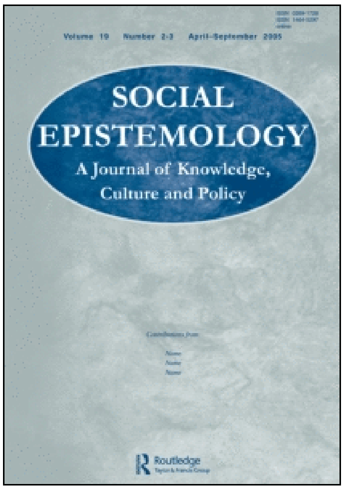

Social Epistemology
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713765921

Entering the Social Experiment: A Case for the Informed Consent of Graduate Engineering Students

Erik Fisher; Michael Lightner

Online publication date: 23 December 2009

To cite this Article Fisher, Erik and Lightner, Michael(2009) 'Entering the Social Experiment: A Case for the Informed Consent of Graduate Engineering Students', Social Epistemology, 23: 3, 283 — 300

To link to this Article: DOI: 10.1080/02691720903364167

URL: http://dx.doi.org/10.1080/02691720903364167

Social Epistemology
Vol. 23, Nos. 3–4, July–December 2009, pp. 283–300

Routledge
Taylor & Francis Group

Entering the Social Experiment: A Case for the Informed Consent of Graduate Engineering Students

Erik Fisher and Michael Lightner

Taking up the notion of engineering as social experimentation, this paper argues that engineering research laboratory directors have a responsibility to inform graduate engineering students who participate in their research projects of the potential broader social dimensions of those projects. Informing engineers-in-the-making of the broader social dimensions of the research they are learning to conduct would help ensure their future capacity to act as ethically responsible social experimenters. The paper also argues that graduate engineers have a right to be informed participants in activities that may have broader social dimensions than are recognized by formal research evaluation or educational processes. The process of obtaining the informed consent of graduate engineering students, if implemented effectively, would thus help ensure both their capacity to act as moral agents and their own moral integrity. Since the eventual outcomes of research can be uncertain, complex, and contested, most traditional institutional frameworks—such as principle-based codes of conduct and risk–benefit frameworks—provide an insufficient basis to inform engineers and citizens. Rather, we recommend an ongoing discursive process that explores a number of different actors, contexts, and scenarios, and that evolves with the social context of the engineering research in question. While this may seem burdensome to the engineering research process, it can be integrated directly into the group research meetings and mentorship activities that typically already go on. Moreover, it can actually be seen to benefit engineering practices.

Keywords: Social Experimentation; Informed Consent; Education; Nanotechnology; Synthetic Biology; Engineering Ethics; Governance

Erik Fisher is an Assistant Professor with a joint appointment in the School of Politics and Global Studies and the Consortium for Science, Policy and Outcomes at Arizona State University. He serves as Assistant Director for International Activities of the Center for Nanotechnology in Society at Arizona State University. Michael Lightner is in the Electrical, Computer, and Energy Engineering Department at the University of Colorado, Boulder where he is a Professor and Department Chair. A Fellow of IEEE, he was elected and served as the 2006 IEEE President and CEO. Correspondence to: Erik Fisher, Consortium for Science, Policy & Outcomes, Arizona State University, Interdisciplinary B 366, 1120 S. Cady Mall, Tempe, Arizona, 85287, USA . Email: efisher1@asu.edu

ISSN 0269–1728 (print)/ISSN 1464–5297 (online) © 2009 Taylor & Francis
DOI: 10.1080/02691720903364167

Introduction

New and emerging technologies are continuously being proposed, explored, and developed in academic laboratories around the world. Such new technologies and the increasingly powerful technological capacities they enable can occasion ethical concerns and public controversies, for instance over both the intended and unintended consequences they potentially entail. Cognitive enhancement technologies (Sarewitz and Karas 2006), synthetic biology (O'Malley, Calvert, and Dupré 2007; Vriend 2006), *in vivo* biochips, and the broad field of nanotechnology (Allhoff et al. 2007; Cameron and Mitchell 2007) represent only a handful of the emerging technologies and broad technological capacities that are being funded and developed in engineering laboratories around the world, and that are at the same time subject to prominent ethical concerns. The tension between these paired trends of, on the one hand, seeking out and promoting increasingly new technological capacities and, on the other, voicing concern over the potentially disruptive social dimensions of such new capacities, is likely not only to continue but to become more visible and acute (for example, Fisher and Mahajan 2006). Part of what it means to continually invest in cutting-edge technological research is that scientific and engineering education and training programmes are refined and, from time to time, transformed. In general, we argue that researchers, specifically graduate engineering researchers, need to be informed about the nature of the social dimensions of their work if they are to perform their duty to inform public discourses and decision-making, and if they are to function as morally autonomous beings in the process. For both reasons—responsibility and right—we consider the mechanism of informed consent as it applies to the role and identity of graduate engineering students who are in the process of entering the social experiment of engineering (Martin and Schinzinger 1996).

Informed Consent

The modern institutionalization of the practice of obtaining informed consent can be viewed as the result of a process of "disaster response" (Bozeman and Hirsch 2006). In the aftermath of the atrocities of German and Japanese medical experiments on human subjects during World War II, the Nuremberg Code of 1948 was created, which required free and informed consent for all human participants in biomedical research. In 1964 the World Medical Association adopted the Helsinki Declaration, which strengthened and developed the principle of informed consent. In 1974 the National Research Act was passed largely in response to the abuses of the Tuskegee studies. The Act established the US National Commission for the Protection of Human Subjects of Biomedical and Behavioral Research, which in 1979 produced the Belmont Report (National Commission 1979). This report became the basis for an expanded version of US Code having to do with the protection of human subjects in 1981 and later in 1991.

The practice of requiring and obtaining the informed consent of participants in scientific research projects derives from the ethical principle generally formulated as "respect for persons" or sometimes more narrowly as "respect for autonomy". This principle posits that human beings are autonomous agents and ends in themselves. Accordingly, there is a moral injunction against treating them as means to the ends of other human beings. In their *History and Theory of Informed Consent*, Faden, Beauchamp, and King state that, "it is one thing to be autonomous, and another to be *respected* as autonomous" (1986, 8). Thus, moral rights and responsibilities are distinct from social practices, including those that are legally mandated. While the legal basis for informed consent stems from the liability of those who act as "agents of disclosure", Faden, Beauchamp, and King suggest correlating "the right to make an autonomous choice and the right to perform autonomous actions" to the [negative] duty "not to interfere with the autonomous choices and actions of others and, in special relationships … the [positive] duty to enable others to make autonomous choices" (1986, 7). This understanding of the rationale behind obtaining informed consent raises two related questions with respect to the role and identities of the researchers who conduct scientific activities: what information do agents of disclosure require in order to respect the rights of others to make autonomous choices, and—especially in light of the scale and complexity of modern scientific, medical and engineering research agendas—to what extent should researchers themselves be considered as research participants?

Engineering as Social Experimentation

One thing that characterizes the post-World War II history and theory of informed consent as it has been applied to biomedical and many other forms of scientific research is that, whether as a principle or a process, the concept has been primarily associated with upholding the rights of patients and research subjects through insistence on the responsibilities of professionals and researchers towards these people. More recently, some have proposed extensions of the process of obtaining informed consent by broadening the population to whom the associated rights apply. Thus, Martin and Schinzinger (1996) suggest that engineering can be thought of as social experimentation, and they discuss the implications this idea has for informed consent:

> Viewing engineering as an experiment on a societal scale places the focus [of informed consent] where it should be: on the human beings affected by technology; for the experiment is performed on persons, not on inanimate objects. In this respect, albeit on a much larger scale, engineering closely parallels medical testing of new drugs and techniques on human subjects. (Martin and Schinzinger 1996, 84–85)

Their idea broadens the notion of informed consent and those to whom it applies by likening engineering to an ongoing social experiment. In this case, those who are affected are not only volunteer research subjects affected by a specific research project, but also broader populations who do not participate in a controlled laboratory research experiment but in an open social experiment that takes place in the form of a "real world experiment" (Gross and Hoffmann-Riem 2005). Accordingly, the affecting object's focal point is more a matter of technology in society than science in the laboratory.

Drawing on the same analogy of social experimentation, Sarewitz and Woodhouse (2003) discuss the idea of obtaining the informed consent of members of the general public in light of the case of nanotechnology:

> Given the huge uncertainties about the future social impacts of nanotechnology, we ought to think of the unfolding revolution as a grand experiment—a clinical trial—that technologists are conducting on society. From this perspective, we can reflect upon the robust societal consensus that demands prior informed consent as the basis for participation in scientific experiments. (2003, 80)

As do Martin and Schinzinger, the authors here expand the notion of informed consent by analogy, in both cases through broadening the life of the technological research project in terms of its scale, time horizon, and affected population. The shift they recommend in both cases is from obtaining the informed consent to participate in individual research projects to that of obtaining informed consent to participate in socio-technological change more broadly. In addition to expanding the population on whom potential risks and benefits are imposed, engineers are now likened to clinicians or social experimenters who therefore have a corresponding obligation to anyone who may be affected by their experimentation—that is, members of the general public.

Thus, Martin and Schinzinger encourage engineers to be "responsible experimenters" and to act accordingly: in this case, to interact in certain ways with the public. In their view, the moral (and legal) function of engineers in informed consent *vis-à-vis* "interactions between engineers and the public" (Martin and Schinzinger 1996, 85) consists of providing information and knowledge, and respecting the rights of members of the public to autonomously "enter into the experiment" (1996, 85). Thus, they recommend that engineers provide "the kind of sound advice a responsible physician gives a patient when prescribing a course of drug treatment that has possible side effects" (Martin and Schinzinger 1996, 85).

In a departure from most discussions of informed consent—and as a variation on the typical understanding of the autonomy of engineers (Fuller 1997; Kitcher 2007)—we further expand the notion of engineering as social experimentation to include university-based engineering research, especially on emerging technologies (see Petroski 1992), and we suggest that graduate engineering researchers not only require special kinds of knowledge if they are to act as effective agents of disclosure, but that they have unique rights arising from their roles as morally autonomous engineers-in-the-making.

Engineers as Informed Public Agents of Disclosure

In Martin and Schinzinger's idea of engineering as social experimentation, engineers ought to inform the participants in their experiment of potential unintended consequences analogous to medical "side effects". The medical analogy breaks down but in an interesting way. Like medical side effects, unintended socio-technical consequences are uncertain and complex, and may be controversial. But unlike medical practitioners, who are trained in how the human body functions and consequentially in how it may experience adverse effects, engineers are not trained in the body politic in the same way:

socio-technical change, let alone social change, is not an object of study for engineers. Thus, if engineers provide sound advice to members of the public about potential negative, adverse, and unintended social consequences of a particular project—let alone an entire suite of interacting technologies—they should probably know something about the nature of these things. To act as responsible informants or "agents of disclosure" to public debates and discussions, they should have at the very least a rudimentary understanding of what socio-technical interactions consist of.

This is where it gets interesting: the uncertainties involved in understanding the nature of how technology functions in society are at least as challenging as understanding the side effects of medical technology within the human body. For instance, emerging technological trajectories are governed over the course of multiple stages of development—before, during, and after research and development—and by multiple groups of actors: elected officials, programme officers, scientists and engineers, industrialists, consumers, lawyers, regulators, and many others. The complexity, uncertainty, and distributed nature of technological development mean that it defies simple normative assessment or even a clear understanding of the potential risks and benefits, let alone direct social shaping or control (Dupuy and Grinbaum 2004; Miller and Pfatteicher 2007).

Given that it is difficult, if not impossible, to know with certainty what the specific socio-technical outcomes of a particular set of engineering activities will be, informing the public is more properly a matter of anticipation—of a number of potential outcomes or futures—than it is a matter of prediction (Barben et al. 2008). Anticipation includes the ability to consider a number of potentially interacting social and technical variables, as well as to explore different assumptions, values, and worldviews (Rip and te Kulve 2008).

In addition to the conflicting ethical concerns and truth claims that will undoubtedly swirl around almost any public controversy about new and emerging technology, informed public deliberation leading to some form of robust consensus would need to be based upon an understanding both of the material configurations and of the social network of innovators, manufacturers, and envisioned users that would jointly produce outcomes. This is where engineers can be particularly effective as informed public agents of disclosure. For a prerequisite to understanding social dimensions of technology and socio-technical interactions consists of an understanding of the people, organizations, and institutions that are involved in producing information, claims, and actions. Engineers play unique and important roles in the *de facto* social shaping and social embedding of technology, in part because they have opportunities to reflect on and make changes directly to the material configurations (Newberry 2007). Thus, if engineers have a responsibility to inform others of the potential consequences of a new technological project or agenda, they have an obligation to know something about the nature of such potential consequences.

Engineers as Morally Autonomous Participants

As suggested earlier, from the standpoint of informed consent, engineers are conceived of in terms of their public responsibilities as social experimentalists, but not in terms of their rights as autonomous subjects who choose to participate in such experimentation. Martin and Schinzinger thus call for engineers to be "responsible experimenters" on the basis of their being the "main [but not the only] technical enablers or facilitators" of socio-technical change (1996, 89). As the characterization of policies for informed consent as a form of disaster response indicates, "respect for persons" is a negative injunction meant to protect would-be victims of ill-conceived if not malicious experimentation. This framing suggests that the role of engineers, technologists, and other social experimentalists is essentially that of active participants who "enact" the research, development, and innovation processes that comprise social experimentation. Hence, the moral autonomy of engineers is generally only discussed in so far as they are moral agents and largely in terms of whether or not they have a right to make research decisions that are controversial.

While this conception seems for the most part entirely defensible, it overlooks the ethical integrity of at least one subgroup of social experimentalists: the host of engineers-in-the-making in university laboratories. These individuals, through conducting much of the research that enables more visible engineering applications, are in the process of acquiring the skills, practices, and perspectives necessary to make them into professional researchers, laboratory directors, research managers, industry leaders, programme officers, and to otherwise participate as leaders and promoters of innovative social experimentation. We suggest here that engineering researchers-in-the-making—students who are undergoing a process of apprenticeship and mentoring and who are subject to various research pedagogies—are participants in social experimentation in two senses: as enactors of research, but also as moral subjects who have a right to know that their work may entail unintended consequences and may be the subject of public controversies.

Engineering graduate students are not simply consenting adults who choose to participate in broad-scale social experimentation, who realize that such an endeavour carries with it a set of complex, uncertain, and potentially controversial outcomes, and who happen to already be informed about the various unintended consequences and related uncertainties, complexities, and potential controversies of the project they are taking on for graduate work. If they were, they would already possess the knowledge and understanding required to inform other members of the general public who likewise do not possess it. In this case, it is unclear how they would have arrived at such a sophisticated understanding of technology in society, when as beginning graduate students they still have not formally mastered the technical competencies and cultural practices that help allow research to get to the point that it actually contributes to innovation. Alternatively, if graduate engineering education already provides a sufficient understanding of the broad social dimensions of engineering research itself, including an informed awareness of the potential negative unintended consequences, let alone of the nature of socio-technical change, then efforts to integrate anthropological, sociological, philosophical, and political practitioners and perspectives into engineering research projects and education would be redundant. The opening chapters of most engineering ethics textbooks are intended to provide refutations to the second counter-argument, and hence apply to the first. Moreover, in our experience, graduate engineering students are not likely to have reflected upon their own roles within social experiments (Fisher 2007, 158).

It follows that these individuals not only have a responsibility to act as informed public agents of disclosure, and hence should be adequately informed so that they are enabled to fulfil this responsibility; they also should be given the opportunity as members of the public to reflect on the nature of the work they are learning to undertake—both with respect to specific research projects and with respect to the more general idea of engineering as social experimentation. They have a right to know whether they are likely to be seen as having responsibilities to inform others, to have specific moral objections or reservations of their own that should be respected and addressed, or are likely to become targets of controversial public science.

The Education of Social Experimenters

It would be futile in most cases to attempt to pinpoint a precise time when an individual begins to participate as a moral subject either in a particular social experiment or in modern social experimentation more generally. For purposes of formulating a mechanism to help ensure that engineers-in-the-making both become informed public agents of disclosure and at the same time are treated with respect as autonomous moral subjects who are choosing to participate in specific and general forms of social experimentation, however, the same may not be as true for many engineers. If there is a moment at which an individual engineer enters into the ongoing and continuous social experiment as both moral agent and subject, it could be said to occur when she shifts from acquiring textbook knowledge and performing classroom exercises to formally conducting privately or publicly sponsored engineering work. Such is the case for the engineering graduate student, for whom the laboratory is a potential introduction not only to a series of research and material practices, but also a potential gateway to the world of sponsors, clients, suppliers, end users, research networks, and numerous other social and institutional actors who help promote and conduct social experimentation.

As becomes clear upon reflection on the likely temporal and spatial separations between the largely enabling work conducted within engineering research laboratories and the prospect of commercialized technologies, on the distributed nature of engineering work across numerous times, places, and agents, and on the fact that outcomes can be uncertain, complex, and contested, responsible participation by most engineers and by graduate engineering students in particular is anything but a straightforward matter (Fisher, Mitcham, and Mahajan 2006). Seen in this way, the complex social context of engineering endeavours belies the idea that risks and benefits are straightforward concepts or that unintended consequences can be known in advance (Averil 2005).

Rather than basing an education for responsible social experimentation on general ethical principles—which can be often fail to apply to specific contexts (Schuurbiers, Osseweijer, and Kinderlerer 2009), or attempting to create engineers who can simultaneously function as risk assessment experts, risk managers, or public risk communicators—which can be unrealistic, we suggest that graduate engineering education should cultivate a necessary condition for any specific ethical response under conditions of uncertainty: the reflexive awareness of the engineering student concerning the broader social systems in which her laboratory project, institution, and sector is already embedded. Basing an education on socio-technical change on the *de facto* social contexts of the laboratory within which engineering graduate students already work could afford numerous opportunities for learning about the immediate and mediated social dimensions of engineering. This type of learning can in turn go a long way towards creating informed agents of disclosure and informed participants in social experiments, since it would consist of real-world examples of complexities, uncertainties, and potentially conflicting interpretations and agenda regarding the same general technological trajectory. Reflexive awareness can be engendered through situated conversations that informally or formally tease out connections, scenarios, and potential controversies that link her work in the laboratory to the social and human context that gives meaning to the social experimentation metaphor. In this way, students and researchers can gain the foundation for what it would mean to be responsive to social concerns and to act as responsible social experimentalists.

The difference between what we are recommending here and what already occurs is that such opportunities for learning about the social contexts and dynamics of technological change would need to be taken advantage of through observation, discussion, and reflection; otherwise, there is little reason to think that such learning would occur. This is because, in our experience, interdisciplinary reflection among research groups about such things rarely occurs within laboratories (cf. McGregor and Wetmore 2009). While undergraduate ethics courses may provide opportunities to reflect on paradigmatic cases, graduate engineering students are rarely given the opportunity to engage in such reflections in connection to their own work, let alone to articulate and work through their own responses in the company of their fellow researchers and research mentors.

Understandably, the main order of the day is ensuring productive research. Typically, during regular research project group meetings, results, methods, potential publications and new ideas are proposed, reviewed, and criticized. And while the group research meeting is in many respects an excellent place for this kind of social and ethical reflection to occur, the problem is that it often does not occur there: we suggest that most students are not informed of such things and are not practiced in the discussion and anticipation of scenarios.

The Responsibility of Laboratory Directors

The responsibility to inform engineering students that they are engaged in social experimentation is arguably a broad one. If engineering students have rights, as we have argued, who has the responsibility to uphold these rights? In the context of university-based research, engaging the informed consent of these researchers is, we argue, the responsibility of the research directors under whose tutelage academic researchers are being trained in the art and science of engineering research, and under whose mentorship they operate. This responsibility can be conceived as an extension of their responsibilities to train and mentor graduate students and to prepare them for research-oriented careers.

During the formative period of graduate education and learning, a graduate engineering student works largely under the supervision of his or her laboratory director—whose job it is to provide guidance and attend to a host of related responsibilities, from signalling performance expectations and enforcing safety practices to providing funding and seeing to export controls. In that the laboratory director already has the responsibility to prepare the student for a professional or academic career, this involves informing the student about the context of research—who is publishing what, who is funding which projects, who is interested in building which facilities, who is hiring, and who is a likely client. An extension of this context would encompass reflection on the social dimensions of engineering research. In any case, since the laboratory director sets the tone of the discourse that is appropriate in the laboratory during group and one-on-one meetings, such reflection would essentially be impossible without his or her consent. We suggest that it is therefore also the responsibility of the laboratory director to provide an open atmosphere of conversation about the potential broader social dimensions of the research project—whether with regard to potential risks and benefits, social controversies, industrial contexts, and so forth, such as would be needed to think through responsible informing of both the autonomous researcher and the general public.

In university settings the laboratory director, typically the faculty member in charge of the research, has the responsibility both of following university, state and federal regulations and of negotiating the boundaries of these regulations. A typical situation is research that involves animal or human subjects. In this case, before the research can begin, protocols for the experiments need to be developed and approved by the university's Institutional Review Board (IRB) and sometimes by the funding agency. When there is an IRB protocol, the faculty research director is responsible for ensuring that the graduate research students are trained in the protocol and for ensuring that the protocol is followed rigorously. This is not simply for the well-being of the subject, but also for the validity of the experimental data. Accordingly, in addition to being responsible to engage graduate researchers in the specific intellectual and practical aspects of the research area, it follows that laboratory directors, as university agents, are responsible for assuring that these researchers comply with ethics policies and, in the case we are considering here, are informed of the range of implications of their work and explicitly consent to the practices in place to address ethical concerns.

Ethics Policies

Ethics policies are intended to integrate explicitly normative principles, practices, and procedures into research and development. Similar to the notion of institutionalized science ethics (Bozeman and Hirsch 2006), they obligate scientific, engineering, and medical researchers to adhere to standards that are designed to bring research into compliance with institutionalized principles, standards, practices, or codes of conduct. Ethics policy frameworks tend to focus on the responsibilities of research practitioners to assure the integrity of their research practices and results, the rights of their research subjects, and the welfare of the general public. In addition to research practitioners having duties and responsibilities as moral agents, we suggest a new ethics policy that inquires into how these things play out in the case of engineering as social experimentation would be reasonable.

Currently, beyond refraining from inappropriate actions, avoiding judgements that lead to harm, and informing others of risks, institutional frameworks do not recognize the moral standing of researchers regarding socially sensitive and ethically controversial research. Responsible Conduct of Research denotes a number of practices and issue areas—including data collection, authorship, peer review, and so forth—that have to do with assuring the integrity of research practices, conduct, and outputs. In these cases, integrity consists largely of the quality of maintaining accepted standards of practice and of avoiding egregious violations of clearly established norms. In short, this collection of ethics policies focuses on socially codified principles and procedures, but not on more complicated end-user dimensions of research and its possible macroethical implications.

Another example are the various forms of IRBs, which require researchers who work with human and animal subjects to adhere to rigorously reviewed and approved experimental protocols. In the case of human subjects research, protocols must ensure the rights of human research subjects, including obtaining the specific informed consent to participate in the research. IRBs thus focus on the ethical treatment of research subjects. One indication that the primary focus of IRB principles is not on end-use but rather on the welfare of individual research subjects, is that what could have public benefit may in fact be harmful to individuals who are protected by these principles (Swierstra and Rip 2007). Thus, researchers are viewed in their capacity as experimentalists and thus seen in terms of being moral agents, who are able to ensure the safety and rights of their subjects.

In neither of these cases is there an explicit or implicit role of research practitioners regarding the potential societal dimensions, context, or outcomes of their work. A notable exception to this is the National Science Foundation's "Broader Impacts Criterion" (BIC), which explicitly requires National Science Foundation research proposal authors to address the "broader impacts" of their proposed research. A glance at the text, however, indicates that broader impacts can include education and outreach activities that are attached to, but not integral to, the content or outcomes of the research. Moreover, when there is mention made of outcomes that are related to the eventual social function and use of the given research, there is an apparent bias towards positive outcomes. In other words, while the BIC requirement theoretically provides an opportunity for proposal authors to consider the potential controversial outcomes of their work, there is no reason for them to link the technical work with such considerations. Thus, BIC would seem the most likely candidate for linkage, but in fact it requires neither of these, and it therefore pays no attention to the moral integrity of researchers beyond their responsibility to make a case for the "beneficial" social relevance of the activities of the proposed research.

Clearly, policies focusing on environmental health and safety dimensions, such as the proper handling of hazardous or potentially hazardous materials, do take the welfare of researchers into account. For instance, the Occupational Safety and Health Administration requires that information on all potentially harmful substances be provided on Material Safety Data Sheets (MSDS). Institutional Biosafety Committees are meant to ensure that recombinant DNA research is conducted in compliance with safety guidelines issued by the National Institute of Health. But we point out that safe handling policies are independent of the moral autonomy of researchers, and there is no requirement to read or reflect on environmental health and safety practices or Material Safety Data Sheets information. Not only are rules-based systems vulnerable to institutional failure (Bozeman and Hirsch 2006), they become easily mechanized and fail to engage the ethical capacity of researchers whose daily work may potentially be associated with a range of downstream societal implications (Berne 2004).

In short, none of the ethics policies considered above ensure that research practitioners be informed about the likelihood—or lack thereof—for eventual societal outcomes associated with their work and their possible ethical dimensions. With respect to our focus on the right of graduate engineering researchers to be informed and on consensual participants in potentially controversial research, some combination of the IRB principle of informed consent and the BIC acknowledgement in potential socio-technical outcomes would be required. While others have considered the possible need for the informed consent of those who may be impacted by the eventual use of various technologies, the authors are aware of no recognition of the need for procuring the informed consent of graduate engineering researchers.

Current laboratory, education, and research training practices—including environmental health and safety training—do not assure informed consent of graduate engineering researchers with respect to their research projects. In most engineering research, IRBs are not involved and the closest parallel has to do with the use of potentially hazardous materials. While the details vary across institutions, there is typically a safety seminar taken by new graduate students to introduce them to relevant safety issues when handling potentially hazardous materials as well as best practices in laboratories. At the college or school level, there may be a safety officer responsible for periodic inspections, but the primary responsibility for laboratory safety lies with the faculty member(s) in charge of a given laboratory. Again two important outcomes that are tied to the existing research framework are the safety of the researchers in the laboratory and the laboratory equipment, and the validity of the data and materials produced in the laboratory.

Productive Consequences

An approach to ensure the informed consent of graduate engineering students in research could achieve three important broader outcomes: developing and protecting the ethical integrity of research students; doubly ensuring adequate protection of workers; and supporting the capacity of the future researcher and the research group to perform moral duties, and in the process creating greater sensitivity on the part of researchers to changes in the research environment. This latter outcome is of particular interest in so far as it may increase the responsive capacity of researchers to actively engage research developments from both technical and ethical standpoints, thus productively linking two domains that are rarely treated in tandem. An approach such as this could arise naturally out of existing safety training with the addition of an important ethical dimension. Thus, we advance three consequential reasons in support of recognizing the moral autonomy of graduate engineering researchers to participate as informed and consensual participants in research.

Moral Autonomy

In order to be conscientious participants in social experimentation, in research that is controversial or that has potential societal consequences that will naturally be subject to different interpretations of risk/benefit framings, graduate engineering researchers require information about the nature and context of the undertaking. Whereas professional engineers and professors by definition can be assumed to have chosen autonomously to participate in their research and development projects, the same cannot be assumed for students. This is in part because they are engaged in educational pursuits—they do not profess or speak as experts. Their awareness, judgement, and consent thus cannot be taken for granted—as it otherwise is in the case of those who perform "experiments" (whether laboratory or societal) on subjects with recognized moral standing. An interesting corollary to this: if there are no negative but also no positive outcomes likely to stem from a given project, this is also something students should be informed about and should consent to—since federally funded basic research with no social value is something that can be ethically controversial.

Worker Safety

Graduate engineering researchers can be exposed to safety and health risks through their work, especially in the areas of potentially hazardous materials. This is especially the case when the materials are new or otherwise lack specific regulations and established practices. This is the case with nanomaterials, which are arguably subject to "the extrapolation problem" (Schrader-Frechette 2007, 54). Regardless of whether one posits that materials such as these are hazardous or not, the point is that the hazards and risks are in fact not known. Nano-toxicology research is only in its infancy. Thus, students should be made aware when laboratory practices are potentially controversial or are still in the process of becoming codified.

Naturally, as in clinical trials, there are steps taken to ensure safety. In the case of engineering education, there are protocols, classes, and practices that are meant to be adequate safeguards of the health and safety of the workers. As argued above, however, these considerations were not sufficient to override the obligation of ensuring informed consent of research subjects who are given the right to know and to decide for themselves. The case is not different for engineering research students, who should be given the chance to identify and anticipate a range of social outcomes and consequences, the practices in place to protect workers; furthermore, they should be given the opportunity to consent to participate in light of any identified risks, benefits, and practices: to agree that the protections are adequate. If little is known of the potential outcomes, which is most likely the case, that in itself is information that should be passed on to them in order for them to make their own decisions as moral subjects.

Responsibilities

Finally, in order for researchers to fulfil their duty to inform the research subjects and members of the broader public of potential risks or controversial outcomes, graduate students need to know what these potential consequences and controversies may be. They should also consent that the safeguards in place and the information made available to those potentially affected is adequate. This is less a matter of their right as participants, as it is to aid them in their responsibilities to act as informed agents of disclosure—which requires being in the habit of providing information. Moreover, given that the process of obtaining informed consent will entail an examination of the adequacy of existing practices, this means that these very processes are more likely to evolve and improve through being vetted by more numerous reviewers. It also suggests that those entrusted with adhering to the safety and ethical practices that do exist will be more likely to remember them and thus to practice due diligence.

Proposed Process: Research Group Discussions

We propose a process of obtaining and maintaining graduate researchers' informed consent, both at the outset of a project and in response to relevant changes in the project's direction and broader context. In essence, the process develops the ethical framework of the researchers as their technical research skills are being developed. The process should provide information, and should permit consent. Any anticipated consequences or controversies that are likely to arise as legitimate questions in the deliberations of graduate researchers should be given fair hearing not only at the beginning of a project, but in an ongoing way whenever new developments inside or outside the laboratory are triggered. Ideally, this process would fit seamlessly into existing practices.

The process of informing would involve not only information feeding, but deliberation and discussion. This is because the uncertainties involved do not allow a tidy list of indisputable or even generally accepted facts. Ideally, since much research and development is distributed across different agents with different functions, the whole group would be present to consider certain macro-level concerns.

Discussions of research progress routinely occur in research groups. Depending on the particular culture of the laboratory or research group, these often involve all project members and can involve considerations that are both directly and at times indirectly related to the research underway. For instance, they can include discussion of results, experimental design, and research coordination, as well as goals, objectives, outputs, and relevant developments—new funding opportunities, visiting professors, guest lecturers, developments in the literature. Some groups discuss how to commercialize their research, others how to obtain funding. And while perhaps rare, such discussions can cover developments in the world of policy and industry. They are a time when negotiations and other social dynamics can play out, introductions are made, decisions come to the fore, and so forth. Thus, research group discussions are focused on the evolution and direction of research. A practical way to ensure the informed consent of graduate engineering researchers without unduly compromising productivity would consist of group discussions to raise general awareness of "broader impact"—including both potential positive and negative societal consequences and controversies.

These discussions would require the specific agreement on the part of researchers that they have been informed of potential broader societal implications, that they explicitly agree to begin or continue with the research, and that established laboratory practices are in their view adequate to protect society from inadvertent harms. We note that the last point is an outgrowth of the safety training that is typical in dealing with potentially hazardous materials, but now within an ethical framework informed by a larger discussion of societal and potential downstream impacts. In this approach, informed consent should be procured in the early stages of research, and should emerge from deliberative activities involving all research group members.

As research proceeds, however, its evolving nature may then require additional opportunities for further employment of the informed consent process, thus revisiting and, if necessary, deepening the deliberative process of assuring continued informed consent. Re-initiating the informed consent process would be triggered by the addition of a new research student to the group. Substantial changes in the direction or evolution of the research would also constitute a need to re-open group discussion. Experimental data generated within the group, or found within the body of literature relevant to the research, would likewise mark the need to renew the discursive process of giving consent. Finally, events that occur in the outside environment—such as documented unintended consequences stemming from relevant technological developments—would occasion a return to the deliberative activities to assure laboratory procedures are appropriate, discuss additional implications of the research, and reconfirm the consent of the engineering researchers.

The process of obtaining the informed consent of graduate research students, in order to respect their moral autonomy, would most probably need to accomplish the following steps: formally present students with the issues of the materials they will use and the environment in which they will use them; permit students appropriate time to formulate questions, explore relevant literature, and even take part in group deliberations; and elicit from them their formal consent to performing the experiment or working with the chemicals and compounds.

Tailoring Consent to Context

We note that graduate students are trained in handling hazardous materials only if such training is part of the laboratory and/or university protocol. Even with such training, however, students are rarely informed of the larger dangers of violating a safety protocol. For example, a typical procedure is to control the disposal of hazardous materials—arsenides, acids, and certain organic compounds. A general statement on the dangers may be given as part of the training—but is the graduate research student informed of the specific outcomes and dangers of disposal through a particular drain? That drain may quickly enter a water ecosystem that could be drastically impacted by the material, including mutations of flora and fauna. A set of pipes might corrode, leading to a leak into a public space. In some cases these dangers are emphasized, but unfortunately in many cases we believe that they are not. Thus, since each particular research project, environment, and set of individuals is unique, the specific context of each project would ideally need to be reflected upon.

Synergy with Technical Practices

The issues that we have been raising might seem onerous in many laboratories, especially when the chemicals are well known, the potential impact documented and the appropriate protocols well established and almost common knowledge. Consider, however, that much of the emerging research in which investigators and funding agencies are interested has none of these characteristics. New materials are being created—tissue engineering is one example, another is nanotechnology being used to create biomarkers. The proper way of controlling the dispersion of the materials may not yet be understood, and the toxicity and/or ecotoxicity of the materials if freely released into the environment only imagined.

In this, more and more common, environment of new materials and processes, one might ask how informed consent is even possible? Our contention is that, by having consent obtained with detailed discussion, the research and ethical growth of the graduate student researchers are both served. Handling new materials is not easy—a point underscored by the concept of "radical design", which lacks established standards and specifications (Vincenti 1990). An ongoing dialogue between the faculty member(s) and student researchers(s) allows a grounded and conscientious understanding of the complexities and uncertainties associated with doing cutting edge research. Further, it supports the real-time development of knowledge about the materials to be shared and the protocols to be evolved as understanding and insight is gained. Sharing these protocols beyond the laboratory with other researchers then arguably becomes an ethical responsibility. Having graduate research students participate in this dynamic informed consent and ethical deliberation can help set them on a career as a morally autonomous and conscientious researcher.

In addition to the ethical consideration described above, the constant discussion of the materials, protocols and insights of all members of the research team will quite probably lead to a better understanding of the materials and processes and quicker advances in the research. The triggers for research creativity often come when addressing a problem from a different or oblique viewpoint. Continuous informed consent is one such potential trigger and we believe that, in a dynamic research environment, this would act synergistically with the goals of the research. In other words, the research environment would be more productive. Thus, having the opportunity to choose to participate in an ethically informed way in such research would not only help protect the ethical integrity of graduate researchers, it would also potentially enhance the development of their ethical and technical skills in a mutually beneficial way.

Conclusion

Traditional ethics policy frameworks tend to focus on the responsibilities of medical and other researchers to assure/ensure the integrity of their research, the rights of their research subjects, and the welfare of general public. Beyond their duties as moral agents, however, there is little institutional recognition of the moral autonomy and capacity to act as informed agents of disclosure of engineering researchers. In a departure from most discussions of informed consent, we argue that more attention should be paid to the moral autonomy of engineering researchers-in-the-making, who may know little about the broader dimensions of their work and who may lack the skill and habit of reflecting on them. Graduate engineering researchers should therefore be given an opportunity to consent to being informed participants in potentially transformative and even controversial research. Having the opportunity to choose to participate in an ethically informed way in such research would respect the ethical integrity of graduate researchers and would also enhance the development of their ethical and technical skills in a mutually beneficial way.

From the standpoint of moral integrity, scientific, engineering, and medical research practitioners are conceived of in terms of their responsibilities, but not in terms of their rights. This is problematic in the case of the moral autonomy of graduate engineering researchers. We have argued that recognizing the moral autonomy of graduate engineering researchers by obtaining their informed consent with respect to their research projects would help develop and protect their ethical integrity; moreover, it would support their capacity to perform their moral duties; and finally would, by creating greater sensitivity on their part to changes in the research environment, make them more effective governing agents of technology in society.

For many engineering researchers unused to the rigours of IRB research, the suggestion in this paper may well seem absurd. If viewed as natural extensions to safety protocols, however, there can be some appreciation of the goals. Further, if the dynamic or continuous informed consent can be seen as a natural outgrowth of the research through laboratory team discussions, reviews of literature and creative engagement in understanding potential implications of research and new materials, then the benefits to the research itself can easily be imagined. The challenge will be the degree to which the proposed ideas can happen within the natural work flow of a university research laboratory in contrast to being imposed in a formal sense as a new type of IRB that takes into account the moral and technical development of engineering researchers-in-the-making.

Finally, and perhaps most importantly, the type of practice we suggest will, we believe, lead to both better and safer research and a cadre of new PhD students who have a grounded basis for discussing ethical issues associated with technology. Not only would such engagement be in line with internal laboratory governance practices, it would also better assure that research students are adequately informed and in explicit agreement with such practices. Thus this informed consent would protect the ethical integrity of research students whose ethical capacity to conduct research is still developing. Moreover, for graduate researchers, ethical capacity is developing alongside technical capacity; thus, we also argue, this engagement could lead to a more productive environment for engineering research in light of the interplay between technical and ethical considerations—promoting reflexive awareness (Fisher, Mitcham, and Mahajan 2006; Schuurbiers and Fisher 2009). If, through the example of certain research leaders, these ideas can become best practice—rather than mandated by top-down command and control mechanisms, resulting in highly constrained bureaucracy—then it is likely that the public at large, universities, research laboratories, faculty and graduate research students will benefit from a process of informed consent.

References

Allhoff, F., P. Lin, J. Moor, and J. Weckert, eds. 2007. *Nanoethics: The ethical and social implications of nanotechnology.* Hoboken, NJ: Wiley.

Averil, M. 2005. Unintended consequences. In *Encyclopedia of science, technology and ethics,* rev. ed., edited by C. Mitcham. Detroit, MI: Macmillan Reference.

Barben, D., E. Fisher, C. Selin, and D. H. Guston. 2008. Anticipatory governance of nanotechnology: Foresight, engagement, and integration. In *The handbook of science and technology studies,* 3rd ed., edited by E. J. Hackett, O. Amsterdamska, M. Lynch, and J. Wajcman, pp. 979–1000. Cambridge, MA: MIT Press.

Berne, R. W. 2004. Tiny ethics for big challenges: Calling for an ethics of nanoscale science and engineering. *IEEE Circuits Devices Magazine* (May/June): 10–17.

Bozeman, B., and P. Hirsch. 2006. Science ethics as a bureaucratic problem: IRBs, rules, and failures of control. *Policy Sciences* 38 (4): 269–91.

Cameron, N., and M. E. Mitchell, eds. 2007. *Nanoscale: Issues and perspectives for the nano century.* Hoboken, NJ: Wiley.

Dupuy, J. P., and A. Grinbaum. 2004. Living with uncertainty: Toward the ongoing normative assessment of nanotechnology, *Techné* 8 (2): 4–25.

Faden, R. R., T. L. Beauchamp, and N. M. P. King. 1986. *History and theory of informed consent.* Cary, NC: Oxford University Press.

Fisher, E. 2007. Ethnographic invention: Probing the capacity of laboratory decisions. *NanoEthics* 1 (2): 155–65.

Fisher, E., and R. L. Mahajan. 2006. Contradictory intent? US federal legislation on integrating societal concerns into nanotechnology research and development. *Science and Public Policy* 33 (1): 5–16.

Fisher, E., C. Mitcham, and R. L. Mahajan 2006. Midstream modulation of technology: Governance from within. *Bulletin of Science, Technology and Society* 26 (6): 485–96.

Fuller, S. 1997. *Science.* Minneapolis, MN: University of Minnesota Press.

Gross, M., and H. Hoffmann-Riem. 2005. Ecological restoration as a real-world experiment: Designing robust implementation strategies in an urban environment. *Public Understanding of Science* 14 (3): 269–84.

Kitcher, P. 2007. Scientific research: Who should govern? *NanoEthics* 1 (3): 177–84.

Martin, M. W., and R. Schinzinger. 1996. *Ethics in Engineering.* 3rd ed. New York: McGraw-Hill.

McGregor, J., and J. Wetmore. 2009. Researching and teaching the ethics and social implications of emerging technologies in the laboratory. *NanoEthics* 3 (1): 17–30.

Miller, C. A., and S. K. Pfatteicher. 2007. Nanotechnology in society education: Cultivating the mental habits of social engineers and critical citizens. In *Nanoscale science and engineering education,* edited by A. E. Sweeney and S. Seal, pp. 567–76. Stevenson Ranch, CA: American Scientific Publishers.

National Commission. 1979. The Belmont report: Ethical principles and guidelines for the protection of human subjects of research. The National Commission for the Protection of Human Subjects of Biomedical and Behavioral Research, 18 April.

Newberry, B. 2007. Are engineers instrumentalists? *Technology in Society* 29 (1): 107–19.

O'Malley, M. A., J. Calvert, and J. Dupré. 2007. The study of socioethical issues in systems biology. *American Journal of Bioethics* 7 (4): 67–78.

Petroski, H. 1992. *To engineer is human: The role of failure in successful design.* New York: Vintage Books.

Rip, A., and H. te Kulve. 2008. Constructive technology assessment and socio-technical scenarios. In *The yearbook of nanotechnology in society, vol. 1: Presenting futures*, edited by E. Fisher, C. Selin, and J. Wetmore, pp. 49–70. New York: Springer.

Sarewitz, D., and T. H. Karas. 2006. Workshop report: Policy implications of technologies for cognitive enhancement. Workshop held at Arizona State University, 3–5 May, sponsored by the Consortium for Science, Policy and Outcomes at Arizona State University and the Advanced Concepts Group at Sandia National Laboratories.

Sarewitz, D., and E. Woodhouse. 2003. Small is powerful. In *Living with the genie: Essays on technology and the quest for human mastery*, edited by A. Lightman, D. Sarewitz, and C. Desser, pp. 63–83. Washington, DC: Island Press.

Schuurbiers, D., and E. Fisher. 2009. Lab-scale intervention. *EMBO Reports* 10 (5): 424–42.

Schuurbiers, D., P. Osseweijer, and J. Kinderlerer. 2009. Implementing the Netherlands Code of Conduct for Scientific Practice: A case study. *Science and Engineering Ethics* 15 (2): 213–31.

Shrader-Frechette, K. 2007. Nanotoxicology and ethical conditions for informed consent. *NanoEthics* 1 (1): 47–56.

Swierstra, T., and A. Rip. 2007. Nano-ethics as NEST-ethics: Patterns of moral argumentation about new and emerging science and technology. *NanoEthics* 1 (1): 3–20.

Vincenti, W. G. 1990. *What engineers know and how they know it.* Baltimore, MD: Johns Hopkins University Press.

Vriend, H. 2006. *Constructing life: Early social reflections on the emerging field of synthetic biology.* Amsterdam: Rathenau Institute.