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ORIGINAL PAPER

Researching and Teaching the Ethics and Social Implications of Emerging Technologies in the Laboratory

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Abstract Ethicists and others who study and teach the social implications of science and technology are faced with a formidable challenge when they seek to address "emerging technologies." The topic is incredibly important, but difficult to grasp because not only are the precise issues often unclear, what the technology will ultimately look like can be difficult to discern. This paper argues that one particularly useful way to overcome these difficulties is to engage with their natural science and engineering colleagues in laboratories. Through discussions and interactions with these colleagues ethicists can simultaneously achieve three important objectives. First they can get a great deal of assistance in their research into the social implications of future technologies by talking with people that are actively creating those futures. Second their presence in the lab and the discussions that result can be a very powerful method for educating not only students, but faculty about the ramifications of their work. And third, because the education is directly linked to the students' everyday work it is likely that it will not just be a theoretical exercise, but have direct impact on their practice.

Keywords Emerging technologies · Ethics · Laboratories

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Introduction

Scientists and engineers are developing an astounding array of new technologies in an effort to transform the world as we know it. They promise that some of these technologies will not simply generate incremental change, but rather will be a technological leap over what we currently have and thereby create massive

transformations. Commonly referred to as "emerging technologies,"[1] these devices, techniques and applications include work being done in nano-scale science and engineering (NSE), artificial intelligence, neurology, and the intersection of bio-info-cogno. The proponents of emerging technologies such as these prophesize that they will significantly change our world—from the laboratory to the broader society—in numerous beneficial ways [1–4].

But while many of these developments offer great promise, the fundamental changes to society that they may enable will not come without difficulties and potentially more serious problems [5–7]. Often these technologies are touted as "the next revolution"[8, 9]. While those promoting the technologies likely do not mean to evoke the original definition of the word "revolution," which denotes a radical change in ideas often accompanied by violent upheaval and dramatic loss of life, even if some of the technical changes they are outlining are possible, there will certainly be widespread social implications. As it seems likely that at least a few of these products will become as pervasive and influential as the integrated circuit, they will also have analogous profound systems implications that affect every aspect of modern society. For instance, concerns have been raised about the potential environmental impacts of these technologies [10] and there are even critics who contend that some of these technologies will force us to reevaluate what it means to be human [11].

The scale and scope of the implications of emerging technologies demands that they be carefully considered. To realize the benefits of and to avoid problems associated with emerging technologies will require significant attention to social, political, and ethical systems as well as the scientific and technical [12, 13]. These issues will affect people around the globe and all people who make decisions about science and technology—whether they be bureaucrats who decide which research projects to fund or consumers who must decide which products to purchase—have a responsibility to carefully consider the choices they make [14].

But the novelty of these endeavors forces the question: Who is in a position where they understand both the technology and the issues well enough to make informed decisions or, perhaps even more importantly, offer sage advice? Emerging technologies present ethicists and others interested in understanding the relationships between science, technology, and society, with a formidable challenge. By their very nature, the implications of emerging technologies are not yet fully understood. Emerging cross-disciplinary areas such as nanotechnology are so new that no consensus about ethical standards, guidelines, or educational programs in social and ethical implications has had a chance to develop.[2]

Since most traditional systems of ethics education and research are not equipped to handle emerging technologies, we encourage ethicists and normatively minded social scientists to engage in projects that are not so traditional. There are great advances to be made by leaving offices and traditional classrooms and spending time in laboratories where cutting edge research is being done. Not only can ground-breaking technical work on emerging technologies be done in research laboratories, new understandings about their social and ethical implications can be developed there as well.

The practitioners and projects in these laboratories can provide an opportunity for ethicists to simultaneously achieve three objectives: First, they can get access to information about future technologies that is not readily available in other places. This will give them the opportunity to conduct their own research on emerging issues and begin to understand the ethical questions they might generate. Second, it will provide an opportunity to educate leading scientists and engineers in the ethical implications of their work. Numerous groups have been calling for such education

[1] While these are often referred to as "emerging technologies," it is a phrase that we find troubling. It could imply that these technologies are somehow inevitable. We maintain that they will only "emerge" if people and institutions spend the time, money, and effort to make them a reality and that it is how these people and institutions interpret needs that will decide the precise characteristics of the technologies.

[2] In this article we do not draw a strict distinction between "social implication," "ethical implication," or "political implication" in large part because we did not draw such a distinction when we discussed issues in the laboratory. There can be important methodological reasons to separate these three ideas. For most of the students we interacted with, however, thinking about these ideas in the context of science was so new that we were more interested in exposing them to a variety of ideas, rather than compartmentalizing them. In the end they recognized that the issues are inherently interrelated and one must understand them from multiple angles to be able to act towards multiple ends.

especially in engineering [15] and the field of research ethics [16, 17]. Spending time in the lab can give the ethicist direct access to those engaged in research. Third, it can help empower those who shape the direction of innovation to be more reflective on the social implications of their work. It is one thing for engineers and scientists to understand the ethical implications of their work. It is another thing for them to draw on these ideas to actively inform or change their practice. By having a dialogue in the laboratory environment, we believe it becomes much more likely that they will be able to integrate ideas about ethics into their worldview.

Bringing together scientists and engineers doing cutting edge research in their fields with experts in the social and ethical aspects of science and engineering to engage in directed conversations about their work opens up a productive way to research and teach the ethical aspects of emerging technologies as well as an opportunity to have a direct impact on day-to-day decisions being made about knowledge-based innovations. This article summarizes many of the benefits of such an approach, outlines some dangers to avoid, and provides some lessons based on a small pilot study.

Sharing Expertise

Social scientists, especially anthropologists, have been spending time in laboratories for several decades [18–21]. Most frequently these efforts have been made to better understand the work being done by scientists and engineers. But often these projects benefit more than just the visitors. The anthropologists brought with them a new set of ideas, expertise, and viewpoints and spurred researchers to rethink their own work. When anthropologists asked scientists why they used certain techniques, the scientists often took a short break from their routine and reflected on the decisions they made. In these reflections the scientists began to consider alternatives, thereby opening the door for new creative thought. The inquisitiveness of an anthropologist can help scientists to take a different view of their work.

The approach we are advocating takes this finding from ethnographic research and seeks to use it to a directed end—to get scientists and engineers to better understand the ethical and social implications of their work. The idea is that by spending time in the laboratory with PIs, post-docs, and graduate students, experts in the social and ethical aspects of science and engineering may have more success in researching and educating practitioners about the implications of emerging technologies than if they remained physically separate. The laboratory can be a place where not only technical expertise, but social and ethical expertise can be exchanged, discussed, and debated.

The laboratory is not a traditional location for ethical research or education, however, and will require some important changes if these efforts are to succeed. First, it will require some changes on the part of the scientists. Discussing ethics is not always easy for scientists to do. Usually it is done briefly in an outside lecture on responsible conduct in research that they dread going to and largely ignore. Bringing these conversations into the lab wouldn't be completely foreign. Scientists have found that for both safety and litigation reasons it is important to discuss issues like hazardous material regulations in the lab. But they most often do this on their own terms and in their own way. They may assume that if they let an ethicist in their lab they would be unnecessarily distracted, open themselves up to uninformed critiques, and, as a worse case scenario, have "the whistle" blown on them. But scientists and engineers are increasingly realizing that discussing ethical issues can be very valuable. Concerns about environmental health and safety and other issues have made a number of scientists recognize that they cannot stand on the sidelines, but rather must directly engage these issues. This is not true of all scientists, but more and more some are reaching out to ethicists for assistance in these very complicated matters and the prospects of doing this in the laboratory might make it even more palatable.

Second, to make such an exchange possible, ethicists will in turn need to recognize, as many already have, the benefits of learning from and interacting with other sets of expertise. They will need to leave behind the safety of the lecture hall and prepared notes. By entering the laboratory, the ethicist takes his or her set of expertise into the scientist's domain. Not only is it more likely for scientists to find time in their lab, it is also a place where they feel comfortable which makes open discussion much easier to facilitate. This decreases the chance that ethicists will be compelled to talk at scientists and increase the chance that they can help to facilitate directed conversations. Scientists know far more

about the technical details than the ethicist ever will. Recognizing this expertise, rather than talking down to it from behind a podium, can significantly increase the likelihood of a fruitful conversation. Rather than pretend they have the answers, it is important for the ethicist to freely admit that there are a number of unresolved questions and that he or she needs help developing new ideas about what an ethics for emerging technologies might look like, what the societal implications might be, and what the scientists' responsibility is in response to those implications. Many ethicists are keen to leave the ivory tower. They want to have an impact on the way people behave. If they begin to see the benefits of entering scientific laboratories at least some are likely to.

If both the ethicists and scientists are willing to work together, it is possible to develop a level of trust and create a "safe" environment in which questions of individual values and aspirations along with institutional and societal values can be explored. Those trained in ethics begin to learn from the scientists about issues specific to emerging technology research and at the same time, because the ethicists bring frames, questions, concerns, and ways of thinking about social and ethical implications these regular meetings have an impact on those conducting research in the lab. At the very least arrangements like this could lead to benefits for ethics research, ethics education, and the greater social understanding of the implications of emerging science and technology.

Precedents for the Approach

The idea of bringing together ethics experts with technical experts is not a new one. The field of engineering ethics as we know it today was largely influenced by the efforts of philosopher Robert J. Baum in the late 1970s. Baum secured a large grant from the National Endowment for the Humanities in order to pair up engineers with ethicists to explore ethical problems in engineering. The plan was that these pairs could learn from each other and together develop a better understanding of the implications of engineering. Not only did the project lead to a number of important papers and books [22, 23], it brought together engineer Michael Martin and philosopher Roland Schinzinger who soon after developed one of the most widely used textbooks in the field [24].

The approach that we have in mind is slightly different, however. Rather than bring together pairs of experts to spend time thinking about general problems, we envision the creation of small working groups of engineers, scientists, and ethicists who consider, in real time, technical projects that are being developed. The goal will not be to consider fields in general, but to dive into the implications, problems, and social disturbances that could possibly result from different courses of action the lab is considering. Rather than simply teach individuals and hope they make carefully considered decisions later, we expect that this approach will lead to real-time assessment of the course of the research.

A few recent examples of successful endeavors of this type already exist. For instance, Erik Fisher has spent a great deal of time embedded in laboratories at the University of Colorado and Arizona State University with the goal of helping scientists reflect on their work and adjust their practices and was recently awarded an NSF grant to expand this project international with the "Socio-Technical Integration Research Project"[25]. Julio Tuma, a philosopher at the University of Chicago, has been engaged in a similar project.

But perhaps the most fully recorded recent endeavor is by Rosalyn Berne. In 2002, Rosalyn Berne set out to try to understand what nanotechnology is and what its ethical implications are. Because she felt that practicing scientists and engineers would best understand the answers to her questions, she interviewed over 30 nanoscale researchers. These were not journalistic interviews or historical interviews. As can be seen in the transcripts in her book, she approached each as a colleague and initiated discussions that had a free exchange of expertise and self [26]. At various points in these conversations, Berne and the scientists came to better understand each other's backgrounds and fields of expertise, found common ground, clarified each other's misconceptions, discussed concerns, red flagged issues, and ultimately built a vision of the future they can both share.

Berne's interviews reveal what is possible when experts in ethics and the social dimensions of technology sit down with scientists and engineers, engage with one another in an honest way, and share their knowledge, expertise, and concerns. Both sets of experts come away with a better understanding not only of the other's field, but of their own field as well. Berne better understood the field of nanotechnology, the engineers came to see the ethical and social

implications of their work more clearly, and together they were able to identify and grapple with emerging issues in nanotechnology and ethics. Many of the people she spoke with were very enthusiastic about the process, and it is clear from the transcripts that even though Berne had only a few meetings with each person, many of them were motivated to think much more carefully about the ethics in their work. Had Berne the opportunity to spend an extended amount of time in a single lab, it is likely that she could have had a very important impact on the way its members considered the ethical and social implications of their work and ultimately the directions they chose to pursue.

Case Study

Relying on these precedents, we set out to design a model of interaction based on directed conversations with scientist and engineering in NSE about the ethical and social implications of the work being done in their labs. Our research questions were: Can ethicists gain access to information about future technologies that are not readily available in other places? Will this method provide an opportunity to educate scientists and engineers in the ethical and social implications of their work? And will this method empower those who shape the direction of innovation to be more reflective on the ethical and social implications of their work?

Determining the best way for ethicists and social scientists to approach laboratories and become involved in their work will require a number of attempts and will likely differ from institution to institution. But individual experiences can help to pinpoint some general problems and potential strategies. We will discuss one example that we carried out at Arizona State University where we engaged with a small groups of graduate student scientists, the PI and postdocs in an interdisciplinary bio-optics lab. The pilot project was not quite as integrated as we would ultimately like them to be. We were not in the laboratory on a daily basis, but we met every few weeks in the lab's regularly scheduled meetings. The number of participants ranged from 12 to 20 including visiting faculty, postdocs, and undergraduates, but mainly graduate students. The sessions were approximately an hour each except for the capstone which was an hour and a half. This small experience helped us to confirm a number of our theories and offered some lessons for how ethicist-laboratory interactions could work in the future.

When we began the project we knew that it would be extremely difficult to create a productive dialogue in a lab if we did not have the cooperation of Primary Investigators (PIs) and senior scientists. Much of the cutting edge research is being done by graduate students and postdoctoral researchers and they may be the most open to learning about the ethical implications of their work. But without the support of PIs, two major problems are likely to develop. First lack of support could make it prohibitively difficult to gain appropriate access to their labs. Second, and perhaps even more importantly, if the PI does not convey to the lab that they should engage with the project seriously it is likely to be dismissed as unimportant by many involved.

We were fortunate enough to find a senior scientist who believed in the importance of training his students to be reflective about and able to discuss the ethics and social implications of science. This was in part because he recognized that the project would give his students and others in the lab an opportunity to learn about the methods of ethics and get another perspective on their daily work. But, perhaps more importantly, he also believed that such interactions would give his students practice talking to the public about their work and help them to answers questions about its implications for society. Because of the nature of funding, regulation, and litigation, he saw these skills as essential for a successful career as a scientist in the 21st century and encouraged his students to use the opportunity to help with their professional development.

The PI quickly became a collaborator on the project and helped us to think through the best way to organize it. For instance the first question was where the interactions should be held. We wanted them to be held in a place where the students would feel comfortable and part of their daily routine. The PI suggested that we meet during his normally scheduled lab meetings. It was an idea that worked incredibly well. It made sure that the entire lab was available since they weren't always in the lab, but they were required to attend the lab meetings. Had we interacted in their actual workspace we'd only be able to talk with a few people at a time. It might have been nice to be surrounded by pipettes and fume hoods, but the lab meetings were still a part of their routine. It was a

place that was integral to their scientific work and it was a place that they felt comfortable.

The next question we had for the PI was whether or not he wanted to be present for the meetings. We knew this was tricky because the relationship between the PI and his or her lab can have a large influence on how the students would interact with us. From other experiences we knew that some of the graduate student scientists most interested in the social implications of their work would never speak a word of it in front of their advisor because they feared being seen as unprofessional or "less than scientists." This particular PI was very interested in what we were doing and wanted to learn more about the issues himself, so he asked to be present.

The benefits of having this particular PI as an active participant became evident the first day we spent in the lab. As something of an ice breaker, we asked the students to explain why they chose to become scientists. The first response from one of the students was the traditional "canned" scientific answer: "I wanted to make the world a better place."[3] While we knew there probably was some validity to that answer, it didn't get to the personal level that we knew would be necessary for the dialogue we envisioned. So we simply asked if anyone had any "less noble" reasons. After a few seconds of silence, the PI chimed in: "I wanted to be a scientist because I thought it was fun. I enjoy solving problems." Immediately the mood of the room changed. By not giving the "official" scientific answer and perhaps leaving himself a bit vulnerable, the PI quickly made it known to the students that it was OK to speak their mind and say what their personal beliefs were. The subsequent answers stretched the gamut from "I like working on machines" to "science was the best way for me to be able to leave my home country and come to the United States."

In addition to finding a PI that understood the project, we found that it was important to remember that the participants already have a number of ideas about ethics and the relationship to science. We are not introducing ethics to their world. It is already very much there. Much of their knowledge about ethics, however, is implicit. In other words, they don't necessarily conceptualize their views about these matters as ethical views. We saw it as our job to help to make their ethical views explicit. In order to do this we took a fairly open ended approach. Our goal was not to get through "X" amount of material each day, but rather to get them to reflect on their own approach, talk about their ideas about ethics, and compare them to the others in the room. We did this through a series of short, simple questions. As mentioned above we began with: "Why did you become a scientist." In subsequent meetings we followed that question up with: "How does science affect society?"; "How does society affect science?"; and "How can scientists more effectively communicate with the public?" We started each meeting by giving the lab members 5 min to write out their answers to give them a chance to reflect on their own beliefs. We then facilitated a conversation amongst all the participants, including answering each question for ourselves.

The immediate reaction to our directed conversation was reasonably positive. The students had no idea what to expect. Some were rather skeptical going in and, while we did not win over everyone immediately, a number commented after the first session that they learned a lot by discussing their motivations and felt that it was something they had on their annual retreat a few weeks previously.

On the second day, we asked how science affected society in an effort to get the students to think about how what they do affects people outside their lab. Initially most of them wrote lists of technologies with no real social context; although a few offered criticism of science and technology, noting, for instance, that vaccination and scientific improvements in global health can contribute to overpopulation and antibiotics lead to resistant bacteria. We found that while our goal was not to stick to a specific pedagogic structure, we did have to do a combination of guiding and instruction. When they posed one-dimensional benefits (or problems) we pushed them to explain the linkages and how scientists may (or may not) have contributed to such societal change. In a very short period of time they came a long way. Their comments became much more sophisticated and it became evident that they had begun to see a much broader effect of science on society than they perhaps had thought of before.

We were quite proud of ourselves for a few minutes. This was exactly the type of conversation

[3] In an effort to keep the conversations at a personal level we did not tape record them. The quotations included in this paper are close approximations from our written notes.

that we had hoped to spur. Then it changed. All of a sudden a few of them started to be much more reserved in what they were saying. From their comments it was clear that after some discussion they began to make the link between what we were abstractly talking about and their own daily life and responsibilities. And they got scared. They had sort of looked outside their routine, enjoyed the view for a bit, and then realized it was kind of scary to go out there. The most vocal response by the end of the session was that scientists shouldn't be given too much responsibility and that the public asks too much of them.

We met with the PI on a regular basis throughout the project to get his feedback on what we were doing. After the first couple meetings he noted that he was learning things that he did not expect. He was most surprised that the answers given by his lab members were so varied. He thought that the motivations and beliefs of his students would all be reasonably similar. Yet the discussions brought out some of the stark differences in people's approaches. While they never got too contentious, after some of the discussions lab members pulled us aside to make sure we knew that their colleagues didn't speak for them, thereby distancing themselves from some of the ideas that had been presented. Even though he worked with them on a regular basis, the PI was surprised to learn about the diversity of opinions represented in his lab.

This diversity created a conversation very conducive to learning. Like the PI, most of the lab members assumed that their colleagues thought about things in the same way. When confronted by different ideas being presented by people they knew and trusted—and that they knew were good scientists—they couldn't simply dismiss them as the uninformed musings of a visiting ethicist. They were forced to confront these new ideas because they had to work with the people who held them.

In our third meeting we asked them—in very general terms—how society affects science. We wanted the question to be an opportunity for the lab members to explain more fully the concerns they developed in the previous session so we prefaced the question by saying that the public does take on some responsibility for science and this impacts the scientists. But we wanted to know how it does so. We prepped them with some possible answers. This led, as we had hoped, to the lab members being much broader in their responses. They raised a number of issues including where to draw the line between science and society, questions concerning intellectual property, how public opinion can impact what scientists are able to study, and how popular concerns can shape public funding, In addition to these broad questions, they also delved into the issues that they faced more directly. They discussed security concerns of the lab, safety regulations, concern about the public's response to animal research, and finally the need to show benefits of research with in a few years. There were some difficulties in this session because the students did not have the background to know how science funding, politics, regulation, and public participation work. While we were hesitant to do too much direct instruction, delving into these issues in future interactions will probably require that some basic information is made available to them.

On the fourth day we explored the question of how scientists can more effectively communicate with the public. The lab members responded with general comments like practicing discussing their work with friends and family, writing publications written for a more general audience, and how science is presented by the media. And we discussed how to prepare an answer to the question "what do you do?" ahead of time by writing it out and presenting it in a way that is both understandable and not "dumbed down."

But perhaps the most interesting part of the conversation had nothing to do with us. The students began to debate amongst themselves whether the relationship between scientists and the public had changed over time. To resolve their dispute they turned to their PI for answers. He was able to draw on his many years of experience and explain to the students how much more important it is to know how to engage with the public today than it was in the past. It was an important point in our discussions. The PI took the opportunity to reinforce the idea that this project was not simply an exercise, it was a way to develop their own professionalism.

While the sessions focused on discussions worked well, we wanted to get the students engaged in producing something of their own as well. We wanted to make sure they had a chance to do some background research, organize their ideas more fully, and make a public presentation. To connect their daily work with the ethical and political issues we had been discussing we conducted a mock city council hearing. The scenario we set up was that the city of Tempe, Arizona was considering adopting a nanoparticle

resolution based on the one adopted by the City of Berkeley, California [27] and the students were to give advice to the city council on whether to adopt it and/or make changes to it. Each of the students picked a topic they wanted to report on and then had 2 weeks to do background research and prepare his or her testimony. This capstone project permitted them to bring to bear in a simulation of an event that frequently serves as the boundary between science and society the ethical and societal concerns about this emerging technology.

Their testimonies during the mock hearing gave clear evidence that they had internalized some of the frames and concepts about values and societal implications of science and seemed somewhat transformed by the exchange of expertise. Their responses were no longer knee jerk reactions, but well thought through explanations of the ethical and political questions raised by the complexities and uncertainties of nanotechnology. They did not explain how different philosophers would interpret the situation (as is common practice in ethics courses), but rather worked to combine their scientific expertise with the political and ethical questions presented to them. They had clearly begun to understand the implications of their work for people and institutions outside their lab.

What was most surprising is that even though many of them seemed to resent laboratory regulations when we first met them, most argued for strict regulation of nanoparticles in the mock hearing. In some ways, they pushed for regulatory measures which were so precautionary, we as ethicists weren't sure we were comfortable with them. We debriefed them by helping them to understand some of the implications that such regulations would have on universities, corporations, and economics in general, while at the same time wondering whether we had underestimated the potential dangers that nanoparticles pose for environmental health and safety. It became obvious that we had only just begun to think about these things, but we had created a group of experts from both science and ethics that could productively work together to explore these issues.

What Is It that the Ethicist Can Learn from the Lab Scientist?

Based on this pilot program and other experiences, we believe that structured discussions among ethics experts, scientists, and engineers can play a very important role in researching the social and ethical issues involved in emerging technologies for at least two key reasons. First, such issues are not always immediately apparent to either scientists or lay observers. Scientists have the best understanding of what is technically possible and what is not, but are often so caught up in the excitement of inquiry, the day-to-day minutia of the lab, and the environment of competition and commercial interests, that they do not take the time to consider the broader ramifications. Ethicists, and others who study the relationship between technology and society, on the other hand, may be concerned about and actively trying to consider issues of justice, safety, privacy, etc., but may have little understanding of what is realistically possible with new technologies.

This divide can be bridged by bringing together representatives from both groups and developing relationships in which these two sets of expertise can come together and inform each other. The discussions give ethicists a window into the latest technological developments and an idea of how researchers are already addressing them. Researchers not only can explain what they are working on, but what they think their next steps will be. The ethicist can also help the scientists see things they might not otherwise have thought about. A well trained ethicist has a great deal of experience thinking about and seeking out ethical issues. In discussions with scientists, he or she can point out issues that would be raised and groups that could be impacted by specific areas of research and development.

This hypothesis was born out by our brief experience in the pilot laboratory program. We gained a better understanding of some of the risks that were envisioned by the scientists we interacted with and they, in turn, became better equipped to think about them themselves. They were better able to understand the ways in which their work could create and/or be used to address significant social issues. Once scientists have a practiced ability to see the potential implications in their work, they are more likely to be able to alert others to potential difficulties in the future. Since the pilot study members of the lab have approached us with additional ethical concerns and we have been able to talk through them to better understand the issues.

Because emerging technologies are at an early stage of development, discussions such as these can help to develop a much better understanding of the specific potential ethical concerns involved than if either group was working on its own. This is not, of course to say that the scientists or ethicists either separately or even together will therefore be able to develop an ability to predict what will happen. The manner in which technology develops and is used is far too complicated [13, 28]. Nevertheless, ethicists starting with a more robust understanding of the technologies through engagement with scientists will facilitate richer theorizing about the possible social and ethical implications of these technologies.

Second, not only can these types of partnerships help to develop a more robust understanding of ethical and social implications, they can also help to raise their visibility for a larger audience. Many ethicists and social scientists working on their own are dismissed by scientists and engineers as irrelevant. Occasionally such researchers are simply dubbed 'Luddites' or naive observers who 'do not understand the science' and therefore whatever concerns they may have are automatically invalid. Ethicists supposedly have nothing to lose by making pronouncements about right or wrong. Scientists who take the time to explore ethical questions, however, might have a lot to lose. After all they could find out that their life's work might be dangerous. Opening up about ethics is far more risky for scientists and therefore the public takes their discussions about ethics more seriously. By working closely with practicing scientists, the research done by ethicists cannot be so easily dismissed. The ethicist can ensure that the ideas, technologies, and futures they think about are plausible possibilities.

The importance of being linked with technical expertise can be clearly seen in the example of Bill Joy's "The Future Doesn't Need Us." The article, published in *Wired Magazine*, has been one of the most widely influential articles in the ethics of emerging technologies in recent years [29]. It generated discussion amongst scientists and engineers around the world about the wisdom of pursuing research into NBIC technologies. This impact was not simply a result of the questions it explored since they had previously been raised by a number of people, but because it was written by Bill Joy, the former head of Sun Microsystems and an engineer of unquestionable expertise. Joy's prominence in the field and obvious interest in technology meant that his questions could not simply be dismissed.[4] While it is not always practical to team up with experts as esteemed as Joy for ethical discussion about technology, working with experts in a particular scientific field can help ensure that the ethicists' work is reviewed for scientific accuracy, a step that goes a long way toward earning the respect of other scientific experts.

While we haven't teamed up with the lab to convince the City of Tempe to create nanoparticle regulations, we did demonstrate in at least a small way the benefits of linking ethics with a senior scientist. The presence and participation of the PI in our conversations made all the difference in how the deliberations proceeded. Without the PI it is very likely that the students would not have taken us seriously. They might have assumed we were anti-technology at best and a possible threat at worst. With his cooperation, however, the students could not so easily dismiss us. If he thought that a discussion about ethics was important enough to risk the dangers that they foresaw, then either their perceptions about the dangers or the benefits must be wrong. The fact that we worked closely with a senior scientist helped ensure that other scientists (and aspiring scientists) took us seriously.

What Standing Do the Ethicists Have in Discussion with the Lab Scientist?

Working on the inside of a laboratory also has a number of pedagogic benefits. The traditional didactic method of teaching is often not an effective way to change a person's practice [31]. If someone who felt they fully understood how to think about emerging technologies pontificated on a lecture circuit about its ethical ramifications, she would have a difficult time leaving a lasting impression on researchers for at least two reasons: First, many of her listeners would likely question her background or expertise. In a one-way conversation it would be very easy to dismiss her as an irrelevant distraction perhaps because she has some misguided agenda or simply "didn't understand the

[4] Joy's interest in ethical issues in science has continued. In 2005 he teamed up with Ray Kurzweil to speak out against *Science* magazine's publication of the 1918 Influenza virus [30].

science." Second, even if researchers deemed her credible and legitimate, merely conveying "new knowledge" to people does not mean they will integrate that knowledge into their actions. Both of these barriers, however, can be broken down if ethicists work closely with researchers in their labs and attempt to understand the work that they are doing.

Talking with (instead of talking to) a scientist can make an enormous difference and is a key step in making discussions in laboratories fruitful. Such conversations make it possible for both groups of people to get to know each other. For instance, chatting about what research is being done and why can make the ethicist appear more like a colleague than an intruder.

We found this worked quite well in our pilot study. The lab members quickly opened up to us when we began by asking general questions rather than pointed and obviously ethical ones. We furthered these efforts by taking the additional step of offering our answers to the questions as well. In some sense we tried to let them know we weren't using them as "lab rats" by asking ourselves the same questions as we were asking of them. We made it clear we were part of the experiment as well.

Engaging researchers in conversations will also make it easier for them to grapple personally with their own work in the context of the broader issues they are inquiring about. Helping them to explore their existing views, values, and ideals, and the ways in which those are or are not consistent with their practices in the lab or the implications of the science they are doing, is much more likely to result in them internalizing those values.

For instance, an ethicist working in a lab has a much greater chance to get scientists to articulate the values that they believe form the basis of their identity, why they are in science, what kind of impact they hope to have, etc., than if he or she spoke to them in a lecture hall. Why? The lecture hall format of ethics discussions is impersonal and easy to dismiss as not relevant to one's own work. By exploring the type of research that they are engaged in and the type that they want to engage in, they can begin to question whether these are congruent with each other. Further explorations can lead to questions about the nature of the institutions within which they are working, the values of those institutions, and how those are or are not consistent with one another. In other words, discussions with researchers can more effectively help them understand that the practice of science and engineering unavoidably includes value choices and that they are responsible for the implications of their work. In some sense this happened most vividly when the lab members realized that not all of their colleagues shared the same views. Many of them felt a need to deal with this incongruence and worked to understand how different views and values could fuel their colleagues' work.

This format can help teach cutting edge scientists and engineers how to reflect on their work and consider the vast number of ways that they will ultimately affect other people [32–34]. A key to making this approach work is to ensure that those participating are reflective and continually examining the ethical bases and implications of their research activities. In the end, those with expertise in the social and ethical aspects of science and engineering will be needed to inject outside ideas into conversations, but precisely how this will work will need to be constantly negotiated. Just as researchers need to be reflect on their practice, ethicists working in labs will need to reflect and adjust to ensure that all voices are being heard. It will be acceptable if the ethicist is seen as a teacher, but only if he or she is seen as a teacher among teachers. The ethicist and researchers must become co-creators in the process of developing new knowledge and insights into the ramifications of emerging technologies. The ethicist has a number of roles in the process; as facilitator of discussions, as teacher of ethical concepts and frameworks, and as student of the possibilities of the emerging technologies.

The process of exploring where scientific and social values come from, what they mean, and how they may be related to decisions about emerging areas of science and engineering—is a key component of the process to get scientists to engage with ethical and social issues as they engage in their technical practice. The benefits of this process can be seen in the previously mentioned work by Rosalyn Berne. In *Nanotalk*, she describes her conversations with nanoscientists and the effect these discussions had on the way they conceptualized ethics in their own practice [35, 36]. Berne demonstrated that when nanoscientists and ethicists sit down to a friendly discussion, they simultaneously learn about the other's field and reflect constructively on their own field. We believe a similar arrangement could be created elsewhere—

where ethics experts learn in concert with graduate student scientists and engineers in essence co-developing a better ethical understanding of emerging technologies. Our pilot study illustrated the effectiveness of the method. These structured discussions can help young scientists understand how to engage in a "conscientious pursuit of nanotechnology"—Berne's argument that scientists and engineers should pay attention to when and how human values are implicated by NSE during its development [37].

Benefits for Society

The long-term goal of any practical ethics project is not simply to educate, but to have a positive impact on society as a whole. This approach can produce such a benefit in two ways. First of all developing a better understanding of the ethical issues early in the development of technologies can give governments, organizations, and the general public time to consider and prepare for them. Rather than deal with problems once they have arisen, early study of the technologies can make it possible to anticipate future challenges and develop strategies for dealing with them on any number of levels.

Second, the educational aspect of this approach can lead to a unique form of intervention that could benefit the broader sphere as well. By placing him or herself inside the laboratory, an ethicist may be able to have a significant effect on how work proceeds there and thus on society as a whole. Historically, the ethical and social dimensions of many scientific ideas were considered after the fact rather than in their development. A number of scholars have recently critiqued this approach and proposed that technology be assessed in real time. Frameworks like "Real-Time Technology Assessment (RTTA)"[38], "Constructive Technology Assessment"[39], and upstream engagement [40] have been developed in order to integrate humanities, social science, and policy research with science and engineering investigations in their earliest phases. One of their goals is to inform technical researchers such that they recognize the ways in which they embed values in innovations and how these innovations can be directed to better promote the public good.

By integrating ethicists into working laboratories, the ideas of assessing technology early in the process can be developed into a new model for the role of ethics in the lab. Ethicists and researchers together can reflect on their practice, be responsive to social concerns, and take responsibility for the social outcomes they actively produce. Ethicists can first help individual scientists and engineers understand the ethical and social implications of their work such that they can deliberate about them and adjust their research according to the values they most hope to promote. By training individuals in this manner, ethicists can help create a new generation of scientists who address the micro-ethical issues within the practice of doing science and the macro-ethical issues of ethically assessing the social outcomes of science [41]. This new model will create scientists and engineers who will address these issues as they are doing the work, and the work itself will be shaped by these value considerations.

These three goals of working in laboratories build upon each other. The ethicists' presence in the lab and interactions with scientists help to develop a better understanding of the ethical issues that may pose challenges in the near future. These discussions in and of themselves are a type of education for those in the laboratory, helping them to recognize the effects of their decisions and the ethics present in their daily work. Ultimately both the knowledge and skills accumulated can inform the practice of the scientists in the labs as well as public decision makers.

Challenges to Overcome

We are not so naive as to think that implementing such projects is easy. They will require a level of inter-disciplinarity that is rarely attained—and often discouraged—in academia. Few universities offer legitimate incentives to promote such cooperation between widely different disciplines. It can be especially difficult for scientists and engineers to be involved because their fields often consider any activities outside of purely technical research to be frivolous distractions.

But there are signs that some of these barriers are lowering. Funding agencies like the National Science Foundation have been stressing that scientists and engineers consider the social and ethical implications of their work.[5] When the U.S. Congress passed the

[5] The NSF has done this most notably through its "Criterion 2"which requires grant applicants to explain what they foresee as the broader impacts of their research.

21st Century Nanotechnology R&D Act to authorize the National Nanotechnology Initiative and large-scale NSE research, it also authorized research into the social and ethical implications of NSE and requested that such research be performed in close conjunction with NSE (P.L. 108–153) [42]. Increasing calls for integrating scientific research, technology, ethics, and studies of their implications are convincing scientists and engineers and their institutions to begin such interdisciplinary work.

Another potential stumbling block will be figuring out how to reconcile projects such as these with the traditional system of engineering ethics education. Our goal is to deliberately avoid the classroom model and many of the approaches used in it. This can create difficulties in things such as assessment. Most systems of education demand that students be evaluated in terms of what they have learned. But using a technique such as a written test immediately conveys the idea that there is a hierarchy of expertise—a situation that we are working hard to avoid. Even if the issue of hierarchy did not exist, testing would most likely not assess the progress toward what we see as the true goals of the project. The objective is not to make sure that students understand certain ethical terms and can apply them in hypothetical case studies. The objective is to change the way individuals behave in their practice—to broaden the scope of their vision, to make sure that they see the values, ethics, and profound implications inherent in their work, and to take responsibility for their impact on the world.

The difficulties in assessing—and justifying the importance of—such a project still remain even if tests and grades are discarded. There are other methods of assessment that involve written projects, even short ones that illustrate to the participants that the process of reflection is working. Nevertheless, the impact of the project—as with any good academic program—may not be clearly visible until many years have passed. It is possible that there could be an immediate impact on the individuals and their labs. For instance, the projects could convince the students in a lab to gather information that they did not traditionally gather. Or they may decide that getting public input into some of their projects might help them to decide which of two approaches might lead to an outcome that will help a broader array of people. But the benefits of having engineers and scientists that are more reflective in their practice may not be evident until they are practicing in the field or perhaps even teaching their own students.

Conclusion

Anthropologists have been studying laboratory work from the inside for years. They have developed close relationships with scientists and engineers and succeeded in not only in helping others to understand the intricacies of "laboratory life," but have also helped these scientists to both reflect on their own practice and understand and appreciate the tools of anthropology. Ethicists could gain similar insights and have an important effect on the daily work of scientists and engineers by venturing into the laboratories as well. They could work with scientists and engineers with the deliberate goal of helping them consider the effects that they have on the outside world.

This approach to develop partnerships between ethicists and scientists and engineers furthers the recognized need to develop effective pedagogy for training graduate students in emerging areas of science and technology in ethics. In areas such as nanoscale science and engineering there is no clear idea yet what the most salient ethical issues are. Engagement in the labs addresses this lack of information with an approach to teaching that makes the student scientist facilitators in the development of the ethics. It rejects the traditional model of ethics training for a model where all participants learn from each others' expertise. Emerging technologies like nanotechnology are too new and complex for ethicists to work in isolation from the creators of the science.

The small test study convinced us that doing ethical investigations in laboratories is both possible and useful. In fact we don't think it went far enough. Lab members informed us that we didn't get to hear the most interesting debates: the discussions that happened in the labs after we left. We believe that a more sustained presence in the lab would lead to even more personal conversations. Yet, even though we were only in the lab for a few hours, we were able to plant seeds for conversations that produced even more reflection.

The PI has also encouraged us to continue similar projects. In fact he thinks that they should be expanded much more broadly throughout the scientific community. He also recognizes the difficulties in producing such

change, but is doing his best to further these efforts. To get more of his colleagues on board he argued in a mass e-mail that:

> All things take time and resources and these activities are no different. We all now think wearing gloves, using benzene in the hood and disposing of it properly is, 'well duh,' but 25 years ago we used benzene on the bench top and rinsed glassware in the sink with it using our bare hands. I think 25 years from now, the integration of larger societal and policy issues directly into the design and implementation of our research will seem equally obvious. His attitude about these meetings and the subject matters illustrated to the students the importance of the issues, made students feel safe to voice their own ethical concerns, and helped us to better understand the unique issues involved in nanotechnology.

Ultimately projects like these will provide lessons not just for researchers, but have a broader impact on the way that ethics education is conducted in emerging areas of science and engineering in general. Ethics education, though required by researchers using human subjects, has not to this point been mandated for researchers in the sciences generally. The lack of good models for ethics education in the sciences has not helped. This approach offers an alternative way to encourage researchers to integrate consideration of values into their work. This method will encourage researchers to explore where scientific and social values come from, what they mean, and how they may be related to decisions about science and technology.

Having researchers reflect on their work and getting them to examine the ethical bases and implications of their research activities will have a significant impact on how science is done and, eventually, on society as a whole. Creating researchers who can discuss their work with other "experts," whether those are ethicists, social scientists, or the public, will result in researchers who are aware of and act upon the ethical and social implications of their work. Many emerging technologies may ultimately impact every facet of our lives, our society, and our environment. Developing new ways to get scientists and engineers to recognize this and integrate these concerns into their practice will help ensure that we build a better future. Emerging technologies present a great number of challenges. But cooperation between ethicists, social scientists, engineers, and natural scientists could go a long way toward addressing these issues.

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