

A Graduate Level Ethics Course: “Societal and Ethical Issues in Nanotechnology”

A. Introduction

Since ABET 2000, ethics training has become an established component of science and engineering undergraduate education, serving to prepare students in the fundamentals of professional practice within their chosen field. It is largely absent, however, in doctoral engineering programs¹. This is of particular concern in the area of nanotechnology, which is largely being taught as a specialty in graduate programs. This paper describes a unique new course in the societal and ethical issues of nanotechnology that addresses this need.

Students who undertake graduate engineering training can find that the conduct of research poses ethical challenges that go beyond the norms of professional practice and engineering ethics with which they are familiar. Nanotechnology’s dramatically interdisciplinary nature makes it particularly important that students who specialize in this area be trained to appreciate ethical issues beyond the confines of basic engineering ethics. A student trained in electrical engineering, who goes on to specialize in nanotechnology, may undertake research developing, for example, nano-sensors that will be implanted in human subjects; he or she will need new skills to appreciate the broader implications of such research -- for instance, its potential privacy implications for individuals and society. In addition, many research students in the United States are from cultures with significantly different approaches to ethical issues, which can pose added challenges in the face of dilemmas created by the development of disruptive technologies. These and other students can also enter nanotechnology programs with backgrounds in non-engineering disciplines, in which they have not been required to undergo any training in ethics.

One can speculate further that this new era of technology, characterized by a high degree of uncertainty², will require a different emphasis in ethics education. The approach of preventing wrongdoing by providing training in professional comportment becomes problematic when change is so rapid, and scope so large, that there are few specific standards or processes to convey. Today engineering ethics is still largely taught on the basis that engineering is a profession.³ This may prove to be less than adequate in the case of nanotechnology. For example, a student with an excellent grounding in professional engineering practice could nonetheless find herself inadequately prepared to face the ethical challenges of a project using quantum dot technology to investigate human consciousness. The complexity, scope, and rate of change of nanotechnology is such that reliance on established practice will only go so far in addressing the novel issues encountered.⁴

This presentation describes a new graduate-level ethics course at the University of New Mexico, **“Societal and Ethical Issues in Nanotechnology”**, which prepares students for this rapidly evolving, multidisciplinary environment. First taught in the Fall semester of 2005, it is a core course on a new Nanoscience and Microsystems Curriculum, and attracts students from both the School of Engineering and the College of Arts and Science.

B. Goals

This course is designed to help students to develop an awareness of the multiple issues they will meet in their careers, and a capacity for critical analysis of ethical and societal dilemmas. It

should prepare them to exercise the flexibility and insight that are necessary to take an ethically responsible position when faced with unprecedented circumstances. Finally, they should acquire an understanding of the scientist's responsibility toward and interaction with society.

Ideally, the course will engender the formation of what Newberry¹ has described as 'emotional engagement' with the ethical context – a condition in which consideration of the ethical context is a significant and continual dimension of an engineer's role. While acquiring this is a slower process than that of learning particular practices, it is one that offers the most profound long-term benefit in technologies, such as nanotechnology, where the rate of advance is such that even after having received training that was appropriate at the time it was given, students may well find themselves working in areas for which they have had little or no ethical preparation.

C. Course Structure

This is a 3 credit, 400/500 level course, offered annually, and cross listed in the School of Engineering and the College of Arts and Science. First offered in the Fall semester of 2005, it attracted 9 students, 2 from the Department of Electrical and Computer Engineering, and 7 from the Department of Chemistry. As a required core course in an upcoming highly interdisciplinary Nanoscience and Microsystems graduate curriculum, enrollment is expected to increase significantly. The course is also to be disseminated via the web portal of the NSF-funded National Nanotechnology Infrastructure Network (NNIN), a network of 13 universities which makes nanotechnology user facilities available to industry and to academe, and which has significant education and ethics components.

The course has five elements:

1. **Introduction**
2. **Analysis of issues** intrinsic to nanotechnology:
 - Nanoparticles - Health, Safety and the Environment
 - Public Perception
 - Privacy
 - Human Enhancement
 - Legal and Regulatory Issues
 - Complexity, Interdisciplinarity and Education
3. **Project** - Survey of public attitudes to nanotechnology
4. **'Applying the imagination'** - an examination of nanotechnology in fiction and the movies, and the use of images in the nanotechnology community
5. **Guest speakers** who bring specific expert input on topics such as intellectual property in nanotechnology, bioethics, and legal and regulatory issues.

Of necessity, the course structure recognizes that many of the issues associated with nanotechnology have yet to emerge. Rather than the students being 'taught' the issues, they are active participants in the class, expected to participate in and contribute to an exploration of these questions, and to develop an understanding that this will be an ongoing part of their careers. For this reason, 40% of the student's grade is given for their degree of participation in the class. A further 40% is awarded for written assignments, and 20% for the class project.

C.1 Introduction

The course began with an introduction to nanotechnology itself. As shown in Figure 1, at the start of the semester most of the students described themselves as being between ‘unfamiliar’ and ‘moderately familiar’ with nanotechnology. The exception who described himself as being familiar with the topic was a graduate student working on a nanotechnology research project. At

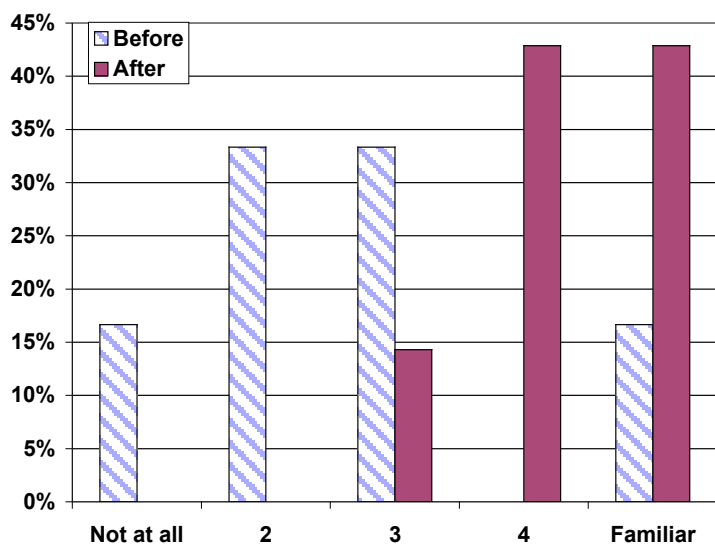


Figure 1: How familiar are you with nanotechnology? (The figures in this article are drawn from a survey given to the students before and at the end of the course. Please note that the number of students enrolled in the class (9) is such that the survey results given in this article are not statistically significant, and are simply given to serve as indicators of effects.)

the end of the semester, the students describe themselves as being ‘moderately familiar’ to ‘familiar’ with nanotechnology. In fact, the scope of nanotechnology is such that most scientists will only be familiar with particular areas of effort, and the students gradually became aware that this enormous scope itself poses a major issue in the advance of the technology.

A subsequent discussion of ‘nanohistory’, as well as pointing out the presence of nanoparticles and nanostructures in nature and throughout human history, delved into the political background of the emergence of nanotechnology, and the ongoing schisms within the nanotechnology community.

While students readily understand that nanotechnology has the potential to bring enormous benefits to humankind, it is often more difficult for them to appreciate that a new technology is shaped by the society in which it develops, and in its turn itself shapes that society.^{5,6} The ‘blow-by-blow’ account of the rise to prominence of this technology clearly demonstrates this effect.

A one-class review of ethical systems functions as a foundation for ethical discussions. Since only one of the students had taken an ethics course prior to this class, this proved to be more necessary than had been expected. In this situation, careful underlining of these concepts as they emerged in discussions throughout the semester was an essential supplement to the necessarily brief initial treatment.

C.2 Social and Ethical Issues in Nanotechnology

In depth analyses of the societal and ethical issues associate with nanotechnology formed the core of this course. Students indicated, as shown in Figure 2, that their awareness of the potential for nanotechnology to pose societal and ethical issues increased significantly, but as shown in Figure 3, this was coupled with their increased sense that these issues can indeed be hard to recognize in practice.

A significant challenge in teaching this course was to enable enough with the technology to be able to detect the societal

and ethical issues as they were introduced. To this end, a relatively heavy reading requirement was imposed during the first third of the semester, easing somewhat thereafter. A class technique that also helped in this was to feature nanotechnology products available on the market, or research projects relevant to the topic under discussion, in each class. As far as possible, the latter were drawn from local institutions, to give immediacy and relevance. As one student expressed it, “we studied what was happening now, at the leading edge of technology”.

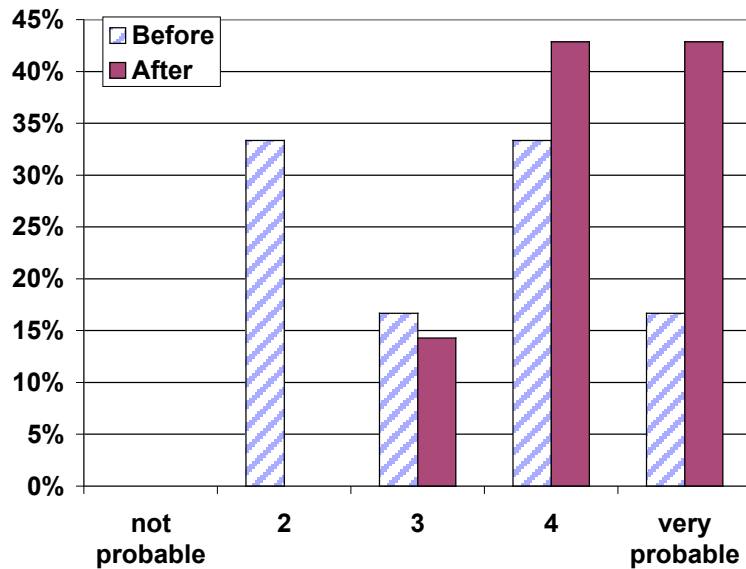


Figure 2: How probable is it that nanotechnology will pose social and ethical issues?

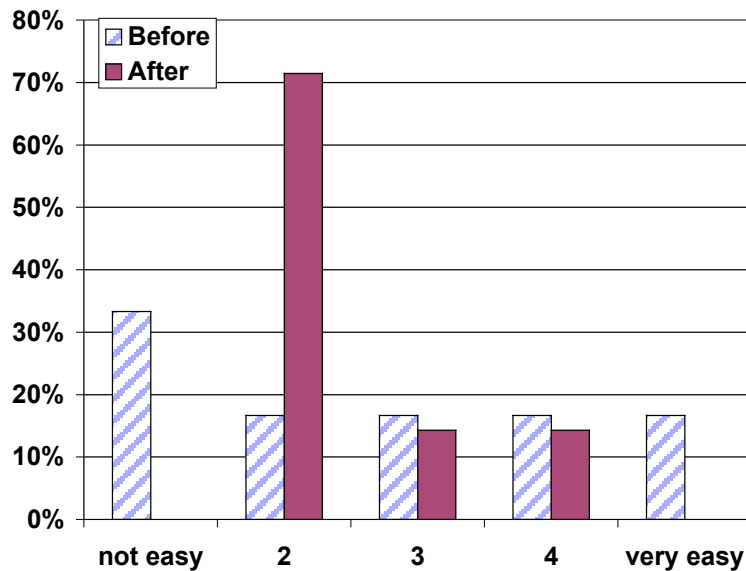


Figure 3: How easy do you think it would be to recognize ethical issues associated with a nanotechnology project?

citing the risk of health problems). Another case study, featuring a research project towards a ‘lab on a chip’ for biomedical applications, provided a focus for an examination of DNA analysis and privacy.

Once the technical basis of these items had been grasped, brief case studies, often drawn from current news releases, then allowed the exploration of their implications. For example, after an introduction to the nanotechnology aspect of widely available stain-resistant trousers, one case study focussed on the THONG protests against the health and safety aspects of nanoparticles.⁷ (THONG - Topless Humans Organized for Natural Genetics - are an activist group whose modus operandi is to protest naked; their current campaign targets Eddie Bauer’s use of nanotechnology to make stain- and wrinkle-resistant clothing,

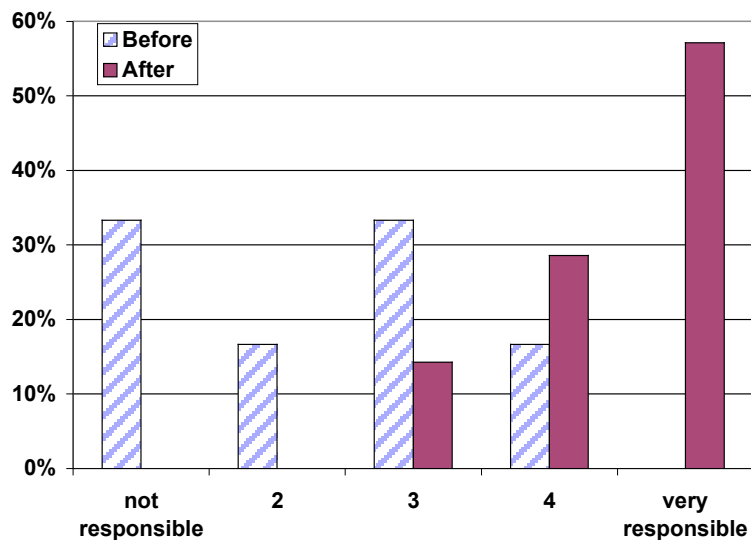


Figure 4: How responsible should scientist be for the eventual societal results of their research?

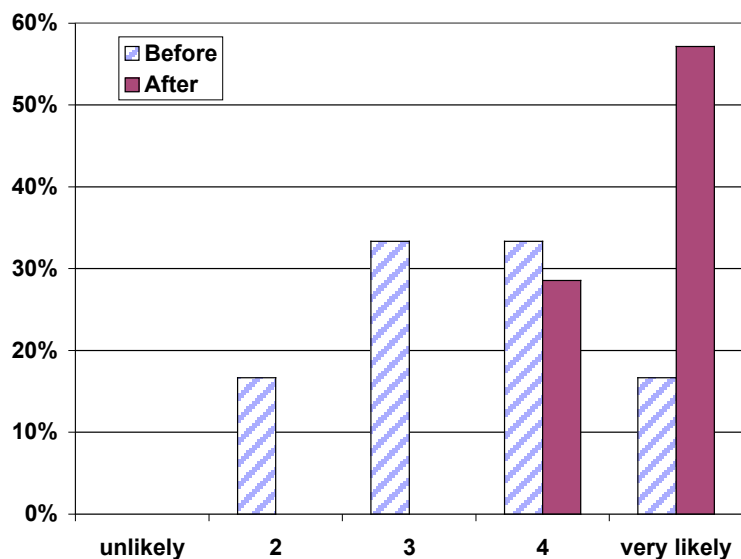


Figure 5: How likely is it that nanotechnology will pose social and ethical issues in the area of Health, Safety and the Environment?

The students were further familiarized with the technology through being required to make free e-mail subscriptions to nanotechnology news services⁸. They were subsequently asked at intervals to choose a news story that interested them, and to consider the societal and ethical implications. In the following class, one or two students were chosen at random to give short (5 minute) presentations of their news item, which then formed the basis for class-wide discussion.

The role of the scientist and engineer in addressing these issues was a recurring theme, and Figure 4 shows the shift in students' attitudes towards scientist's responsibility for the social impact of their work. Specific nanotechnology issues addressed in classes throughout the semester are briefly introduced below; Figures 5 to 8 below indicate the increase of students' sensitivity to some of these issues over the semester.

C.2.1 Nanoparticles - Health, Safety and the Environment

Nanoparticles have now replaced nanobots and 'grey goo' as the current focus of public concern. While much nanotechnology is still at the early research stages, nanomaterials are being successfully used in a number of industries. They offer benefits – in terms of detecting and removing contaminants, offering new medical opportunities, and in the development of benign industrial processes and materials – but they also present risks, particularly in the case of 'free'

nanoparticles (as opposed to encapsulated). This combination of benefit and risk is the ‘two-edged sword’ of all technological advance, which becomes problematic when the focus is on the benefits to the extent that the risks are ignored. In this case we are faced with many unknowns. What are the effects of nanomaterials on public health? There is no common understanding of their risk profile. We know they are of high reactivity, and have the ability to cross cell membranes. At the nanoscale, small is not just smaller – small is different. New behaviors can manifest that bear little relationship to that of the material at the macroscale. A particular issue is that of cosmetics, for which no FDA approval is required, and where nanoparticles are being widely used in sun-tan creams, lotions, and make-up.

C.2.2 Public Perception

The public awareness of nanotechnology ranges from hype (nanotechnology will end disease, pollution and poverty), to fears (‘grey goo’ and nanobots), to lack of information (few are aware of nanotechnology), and to genuine concerns (over health, privacy, and so on). Scientists need to concern themselves with public perception both from a practical point of view and from an ethical point of view. Practically, we need to earn a *justified* societal acceptance of nanotechnology - not just perform a PR job that draws the blinkers over the public’s eye. In this way, we can ensure that the technology develops to meet society’s goals and needs, and avoid a public backlash. The problems encountered by genetically modified foods serve as a grim warning to the nanotechnology community of what can happen if public opinion is ignored.

Ethically, as described by Winner: “Our moral obligations must now include a willingness to engage others in the difficult work of defining what the crucial choices are that confront technological society, and how intelligently to confront them”.⁹ The necessity of this is underlined by Martin and Schinzinger’s view that engineering is a social experiment¹⁰; a corollary of which is that engineers should seek the informed consent of the subjects of the

experiment – in this case, society at large. For this exchange to be successful, engineers and scientists must be able to engage effectively with individuals and groups outside the their area of expertise. The class project, described below, was instrumental in exposing students to the interaction between the scientific community and the public at large.

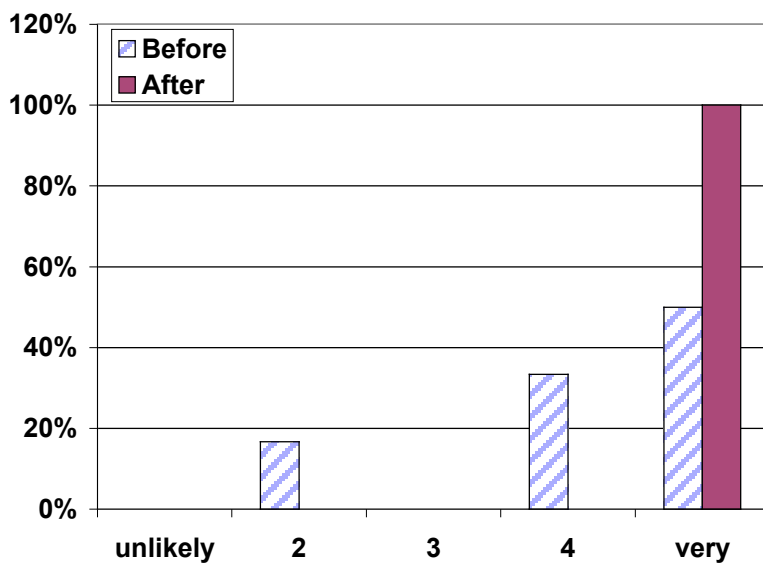


Figure 6: How likely is it that nanotechnology will pose social and ethical issues in the area of Privacy?

C.2.3 Privacy

The power of nanotechnology to gather and handle information of all kinds could result in serious consequences

for privacy.¹¹ Medical sensing technologies pose similar issues to those encountered in gene therapy, where genetic discrimination becomes a possibility. This new area of knowledge has the potential to create a conflict between the privacy of the individual and the economic welfare of institutions. Radio Frequency Identification technology (RFID),¹² miniature cameras and the like, will extend micro-surveillance to law enforcement, healthcare, security, retail, and even into such areas as locating personal property and lost children. To what extent will consumers exchange privacy for personal benefit, and to what extent should this be permitted? How does a

society find the appropriate balance between constitutional freedoms and security, or between privacy, convenience, and economic benefit? And are awareness and consent paramount?

C.2.4 Human Enhancement

‘NBIC’ - the convergence of nanotechnology, biology, information technology and cognitive science offers the possibility of enhanced human performance. This transcends the realm of **therapy** (the restoration of sight through optoelectronic retinal implants, of hearing through cochlear implants, or of memory with chip implants in the hypothalamus; the reconstruction of tissues and organs artificially grown on nanopatterned scaffolds), and by extension enters the realm of **augmentation** (improved children, or superior performance, through enhanced memory or strength, genomic analysis, embedded wireless communication, preventive medicine, cognitive multi-tasking, longevity and so on).

Technological developments are widely applicable, and these applications are often defined by the users themselves. The ensuing ethical concerns are of what we might choose to do to ourselves

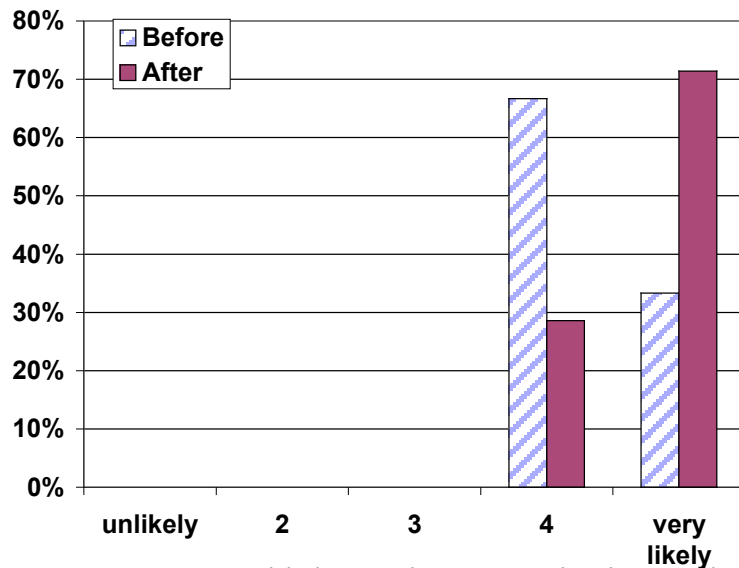


Figure 7: How likely is it that nanotechnology will pose social and ethical issues in the area of Human Enhancement?

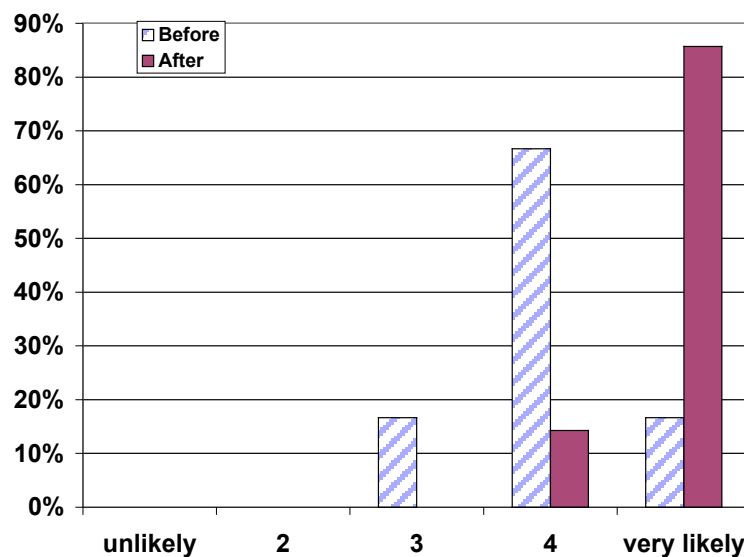


Figure 8: How likely is it that nanotechnology will pose social and ethical issues in the Legal and Regulatory area?

through peer pressure, or through the human desire to ‘excel’, as well as of the pre-emptive choice of parents choosing for unborn children. Furthermore, our choices are based on our concepts of ‘*improvement*’, which can be impermanent, culturally determined, and flawed. We must ask ourselves if a ‘perfect’ human would be....human? What does it mean to be ‘human’? Or ‘normal’? And who decides?

C.2.5 Legal and Regulatory Issues

As with any new technology, nanotechnology will engender a series of legal issues, on subjects such as labor, privacy, security, intellectual property, and so on. The complexity and increasing rapidity of technological change threatens an ever-increasing gap between the cutting edge of innovation and the implementation of a legal framework to deal with resulting issues, in particular since courts and legislatures tend to be reactive rather than proactive. The challenge here is of designing regulation in the face of uncertainty. For example, a prerequisite for regulation is the ability to detect and to quantify. Nanotechnology has as yet no common standards, nomenclature or terminology. The fundamental driver for nanotechnology regulation is again that ‘small is different’; regulations that cover the macroscale forms of materials may prove inadequate in the case of nanoscale forms. Carbon nanotubes, for instance, pose a very different risk profile to that of bulk carbon. Ironically, a telling reason for instituting new regulation may not be that it is necessary from a scientific point of view to protect public health and well-being, but that it is necessary to reassure the public that nanotechnology is not a threat.

C.2.6 Complexity, Interdisciplinarity and Education

Nanotechnology lies at the confluence of the disciplines of biology, solid-state physics, chemistry and materials science. This interdisciplinarity poses an immediate challenge for workforce development. How do multidisciplinary teams interact effectively? Do we educate specialists in each particular discipline, and train them to collaborate, or do we educate generalists who evolve through their work experience? Technologists must develop an ability to move comfortably across disciplines - in much the same way that baby-boomers have become avid world travelers, enriching their own culture with borrowings from foreign environments. These transitions will take place within a workforce that is already experiencing significant demographic change in ethnicity and gender. The non-traditional aspect of nanotechnology’s educational demands may in turn require institutional change in academia.

The scope, uncertainties, and unprecedented rate of change of nanotechnology result in a high level of complexity, both in the technology itself and in its impact on society. We enter the realm of normal accidents¹³ (a phrase coined to describe how accidents become inevitable in situations where technological interactions become so complex that they cannot fully predicted or controlled), and of wicked problems¹⁴ (problems that are not susceptible to traditional analytical approaches, where multiple stakeholders have conflicting ideas, and where constraints change over time). In this area of post-normal science, our challenge is to implement this rapidly emerging technology in a way that is both flexible and beneficial, despite the enormous complexity of the social and technical factors involved.

C.3 Applying the Imagination

Students also investigated the treatment of nanotechnology both in fiction and in the movies. As well as proving an attractive ‘hook’ for the students, these provided compelling imagined

realities of potential consequences of the technology. As Marvin Minsky wrote in the foreword to *Engines of Creation*: “How can anyone predict where science and technology will take us? Although many scientists and technologists have tried to do this, isn't it curious that the most successful attempts were those of science fiction writers perhaps the strongest source of their success was that they were equally concerned with the pressures and choices they imagined emerging from their societies.¹⁵” A published collection of short nanotechnology science fiction stories, *Nanotech*¹⁶, and excerpts from movies including *Minority Report* and the *Stepford Wives*, provided material for this.

An extension of this topic was a class on the use of nanotechnology images in various contexts, which range from schematics (such as graphs or diagrams), to documentation (such as photographs or illustrations), to sci-fi renderings, to fine artists’ treatments of technical progress. As well as obvious ethical implications raised by the manipulation of images, there are more subtle ethical questions. These can arise in areas such as the competing claims of accuracy and clarity, or impact; from a lack of awareness by scientists of how an uninformed observer might interpret an image; or from underestimating the power of images. As students collected, classified and interpreted images of the nanoscale, they learnt that these are essentially visual metaphors - highly useful scientifically as long as they are recognized as not being ‘reality’, but also exerting significant social influence on the advance of a technology.

C.4 Class Project

There is an increasing need for scientists and engineers to be aware of, and to respond to, public opinion and perception. They must understand, too, that this is not simply a matter of informing

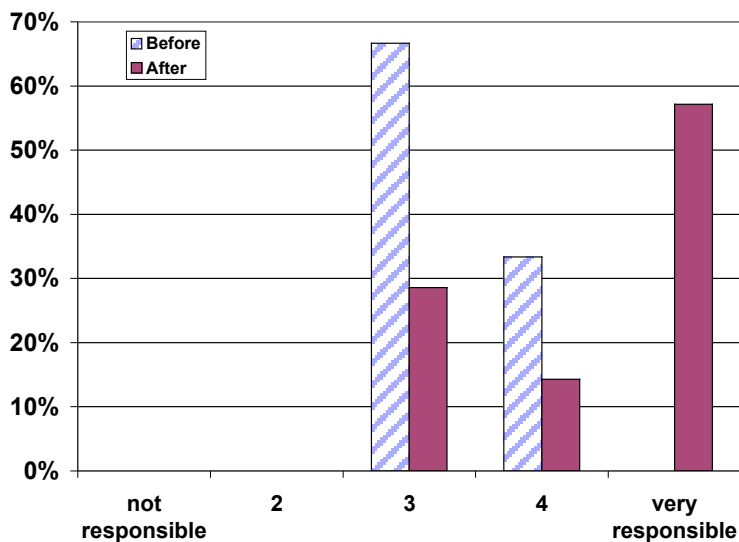


Figure 9: How responsible should a scientist be to discuss his or her research with the general public?

on local public reaction to nanotechnology. Figure 9 illustrates the shift in students’ view of the need for scientists to discuss their work with the public.

the public, but of conducting a dialogue from which they will learn as much as they will convey. Students must thus develop an ability to interact productively with people outside their field. The class project is designed to facilitate this interaction. Students wrote, administered and analyzed a survey instrument that assesses public awareness of and attitudes to nanotechnology. This encourages interaction of students with the public at large, introduces ethical issues implicit in human subject research, and increases awareness of nanotechnology among the survey recipients, in addition to providing some insight

After a guest lecture by an expert in survey techniques, the students were broken into teams to work on survey goals, format, and content. They found their major challenge to be that of assessing public opinion of nanotechnology, when most of the public has yet to become aware of it. As one student put it: *“This experience has impressed upon me the realistic difficulties of truly assessing public opinion.”* Their approach to this was to frame the survey around ‘scenario’ questions – one being:

“Many currently available consumer products use nanotechnology – stain-free pants, for example, as well as certain brands of golf balls, cosmetics, car wax, and so on. When shopping for a particular product, you notice that ‘Brand N’, on its packaging, or in its advertising, says it uses using nanotechnology. How likely would you be to choose ‘Brand N’?” (The respondent rates on a five point scale from ‘very likely’ to ‘very unlikely’).

To avoid ‘survey fatigue’ they decided to limit these scenario questions to four only. Preliminary questions asked for demographic information, and if the respondent had heard of nanotechnology, and if so, where. As the project progressed, the teams interacted to iterate their work into a single survey, which they gave to 70 respondents. They also decided to offer sources of information (both web-based and paper) on nanotechnology at the end of the survey; the conversations that sometimes ensued gave first-hand experience of public reaction to science. *“This experiment and survey have definitely opened my eyes to the need for the scientific community to actively engage the public in these sort of debates,”* one student wrote. *“The survey results have convinced me that more effort from the scientific community is needed in educating the public if the dreams of nanotechnology are to be realized,”* noted another.

This survey was clearly an educational exercise, rather than a research project (given the quasi-random selection of respondents, the obviously unsophisticated structure of the questions, and so forth). The results, therefore, will not be presented in detail. They did, however, echo research survey findings of public attitudes to nanotechnology¹⁷. In particular, they showed that 30% of the respondents had not heard at all of nanotechnology. Only 8% of those who had heard of nanotechnology described themselves as being either familiar, or quite familiar with it. *“I was surprised that only one of the people I surveyed seemed knowledgeable about nanotechnology...however, all of the participants were interested in learning more, and I was able to have interesting conversations with several of the participants after the survey was complete.”* Curiosity on the part of the respondents, as well as a desire to learn more, was reported by the majority of the students. In a demonstration that the best way to learn something can be to teach it to someone else, satisfying this curiosity also appeared to increase their own confidence in their understanding of nanotechnology itself. *“I am glad I got to participate in this project especially because it allowed me to explain what nanotechnology is to others when I would not have been able to do that just four months ago.”*

C.5 Guest Speakers

As well as the speaker on survey techniques mentioned above, guest lecturers covered a range of specialty topics. This was a popular feature – one student wrote: *“having the chance to hear from invited experts was the most beneficial aspect of this course”*. The first of these lecturers spoke on bioethics, of particular relevance given the increasing nano-bio convergence. Another, an expert in international technology policy, spoke of nanotechnology’s geopolitical

implications. Two further lecturers were invited to explore the routes by which nanotechnology moves from the laboratory into society. The first, a faculty member and co-founder of a nanotechnology start-up company, described the constraints and opportunities of the nanotech small business experience. The second, another faculty member, described the university research process, and the extent to which this is shaped by societal forces such as funding processes, safety considerations, collaborative interactions, and so on.

Perhaps the most unique speaker was a philosopher from the Deaf community, who talked of the impact of technology in that community. (The 'Deaf community' is a sociocultural grouping of people who share a non-verbal language - sign language - that provides the basis for group cohesion and identity and group culture. This is a distinct grouping within the 'deaf' as defined as those who cannot hear.) This presentation served as an example of the effect of technology on the 'Fourth World' – small cultures facing extinction through societal homogenization. This speaker, herself deaf, described how cochlear implants have not been universally welcomed among the Deaf community, partly because they challenge their continued existence as a culture. She also described how the emerging possibilities of genetic screening have made it possible in theory for Deaf parents to 'select in' for deafness in their children. These possibilities pose troubling ethical issues. They also require examination of the question of the human 'norm', and of who defines this, as well as challenging an implicit assumption that technological progress is an inevitable benefit. One student commented: *"This was a real jolt to my perception of the disabled, and the meaning of culture to isolated groups of people living in the larger community of man...It is easy to advertise a philosophy that new technology should...be for the greater good – but what does that actually mean?"* This presentation again reinforced the need for scientists to interact with stakeholder groups *"It is first the scientists and engineers,"* wrote a student, *"who must listen to the potential consumers of emerging technologies."*

All of these guest lecturers adopted the interactive, participatory format of the regular classes, with ongoing discussion. While the roster of guest lecturers may change for future classes, the goal will be to maintain the multi-faceted representation of business, research, bio, political, and stakeholder points of view.

D. Reading Materials

The course textbook was *Engines of Creation: the Coming Era of Nanotechnology* by K. Eric Drexler. This was the book that heralded the onset of nanotechnology, written by a figure who played a significant part in its early days, and whose ideas sparked much of the attention to replicating 'nanobots'. While selected chapters from this were very relevant to the early part of the course, as class attention focused on specific nanotechnology issues, it became less useful. It was supplemented by the news services referred to above. Selected topical articles from the media, relevant to the subjects under discussion, were provided in many of the classes.

E. Student Response

Student reaction to this class was very positive. It should be remarked that these students had elected to take this class. When students are obliged to take this class as part of a curriculum in future semesters may have a different response. This may be particularly true of those for whom English is not their first language. This was, in fact, the case for one of the graduate students in

this class, although his level of English was such that this was a relatively minor handicap, which he made (and was encouraged to make) significant effort to overcome in class discussion.

Typical examples of student comments at the end of the semester were:

- *“The information and presentation of it were food for thought.”*
- *“I gained an enormous amount of knowledge concerning the main subject matter – which I knew nothing about previously – as well as a sense of how to explore further.”*
- *“The concepts (were conveyed) in a fair and unbiased fashion, (which) made me feel more comfortable discussing the issues. The classroom environment was very conducive to conversation and this is an aspect of the class I’ll miss very much.”*
- *“Excellent ... course material was presented in terms of questions for the students to work out, rather than as answers that the instructor already knows.”*
- *“I thoroughly enjoyed this course.”*

Common reactions were an appreciation of the emphasis on class discussion; the opportunity to meet expert opinion; the topicality of the material; and the sense that divergent points of view could be ‘safely’ and constructively expressed.

F. Conclusion

A new course on the Social and Ethical Implications of Nanotechnology was given, and well received. Although, since ABET 2000, there is an expectation that graduate students in engineering disciplines will have undergone education in engineering ethics, this proved not to be the case in this class. Because the majority of the students were from non-engineering disciplines, or had taken their first degrees abroad, only one of the nine had received previous ethics training. Since the majority of nanotechnology training takes place at the graduate level, with the students coming from a range of disciplines, this leads one to predict that many students could graduate as nanotechnologists with no ethics training at all. This is a disturbing observation for a technology with such significant social implications. Courses such as the one described here can provide a basis from which to address the research challenges and ethical issues implicit in such interdisciplinary research. Significantly, as students developed their sensitivity to societal and ethical issues in nanotechnology, they nevertheless felt that the issues implicit in a nanotechnology project would not be readily apparent to the scientists involved. This again underlines the need for and value of dedicated ethics training in this area.

In recent times, the increasing capabilities brought about by the rapid advance of technology have given rise to a range of divisive issues, the debates over which have been both heated and polarized. It is becoming increasingly important for scientists to be able to engage in balanced and fruitful public discussion of scientific issues. During this class, as well as gaining an increased sense of a scientist’s social responsibility, and the need for the scientific community to interact with the public at large, students were also given the opportunity to develop their ability to interact with the public in scientific discussion.

Nanotechnology is expected to have a major social impact; sensitizing scientists and engineers to this, and their role in managing it, is crucial if nanotechnology is to realize its potential to benefit humanity.

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