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Teaching Nanoethics to Graduate Students

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Background/Rationale

In the decade since the University of Washington (UW) launched the nation's first doctoral program in nanotechnology,[i] doctoral training in the scientific and technical aspects of this newly established field has become widespread. As increased research and the growing nanotechnology enterprise has brought many promises of nanotechnology into reality, we recognized that students in UW's nanotechnology Ph.D. program need more than just technical training to be responsible practitioners – they also require parallel training in the societal and ethical implications of these unprecedented technological developments. Providing such training requires concerted effort in cross-disciplinary collaboration and communication, not just between scientists and engineers or between biological and physical scientists, which was necessary for their technical training, but among technologists, scientists, engineers, medical practitioners, social scientists and humanists. To address these issues, two interdisciplinary centers at the University of Washington, the Center for Nanotechnology (CNT) and the Center for Workforce Development (CWD), cooperated to offer an interdisciplinary Seminar in Nanoethics during winter quarter 2009, co-taught by a social scientist (Ph.D. Communication) and a practicing nanotechnology researcher (Ph.D. Physics). This paper details the historical background, syllabus, audience, and impact of this new course with an aim to aid others implementing similar courses.

Taking an interdisciplinary perspective, this seminar examined a broad range of ethical issues associated with nanotechnology. Topics included environmental, health, and safety concerns; security and privacy implications; economic effects; national and international political implications; media and public perceptions; cultural and religious repercussions; medical technologies; and legal and regulatory issues. Weekly guest speakers (from across the UW campus and outside) presented a particular aspect of ethical interest, discussed how it relates to nanotech research, and examined possible responses. Students worked in small groups to develop a short case study based on one of the topics presented. The case studies have been made available online through an NSF-funded website on nanoethics at the University of Washington.[ii] The course was offered for undergraduate or graduate credit and was open to students from across the UW campuses.

The new course was introduced to provide a needed focus on nanoethics in graduate education, particularly for graduate students who are preparing themselves for careers in nanoscale science and technology, whether as biologists, chemists, physicists, or engineers. The course was initially developed as part of the nanotechnology degree program, but, when offered, it also attracted non-scientists curious about applications of ethics to the emerging field of nanotechnology. Students in UW's interdisciplinary Dual Ph.D. Degree Program in Nanotechnology are admitted through one of ten participating departments in engineering, medicine and the natural sciences. After completing both the requirements of their home department and additional interdisciplinary requirements, they receive a dual degree in "*Home-department* and Nanotechnology." In addition to completing a nanotechnology-related thesis under the supervision of one of the 85 CNT faculty members, students must complete nanotechnology-related coursework and lab rotation outside their home department, attend our interdisciplinary colloquium series, and complete our core course "Frontiers in Nanotechnology." Prior to the development of the Seminar in Nanoethics, the only exposure to scientific ethics and the societal impact of nanotechnology in the program was an occasional presentation in the nanotechnology seminar series and one or two class periods in the core course. Students enrolled in the Frontiers in Nanotechnology class between 2006 and 2009 (N=58) reported the most common mode of engagement with societal and ethical issues as occurring informally with colleagues (66%) rather than in the classroom (30%), although many (78%) indicated that they could imagine dealing with these issues in the future.

Ethnographic fieldwork at the University of Washington[iii] indicated that most graduate students involved in research at the nanoscale have not been exposed to discussions of ethical issues in their undergraduate or graduate studies. Consequently, they do not find these issues to be particularly relevant to their work as scientists. Notwithstanding, the following issues were raised by graduate students: implications of accepting funding from industry and government, unlabeled products on the market containing nanoparticles, how current regulatory agencies can keep up with a rapidly-developing technology such as nanotechnology, and pollution and natural resource depletion caused by the production of nanoelectronics. Despite the interest in these issues, the students appeared to be largely ill-equipped to integrate their concern about ethical issues into their careers. Reasons for this include a perception that ethics is not a scientist's concern, that these issues are simply not addressed in their classes and coursework, and a reluctance to be seen as advocating for a moratorium on scientific inquiry. In short, these findings suggested a demonstrated interest in ethics among the scientific graduate community, but few resources available to them to integrate their concerns into their studies.

University of Washington Initial Response

In response to these findings, the CNT and CWD pursued several avenues to increase both awareness of societal and ethical issues in nanotechnology and the ability of our students to deal intelligently with them. We initially worked through existing venues, inviting at least one speaker each year for the Nanotechnology Seminar Series to speak specifically about ethics in nanotechnology, and encouraging all speakers in both the seminar series and the Frontiers in Nanotechnology (FN) class to address potential societal impacts of their research. We also changed first one, and later two class periods in the required FN class to discuss these issues. In developing these classes, we benefitted from case studies developed at the University of New Mexico as part of the National Nanotechnology Infrastructure Network, to which UW belongs. Kirsty Mills of UNM was invited to give a CNT Seminar (Feb 2006)[iv] in which she presented several short case studies in nanoethics, and she worked with Professor Olmstead to choose and adapt some of her case studies for discussion in the FN class that April. We also used case studies developed for general scientific ethics at the National Academy of Sciences.[v] In 2008, we replaced some of these with case studies developed at the Center for Nanotechnology in Society at Arizona State University.[vi] Social scientists from the CWD also attended class for these discussions, giving students well-needed balance between technological and social points of view.

Students responded very well to the inclusion of ethical case study discussions in the FN class. In post-class surveys, no students in four years worth of classes checked “Not useful -- cut this out next year,” and fewer than 10% checked “OK, but time better spent elsewhere” for any of the several case studies used. The vast majority believed the discussions were directly useful in either their current or imagined future lives, with the remaining 8-35% believing the discussions related to each case study were “Worth class time, but not directly relevant to me.” The general scientific ethics discussions and case studies specific to nanotechnology were of comparable interest to the students.

We used two different approaches to structuring the classroom discussion: (a) presentation of several short (one power-point slide) scenarios, followed by a structured list of discussion questions that the entire class (14-20 students) discussed together; and (b) slightly more detailed scenarios (one typewritten page) discussed in small groups (4-6 students) with major discussion points then shared with the entire class (each group discussed a different scenario). The latter was more successful in bringing quiet students into the discussion and in allowing for depth on a particular topic, while the former brought a wider variety of topics to the attention of the entire class. We recommend breaking into smaller group discussions for a class larger than 12-15 students.

In the course of teaching these required class sessions on ethics in nanotechnology, we observed (a) many students desired to spend more time learning about these issues (over ¾ reported being “probably” or “definitely” interested in taking a seminar on nanoethics) and (b) very few resources were available for faculty to prepare for discussions that lie outside their traditional expertise. In particular, while several “power-point-level” case studies were available, few if any had enough detail and background information for a non-expert to teach effectively. To address these observations, CNT and CWD faculty wrote a successful proposal to the National Science Foundation to develop a class in which the students would both learn about societal and ethical issues related to nanotechnology and create materials to aid others in teaching classes that address these issues. The conference at which this paper is being presented (and its subsequent archival on the world-wide-web) is another aspect of this NSF-sponsored project, “Nanoethics on the World Wide Web: Helping Faculty Enhance Graduate Education.”[vii]

Structure for Seminar in Nanoethics

Graduate students in nanotechnology tend not to want to take time from their research for “non-essentials,” and we knew that many of our students (and especially their advisors) were skeptical of the need for an entire course on nanoethics. We thus structured the class for minimal impact on students’ research: a 2-credit seminar, graded pass/fail, meeting at times unlikely to conflict with other seminars or data acquisition (9:30-10:20, Tuesday/Thursday, before most experiments get started). We also limited out-of-class commitment to 1-2 hours of pre-class reading per week, plus working in an interdisciplinary group to create a detailed case-study.

The class was co-taught by the authors, whose complementary backgrounds (communication and physics) played a significant role in enriching the class. Our respective professions as a physical scientist (MO) and social scientist (DB) allowed us to address the diverse aspects of the material covered in the class. For example, MO addressed questions about the science behind nanotechnology and DB provided information about the social processes that influence knowledge production. We also had complementary personal networks of appropriate guest presenters.

While the interdisciplinarity of the class was ideal from a pedagogical point of view, administratively, the class had no obvious departmental home or institutional support. The Seminar in Nanoethics was approved on a one-time basis as an undergraduate/graduate special topics class in the physics department (Phys 428/576), but there was reluctance to give graduate credit in physics for a class that had no specific physics prerequisite. Professor Olmstead also taught the class as an overload in additional to her regularly scheduled class, while Dr. Bassett was partially supported by the NSF grant mentioned above. These administrative issues are likely common to all universities, and call for changes at levels above departments or colleges. The CNT is currently working with the university to create a "NANO" prefix to consolidate all courses relevant to nanotechnology in the course catalog. Another long-term institutional need is a schema in which interdisciplinary classes are supported on an equal footing with more traditional classes centered in a single department.

Much of the material covered in this seminar was new to one or both of the instructors, but there was considerable expertise spread across campus. We thus chose a format that alternated presentations by experts with instructor-led discussions of both the previous class' presentation and the readings (usually recommended by the speaker) for the following presentation. In general, we found that the 50 minute class period was not quite enough, especially on days with presentations; the 80 minute period of the FN class would be preferred. Fortunately, we met in a room that was empty both before and after class, so that interested students (and occasionally speakers) could remain for additional discussion, and student teams could meet in the classroom before or after class to discuss their case studies.

Students were expected to be active and prepared participants every day of class, with any assigned readings completed prior to each class meeting. Active participation in class discussions by all students showed this to be the case, and reflected their intrinsic interest in the material.

Topics and Syllabus

The topic of Ethics and Nanotechnology is wide-ranging, as evidenced by the diversity of topics discussed in this conference proceedings. Also, given the paucity of structured learning about general ethics or scientific conduct for most students of nanotechnology, or of nanoscale science and technology for most students of ethics, it was necessary to give background material in both areas.
Course objectives were to:

1. Identify and address ethical issues associated with nanotechnology.
2. Assess possible responses to the issues raised.
3. Develop case studies that provide additional direction for the topics raised and make available as online resource for graduate students and faculty.

The syllabus is given in Table I. The presenters included: practitioners of nanotechnology research, who spoke both on the impact of societal issues on their research and vice versa; researchers on ethics and its applications, who gave both an overview of ethical theory and examples of its application to medical genetics; both a social and physical scientist investigating the impact of technology on social structures; and social scientists who have studied the views of practicing nanotechnologists on ethical issues and the ways in which they communicate about these issues. We used the first two weeks for introductions to both ethics and nanotechnology with a combination of presentations and discussion. The student discussion uncovered student expertise in science, engineering and humanities, as well as in policy, and laid important groundwork for respectful peer-to-peer education the remainder of the quarter. It is important to establish this rapport early in the quarter, with students being willing to express both knowledge and ignorance to each other. Dynamic speakers involving the entire class in discussion helped to establish the trust to express opinions, and we took care to make sure all students were treated respectfully.

The most common "problem" we found, especially with speakers not currently performing research in nanotechnology, was focusing on issues specifically related to nanotechnology. Many ethical issues raised by developments in nanotechnology, especially control of access to life-changing technologies, adequate education about their benefits and risks, and balancing personal and societal choices about how and when to adopt these technologies, are similar to those already faced with modern microelectronics and medicine, and date back at least to the industrial revolution. Students were, however, eager to discuss and learn about these general issues, which helped to identify nanotechnology as part of human development and not a radical departure from historical precedent. We also chose readings for discussion on the degree to which hyperbole and fictional depictions of nanotechnology impact public opinions on its relative risks and benefits.

Student response to the class, including its structure and choice of topics, was uniformly positive, and most specifically mentioned the diversity of topics and perspectives of the students and speakers under "what did you enjoy most about this class?" on the end-of-course survey. Students suggested we expand our speakers to include more practicing nanotechnologists, especially ones with experience in established or entrepreneurial companies, and someone who works in establishing and implementing policy. They also requested more focused readings. The talks that received the most positive comments were those by scientists who discussed how they had directly addressed ethical issues in their own research careers; the least well received were those that addressed parallel issues in technology or medicine rather than specifics of nanotechnology. The latter could likely be improved upon in the future with more focused instructions to the speaker and better choice of reading material.

Audience

Despite its listing as a 400/500 level physics class, the class attracted a wide variety of students, from a freshman pre-engineer to an advanced graduate student in philosophy. On the first day of classes, several students showed up to see if this was an "easy 2-credit class to fill out their schedule" – they did not return. One dozen students (from 10 different departments) took the class for credit, and several others (including post-doctoral fellows and CNT staff) audited the class on a semi-regular basis. It would be difficult to teach this class with more than about 20 students and maintain the open discussions that were the heart of the class, but the diversity of backgrounds was also essential, as is a reasonable audience for guest speakers, so that 10 students is likely the minimum for a successful class. For classes larger than 20 students, the group should meet together for presentations, but split into smaller groups on discussion days.

It is very unusual to both teach and take a class with such a wide variety of backgrounds and interests among the students, and an unanticipated benefit of the class was educating both students and faculty on different ways of learning. One (science) graduate student commented the following quarter, "By participating in a class with students from other levels of education and other disciplines, I was able to pinpoint my weaknesses in communicating scientific ideas to the general populace and improve on the means in which I do communicate." Another commented, “I appreciated the equality established in this course. The interdisciplinary study helps to define society and our current progress. A scientist’s perspective is different from the English major’s. The needs of all were discussed and this I feel is enjoyable and most important.”

Student Development of Case Studies

Students were assigned to -member teams to develop a case study for publication on the world-wide-web (and use in UW’s Frontiers in Nanotechnology class) that addressed a topic related to societal and ethical issues in nanotechnology. Teams each included at least one scientist or engineer, at least one humanist or social scientist, at least one graduate student, and at least one undergraduate student, and were selected by the instructors. Allowing time in class, and a place before or after class, for students to meet in their presentation groups was very important, since most of the students did not run into each other elsewhere on campus. Students chose the topics themselves, with advice and approval of the instructors. This fortunately ended with a reasonable coverage of important issues.
Each student team initially produced a 30-minute class presentation and discussion, after which they incorporated feedback to produce a 3-5 page written case study with references for use in the classroom. After editing by the instructors, these are now available on the world-wide-web.[ii]

Testing Case Studies in a General Class Environment

The case studies were utilized in the Frontiers of Nanotechnology class in Spring 2009. The case study, “The Paradigm Shift of Nanotechnology: Consequences of Status Quo Lab Attitudes,” which addresses issues of laboratory safety and ways to report unsafe practices, was incorporated into a class on general scientific ethical conduct. By bringing up potential differences between safe exposures to bulk and nanoscale materials in addition to more traditional issues of safety and “whistle-blowing,” the case study successfully expanded discussions from previous years into nano-specific areas. The other three case studies were discussed in a second class focusing specifically on societal and ethical issues related to nanotechnology. They dealt with cases (*i*) where one makes a personal (if not necessarily well-informed) choice to embrace nanotechnology with minimal impact on others (“Supplements with Nanoscale Ingredients”), (*ii*) where individual personal choices to embrace the technology are required to establish it, but, once established, the choice not to embrace the technology may have costs (“Visions of Bionic Lenses: Foresight for the Future”), and (*iii*) where decisions made at a corporate and/or governmental level impact how everyone becomes dependent on a nano-based technology and must deal with its environmental impact (“Solar Energy”).

The case study on supplements highlights the lack of regulation in cosmetics and supplements, as well as the unsubstantiated claims made on many manufacturers’ web-sites and advertising material, making it difficult for the consumer to make an informed decision about whether to utilize nanoscale supplements. The case study on bionic contact lenses, that may someday both monitor medical conditions and receive wireless images, brings up discussions of when a technological innovation becomes irreversible (for example, cell phones). “Solar Energy” balances the promise of reducing CO_2 emissions with the potential environmental hazards of chalcogenide-based solar cells, and led to discussion of whether to expand the use of the technology now, or wait until more environmentally benign solar cell materials are developed. All four case studies generated strong interest and discussion among students in the FN class. They also expressed a belief that both the general public and practicing nanotechnology researchers should be made aware of the issues raised, with no consensus on which were the most important (though each listed a different topic as being most important for the general public or for the “nanotechnologist”). One student commented, “I heard a lot of new thoughts and ideas that never hit me. As a new researcher I really think [the] issues were interesting and worth a debate.”

Future Directions and Transferability to Other Institutions

Overall, the class was regarded as a success by all involved. The instructors gained a new appreciation for the complexities of societal and ethical issues and nanotechnology and for means to bridge the traditional divide between the natural and social sciences; the students gained needed perspectives and informed their future career plans; the speakers also expressed gratitude for the opportunity to be involved in this endeavor. There was a general appreciation that more students should be exposed to the concepts brought up in class to help them make educated choices about both creating and using new advances in nanotechnology.

Two factors control the frequency with which the Seminar in Nanoethics should be offered: supply (of faculty and presenters) and demand (students). On the demand side, given that only a dozen students took the class this year, it is unlikely, even with better publicity, that more than twice that number would populate a class each year; this suggests that once per year, or once every other year is a reasonable frequency. Several students in the class, however, expressed a belief that a class addressing societal and ethical issues in nanotechnology should be required for our interdisciplinary degree in nanotechnology; such a requirement has also been suggested for the undergraduate minor in Nanotechnology and Molecular Engineering that UW is currently creating. Either of these actions could double the demand for the course. Creating a requirement of an entire quarter (rather than the current week of FN) on societal and ethical issues in nanotechnology, however, will likely require extended discussions to convince students (and faculty) that their time will be well spent. A survey of researchers in the NNIN[viii] found that only 58% either strongly or somewhat agreed with the statement that “there are significant ethical issues related to nanotechnology,” with 43% either quite or very willing to spend time learning about ethical issues related to nanotechnology and 22% only slightly or not at all willing to do so.

On the supply side, given that no more than two students in the class were from any single department, it is difficult to justify the course administratively within any single department. With the severe budget crises facing UW and other universities, adding classes into the regular curriculum usually must be paired with course elimination in the same budget line, making addition of interdisciplinary classes especially difficult. Also, classes with co-instructors from different departments are typically taught as an overload by at least one, if not all of the instructors. These issues are a real barrier to establishing this course as a requirement for an interdisciplinary nanotechnology degree at the graduate or undergraduate level, since that would require an administrative commitment that the course be taught on a regular basis, and not simply as an occasional “special topics” class.

The use of guest lecturers in this class had two distinct advantages. The first is pedagogical – they greatly expanded the range of expertise and ideas to which students were exposed, and also expanded their networks on campus. For example, one student decided to pursue an independent study course with one of the speakers, whom she might not otherwise have met. The second advantage is logistical – it enabled the instructors to complete most of the time-consuming aspects of class preparation before the quarter started, with the main responsibilities during the quarter being to read preparatory materials, attend the guest lectures, and alternate leading class discussions between the two instructors. Each instructor also prepared a lecture in her field of expertise. The format enabled teaching a new class in a field outside our primary expertise (where creation of new lectures is normally a very time consuming activity) on top of our regular teaching, research and service activities. In the long run, with increased exposure to interdisciplinary teaching and materials, and administrative support for teaching such a class as one's primary teaching assignment, a single faculty member could teach this course as a standard 3-credit, 400/500 level class, with occasional guest speakers, including additional written assignments covering both technical and ethical issues. With increasing acceptance of nanoethics as a central topic in education of both future creators and future consumers of nanotechnological advances, it is hoped that a permanent home for this course will be found.

Table I: Syllabus for Seminar in Nanoethics, University of Washington, Winter 2009

Week	**Topic**
1	Introduction to Class *D. Bassett (UW Communication, CWD); M. Olmstead (UW Physics, CNT)* Introduction to Ethics *J. Benchimol (UW Philosophy)*
2	Overview of Nanotechnology *E. Allen (UW-CNT)*
3	Ethical Issues in Practicing Research: Funding, Animal Subjects, Privacy *B. Parviz (UW Electrical Engineering, CNT)*
4	Applied Ethics of Nanotechnology: Results of Survey of NNIN Users *R. McGinn (Stanford Management Sci. and Eng., and Science, Technology and Society)*
5	National and International Political Implications *V. Chaloupka (UW Physics, Jackson School of International Studies, and Music)*
6	Cultural and Religious Implication of Nanotechnology *C. Speed (UW Comparative Religion)*
7	Ways of Speaking Among Scientists about Nanotechnology and Ethics *D. Bassett (UW Communication, CWD)*
8	Ethics of Framing Issues in Nanotechnology, Learning from Medical Ethics *K. Fryer-Edwards and C. Riley (UW Bioethics and Humanities)*
9	Environmental Health and Safety Issues *F. Baneyx (UW Chemical Engineering, CNT)*
10	*Student Presentations* • The Paradigm Shift of Nanotechnology: Consequences of Status Quo Lab Attitudes • Solar Energy • Supplements with Nanoscale Ingredients • Visions of Bionic Lenses: Foresight for the Future

References

i. *Education in NT: Launching the First Ph.D. Program*, Viola Vogel and Charles T. Campbell, Int. J. Engineering Education, 18 (5): 498-505 (2002).

ii. *Nanoethics on the World Wide Web: Helping Faculty Enhance Graduate Education*, Center for Workforce Development, University of Washington. Available on the web at http://depts.washington.edu/ntethics/casestudies/index.shtml

iii. Unpublished data, UW Center for Workforce Development.

iv. UW Center for Nanotechnology, Nanotechnology Seminar 2005-2006. http://www.nano.washington.edu/seminars/2005-06.pdf

v. *On Being a Scientist: A guide to responsible conduct in research*, Committee on Science, Engineering, and Public Policy, Nat'l. Academy of Sciences, Nat'l. Academy of Engineering, and Institute of Medicine (National Academies Press, Washington, DC) available on line at http://www.nap.edu/catalog.php?record_id=12192

vi. *Nano Futures Scenarios*, Center for Nanotechnology in Society, Arizona State University, available online at http://cns.asu.edu/nanofutures/index.html

vii. Further information available at http://depts.washington.edu/ntethics

viii. "Ethics and Nanotechnology: Views of Nanotechnology Researchers," Robert McGinn, *Nanoethics* 2 (2008) 101–131.