could then be compared and applied to the application of quantum dots for medical contrast imaging. Instructor designed lectures, in addition to science texts for a lay audience, e.g. Refs. [6–9], provided the main learning materials.

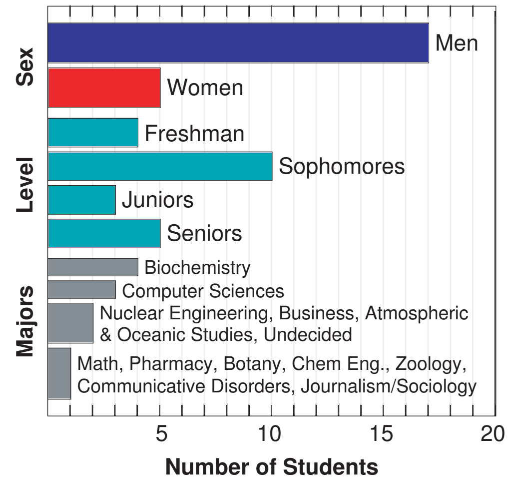

Figure 1: Enrollment in one section of *STS 201: Nanotechnology and Society*. The figure gives the number of students in each category (e.g., Female (5), Freshman (4), majoring in Business (2), and so on).

The class outline given in Table I is mostly chronological except that the nanoscience subtopics were distributed throughout the class instead of in one lump. The class began its first week looking at more general introductory texts on nanotechnology, such as in popular science magazines, think-tank and corporate reports, then began looking at the STS topics one-by-one, interchanging STS with NSE. The last few weeks were spent with the students reporting on their research in a specific topic in NSE. The last week ended in a review and reflection.

The STS readings used throughout the course were introductory in nature (such as in Refs. [12–23]), assuming an audience not familiar with the more complex analytical techniques and terms that may be assumed in higher level sociology or history of science courses. The specific readings for this section are available online [3]. The curriculum in bulk consisted of components which introduced a concept or framework in STS and then used STS as a means to apply or interpret that concept. As a specific example, we have taken one subtopic of the course and listed in some detail in Table II the actual timeline and content of how this particular subject, *How Government Drives Technology: The Military and Technology,* was addressed. Humanities, science, multimedia, and discussion are interwoven to form a learning block. This is typical of the course in general.

IV. REQUIREMENTS AND OUTPUT

Because this was primarily a discussion-based humanities course, class participation (including homework) was highly valued and vital to exploring the issues fully. It weighed at 25% of the grade total, including the expecta-

- How Government Drives Technology: The Military and Technology
  - Day 1
    1. Read *The US National Nanotechnology Initiative After 3 Years* by M. Roco [2]
    2. Read *Command Performance: A Perspective on Military Enterprise and Technological Change* by D. Noble [21]
    3. Group work on worksheet for *Command Performance* article
    4. Instructor-lead discussion and review
  - Day 2
    1. Students find and present to class examples of military nanotechnology they found in the news
    2. Read *Super Soldiers,* MIT Technology Review, by D. Talbot [10]
    3. Watch video *Super Soldiers (Institute for Soldier Nanotechnologies)* [11]
    4. Debate in class incorporating current and prior understanding: L. Winner vs. D. Rumsfield

Table II: Extended example of one subtopic of the course.

tion that students participate or lead group discussions, present before the class, and participate in debates, mock hearings, or other cooperative activities. Reading was assigned for nearly every class but homework was occasional and could include small writing or research assignments to be shared with the class. One example was an assignment where the students chose from a list of professors at the UW listed as doing NSE research and reported back to the class on what the particular research group was doing and if they thought it was NSE. Another example was an assignment to find a NSE product in the news, learn about it, and teach what they learned to the rest of the class. Assignments such as these acted as a means to diversify research into the continually changing forefront of NSE and to highlight examples of humanities/STS topics we were discussing in class.

To a large extent, the course was about connecting disparate questions, concepts, facts, and ideas, and then producing new ones. Writing is a vital process in this endeavor in that it is the formal way of integrating ideas and communicating. In that vein, there were four, 2-3 paged, double-spaced response or op-ed type essays for each of the main topics covered. Each of the four graded essays made up 5% of the class grade for a total of 20%. The topics of these are listed in Table III.

Two formal exams accounted for another quarter of the students grade. One midterm and one final each cover the readings, terms, constructs, and science learned in and out of class.

1. You are interviewing for a job at McKinsey, a prestigious consulting firm. During your interview you mention that you have some experience thinking about the societal implications of technology, specifically nanotechnology. Seeing a possible avenue for future growth, your interviewer asks you to go home and write a two to three-page executive summary defining nanotechnology (which she, a non-scientist, can understand) and postulating on specific areas where McKinsey may be able to do nano-consulting in the future. You must really impress her to get the job.
2. Does nanotechnology have politics? Make your case, for or against, using the articles we've talked about in class (e.g., L. Winner's *Do Artifacts Have Politics?*).
3. Is the field of nanotechnology a revolution or just evolution?
4. Testimony before the congressional subcommittee on the first review of the National Nanotechnology Initiative. Write a brief testimony to congress where you address the following. Government investment in nanotech research. (Should the government continue funding of nanotech? In what specific areas? How?) Public participation in the evolution and funding of nanotechnology. (Should the public be brought into the nanotech development process? How?) You will represent a specific political group (military, AAAS, etc.) assigned in class.

Table III: Essay assignments (abbreviated).

The final 30% of the course requirement was assessed from an individual research project and class presentation. A list of topics was developed by the instructor, and each student selected one to research and become the class "expert" on it. We do not include a complete list of the nanotopics but examples include *Nano-Nuclear Batteries*, *Nanotechnology and Cancer*, *NanoFiltration*, and *Nanotechnology and Agriculture*. This provided a means to explore in more depth some of the different subfields of NSE and allow the students to teach each other instead of sitting through lectures by the instructor. The motivating goal was to produce a pamphlet on key nanotechnologies circa 2005 that may have value to future iterations of the class and to the public. It also provided an opportunity for more advanced students in the class to contribute particular expertise, say in biochemistry, that may be outside the realm of the instructor's specialty. Intended for a lay audience, approximately two-thirds of each roughly five double-spaced page report covered the science behind the chosen nanotopic with the last one-third on the societal implications. Each student also gave a 20 minute presentation, either with PowerPoint or on the black-board, before the class on their research project. These student reports and presentations are available on the web [3].

V. ASSESSMENT

In addition to the traditional evaluation of student work discussed in the previous section, several surveys were given throughout the semester to gauge the students changing perceptions of the course and to provide feedback on further improvement. A summary of both the evaluation and assessment results are given here.

A brief pre-assessment was given on the second day of class and two, more detailed post-assessments were given in the last week of class, in addition to several unofficial feedback surveys throughout the semester. These, together with the midterm and final exams and essay/research writing assignments, show that the enrolled students found the course valuable and that many of the learning goals outlined in the syllabus were met. One typical student comment was: "I really enjoyed the class. Not only did I learn about what advances have been achieved (or will be soon), but also the social implications towards using/creating technology."

The pre-assessment attempted to gauge the comfort and knowledge levels of the topics to be studied in the course as well as of NSE in general. Figure 2 shows the results of the comfort level assessment before and after the bulk of the course. Of particular note is the general increase in comfort level across all topics and the improvement in the area of nanotechnology and society; by the end of the course 95% of the class claimed to be "comfortable" or "very comfortable" with the subject, a tremendous improvement. In addition, the pre-assessment asked the students to define "nanotechnology" and list several nanotechnologies they knew of, as well as whether and where they had heard the term before. About a quarter of the class said that this course was the first time they had ever heard the term nanotechnology. The others cited news, tv, or science fiction as their source of introduction. Initially, most students described nanotechnology in 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" or completely circular definitions such as "study/design/manufacturing of products/objects at the nanoscale." Only one student cited 1×10^{-9} meters as a benchmark. As to examples of nanotechnology, before the course students cited "advanced/really-fast computers" as the most common example for nanotechnology, followed by "medical/medicine", and "stain free pants." The final exams and post-assessment asked these same questions again plus additional, more in-depth questions about the students knowledge of NSE.

The final exam provided an opportunity to test the students hopefully improved understanding and knowledge of NSE. When asked to "define nanotechnology"—a non-trivial question—virtually all the students were able to formulate a working definition of NSE on par with or surpassing the status quo definitions found in the community. The students universally were also able to cite examples of new phenomena that occur at the nanoscale including, for example, increased reactivity, quantum confinement effects, and biological coincidences (such as the ability of nanoparticles to cross the blood-brain barrier), as well as more specific examples. All the students 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 on the pre-assessment that was left mostly blank.

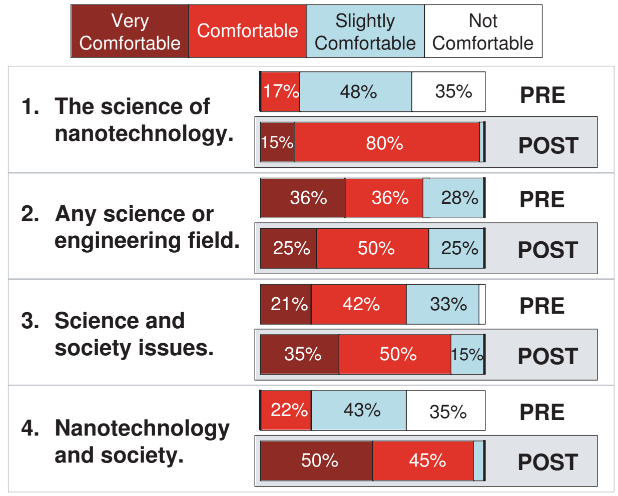

Figure 2: Pre- and post-assessment answers to the question: "Please rate your comfort level with the following topics."

The post-assessment included additional questions to judge the impact of the course on the students. The students were asked explicitly to summarize the class in a sentence or two; several comments are representative of the responses. "This class gave me a good overview of the science of nanotech and its societal implications. I now feel much better about current trends in the field." Another student spoke similarly: "This class goes over technology of the last hundred years (approx.) and focuses specifically on nanotechnology. Major issues involve evolution of technology, political involvement, and social effects." To fully interpret the post-assessment results, it's useful to revisit the makeup of the class and the motivations of the students.

Many of the students (14) took the class to fulfill a humanities requirement with about half also citing general interest in "nanotechnology." Many of the students did not come from a humanities background but instead from the engineering and natural sciences, business, and related. From this starting point, we assess how the class was appreciated.

Most students (17) said they would take the class again if they could go back in time. Only slightly less (14) would actually take it again even if it didn't fulfill some requirement, though a quarter would not. Nearly all (17 yes, 3 maybes) would recommend the course to another student. All said their knowledge of the science of

NSE improved because of this course. One student commented: "I knew very little about [nanotechnology] and I was surprised by how much there is." All said their knowledge of "what nano is" improved. Nearly all (17) said the course made them very or extremely well prepared to explain, in general, what NSE is all about to someone else. For example, one comment stated that the course "provides a basic, layman's definition as well as an in-depth definition." Nearly all (18) considered "Nanotechnology and Society" a valuable field of intellectual pursuit, which was somewhat surprising to us considering the newness and ambiguity of the field when we started.

Did the course modify the career path of the students? Before the course, most students were planning on pursuing a career in science and engineering (3 were not, 2 maybe), and none were considering one in nanotechnology. Students were largely not encouraged to change to a more nano-related career (8 maybe, 10 no), but the course did encourage them to keep an eye out for opportunities and relations to NSE in the their planned field (15 yes). Again, the course did not drastically encourage the students to pursue a career in STS or policy (5 maybe, 16 no). Three-quarters of the class said that their perspective on science, technology, and societal implications changed as a result of the class. Take one student's comment: "Before the course, I thought any/all technological improvements were good. Now I understand more of the social issues of new technology."

Most of the students thought the class was challenging enough, though a few expected more. Most thought the course couldn't or only might be improved upon significantly. About a quarter of the students would have liked to see more science, about a quarter thought there was too much, and the last half thought it was a good mix. Many comments were similar, "just right, any more science and it wouldn't have been understood." All in all, there seemed to be a good balance between science and societal issues for the diverse skill level of the students. Another comment agrees: "Just right, it allowed us to gain/appreciate what it can do and [the] hazards nanotech has. Plus we didn't have to have a complete understanding of nanotech to see societal implications." As to the structure of the class, the presentations were appreciated. One student's observation was typical: "the projects were a big help and allowed us to cover a wide variety of topics." The students also preferred in-class activities, debates, town-hall meetings, and generally doing the work themselves over traditional lecture. Many comments requested more even though most of the course was that way. The research project presentations were universally thought to be a good idea, but the students would have preferred more specificity and direction from the instructor in general. One comment summarizes nicely, "Yes. I think these were the best part. They could have been better if the topics/questions were more specific and written better."

Finally, the essay assignments provided a means to apply and test the application of higher order analytical skills and concepts to present day issues in nanotechnology and society. Although assessment cannot be quantitative in this regard, we found that the students did reasonably well (with some variation in skill level) in thinking creatively and knowledgably on the issues in question. Not only did they show a growing understanding of how nanotechnology will and can effect society (with past technologies as test cases), but how society can form the evolution and application of technology. The subjects of the essays, shown in Table III, should elucidate this.

A rewarding take-home message from the post-assessment and in-class surveys was that the students overwhelmingly preferred discussion/group-oriented classes over lecture-oriented classes in most cases. "Some of the more science based aspects are taught better in lecture format. This was done for the main part. But implications on society is better in discussion format." Another good point was made that justifies the structure of the course as taught: "nanotech is changing so fast, it'd be bad to try and follow a pre-established lecture schedule."

VI. DISCUSSION AND REFLECTION

A humanities course that focuses on technology, such as *Nanotechnology and Society*, creates unique challenges alongside its new opportunities for education. With over half the class composed of science or engineering majors, there was a natural bias against the more open-ended, subjective questions we pose in a field such as this one. In other words, many students expected a class about nanotechnology. In this situation, it is the instructor's responsibility to expand the students world view such that the true content of the course becomes digestible and even motivating. This requires some convincing.

Clarity, from day one, is the first step in good student engagement. The philosophy and content of the course must be clearly and repeatedly explained, focusing on why this subject is worthwhile and what will be gained from a significant time investment. The instructor's (CT) technical background helped somewhat in that it gave credibility and a starting point for a new direction of intellectual pursuit. In the end though, personal attention—learning the students' names, majors, career plans, interests—becomes necessary to enlist the whole class in learning, especially in the context of group work, class participation, and active learning (non-lecture-based) activities. Not surprisingly, this entails a great amount of effort on the instructor's part. It is also tremendously rewarding.

Teaching the course required a lot of leadership. We pushed and pulled in new directions as the course navigated through different paces and types of content. As a practical matter, we bounced back and forth between STS and NSE to keep interest and integrate concepts and theories learned throughout. Since this was the first time the course was offered, extra preparation was needed for each class. The course schedule was also quite fluid as the order and depth of the course material was continually calibrated to match the students learning pace and the instructors growing experience. Because we did not know what types of students would enroll, the previous semester's planning (see Section 2) inevitably changed. In fact, we had originally thought the course would be mostly freshman, using the history of STS 201 as a guide. Instead, we attracted a much more diverse and older student body.

Older students from science and engineering majors tend to be more resistant to active learning techniques and class participation due to their limited experience with such class formats. They are also in general more competent overall, be it in writing, reading, or analytical comprehension abilities, which can lead to boredom in mixed skill-level environments. We made this into an opportunity, however. The research projects and essay assignments provided a good means to challenge the students while keeping everyone engaged at their ability-level. The NSE reports in particular allowed the more advanced to show their abilities. In this manner, the students themselves became teachers or knowledge centers and were assigned to be the class expert on their particular nano-topic. The nano-report research projects became continuing educational tools for both the researcher and the rest of the class in research and communication techniques as well as general knowledge.

So how much work did it take? For the students, the right balance had to be maintained between university requirements and their expectation and commitment level (good but not infinite). The class decided collectively to meet as groups in-class but have homework and assignments be individual outside of class. The commitment was not there for a completely group project type course. The philosophy of work tended to be an expectation of reading preparation and group discussion in class. For important concepts or theories in STS, the class settled into a routine of working in groups on work sheets or quizzes provided by the instructor, then as a class reviewing their work. The nanoscience discussions tended to be more whole class oriented with individual students contributing their research or perspective. In our experience, after the learning goals were set by the instructor, the class preferred to do the work in small groups. The amount of work required on the students part was similar to other courses at the UW.

The instructor had more extensive duties. In addition to all that comes with preparing a first-time course (with no standard text), the research projects in particular required special attention. The students learned more about NSE through the projects and applied their new-found societal analytical toolset to explore the ramifications of their nano-topic. The instructor's philosophy was to model the progress and requirements of the project on a real-world research group, where the students would need to meet milestones and share their progress with the rest of the class at group meetings, taking and responding to feedback. The formal class presentation was one step in this process of producing a world-readable report. The implementation of this approach was good but not perfect. Some of the students would have benefited from more hand-holding and specification. Despite the instructor's not limitless time, the assessments showed that the experience was found valuable by virtually all of the students. In all, realistic time constraints were not a barrier to preparing and teaching an effective an interesting course from our perspective.

Scientists and technologists, as well as science students, think about the societal ramifications of technology all the time. From an interesting newspaper article to a science fiction show, scientists have long found many avenues to think outside the lab. But thinking critically and structurally about such issues in a course like this (modeled on the collaboration and experience of science and technology studies, history of science, and public policy professionals) is generally a new, and we have found, quite worthwhile experience. An exciting new field of study like nanotechnology can provide the meat of a new concept in technology and society education, learning about the issues of technological change alongside technological developments, in real-time. We can educate the congressman, the business class, and the society-shapers before they make the decisions that will push America into the future, and the scientists and engineers before they build it.

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