Codifying the Ethics of Nanotechnology
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Abstract

As nanotechnology involves many people from differing disciplines, having an understanding of the expected norms of practice seems important for cooperation. A code of ethics could provide such a set of norms or "areas of awareness," but nanotechnology may need to form some sort of disciplinary identity. Currently, nanotechnology has been defined largely by what is funded as nanotechnology. Nanotechnologists themselves need to sort out what their practice involves and discuss ethics in their particular context. I hope for this paper to explain the functions of codes of ethics, the aims of nanotechnology as described in available documents and proposals, and the reasons a code of ethics for the field might be useful. Further, I make my own suggestions for what a code of ethics for nanotechnology might entail.

Introduction

The emerging field of nanotechnology is beset with hope and hype. Nanotechnology holds for itself great promise or great disappointment. Visionaries like Eric Drexler have imagined worlds of possibilities open with the manipulation of atoms,[1] while less optimistic minds imagine nanomachines undoing the world.[2] How should we look at this new field of nanotechnology? What are we to believe? This collision of hope and hype is potentially dangerous. One way to promote trust and public acceptance is to take steps to ensure professionals in this field are being careful and mindful of what they are doing, and one step in this direction could be accomplished by the development of a professional code of ethics for those who work in nanotechnology. Codes of ethics signal the seriousness of a group of professionals to think about their impacts and goals.

Nanotechnology is done by a multidisciplinary group of people – professionals in varying fields coming together to investigate the very small. A "nanotechnologist" may be someone who was originally trained as a biologist, a microscopist, an electrical engineer, or any one of a great multitude of professions. Nanotechnology is something different, though, from any of its contributing fields, science and engineering generally. Nanotechnology's aim is distinct from the typical construction of science and engineering, and its professionals have yet to be defined within this specialty.

The emergence of professional organizations and professional codes of ethics are an important part in the development of a discipline or sub-discipline. They help provide a professional identity for a field of study. Nanotechnology, being so diverse and distinct because of its diversity, should be developed to address the aims of the many other disciplines it encompasses, but this coming together of disciplines also serves to make the formation or "professionalization" of this field more difficult and complex. How should this profession develop, and what values should it hold? What is its identity? What is the aim of this new field? In other words, what should its code of ethics be? By working on a code of ethics, nanotechnologists can work to communicate about their aims and boundaries. Such a project could be used to ease tensions in the community and create a coherent community of nanotechnologists. Through this paper, I will provide a non-technical grounding for discussion among nanotechnologists. Whether or not a code of ethics is created, nanotechnologists need to start discussing what the label means and the identity it entails in order to allow for greater communication and understanding.

Terminology

The term 'nanotechnology,' for uses in this paper, encompasses both what might be thought of as nanoscience and what might be seen as nanoengineering. Since both scientists and engineers are receiving grants for nanotechnology, it seems only appropriate to incorporate both foci as being beneath the umbrella term 'nanotechnology.' Nanotechnology is defined in different ways depending on where you look. Often you will see a division made between nanoscience and nanotechnology, but this division seems somewhat artificial because there is a high degree of multidisciplinarity in the field. This collaboration and diversity has been pushed by the agencies grounding the funding for nanotechnology.[3] Furthermore, there are discrepancies when one fails to account for the interdisciplinary work that is labeled as nanotechnology. Noted physicist Richard Feynman is considered one of the fathers of nanotechnology, but he was not an engineer by training; he is credited with coming up with the idea of nano*technology – not* nano*science* - in his 1959 "There's Plenty of Room at the Bottom," a lecture given at Caltech in front of the American Physical Society – a society comprised of physicists.[4] The National Nanotechnology Initiative (NNI) funds the National Science Foundation, but also more focused research groups, such as the Department of Defense and the National Institutes for Health.[5]

The National Nanotechnology Initiative, funded by the United States Government, defines nanotechnology with a three-pronged definition.[6] First, the definition covers scale – nanotechnology involves only "[r]esearch and technology development…. in the length scale of approximately 1-100 nanometer range." Second, something is nanotechnology only if it involves "creating and using structures, devices, and systems that have novel properties and functions because of their small and/or intermediate size." Third, nanotechnology involves the "ability to control or manipulate on the atomic scale." Variations of these basic ideas can be seen in much of the nanotechnology literature[7]. The NNI definition seems to combine understanding of novel nanoscale phenomena with a push for control and manipulation, something engineers have traditionally aimed to do. The NNI even tells us that:

> Nanoscale science, engineering, and technology, collectively referred to as nanotechnology, define research and development (R&D) aimed at understanding and working with – seeing, measuring, and manipulating – matter at the atomic, molecular, and supramolecular levels... Nanotechnology R&D is directed toward

> understanding and creating improved materials, devices, and systems that exploit these fundamentally new properties, phenomena, and functions.[8]

'Nanotechnology' isn't simply nanoengineering, but it isn't just nanoscience either. There is something that transcends the traditional division of the two fields going on. The pure-applied distinction normally considered between science and engineering continues to be destabilized with nanotechnology.

The aim of science is idealized as a search for truth. There are many scientists involved in working on nanotechnology. But, nanotechnology is not about pure scientific aims. According to the National Nanotechnology Initiative – and note that this initiative is not the National Nano*science* Initiative –, nanotechnology is set to create "the Next Industrial Revolution"[9] The NNI wants to "fuel innovation" by "improving fundamental understanding," "focusing on applications," using multidisciplinary collaboration, and encouraging "technology transfer."[10,11] Nanotechnology's aims are about using basic science to work to advance technological endeavor. This close tie between basic scientific work and technological advancement is a new way of characterizing the work of scientists and engineers. The professions become closer by this emphasis, and the previous paradigms of work become molded together.

The aims of nanotechnology set it apart from traditional constructions of science and engineering. John H. Marburger, III, of the Office of Science and Technology Policy wrote to Congress:

> Applications that draw on advances in the multiple disciplines, such as chemistry, physics, biology, and materials, are blurring the distinctions of traditional scientific domains and creating a new culture of interdisciplinary science and engineering.[12]

A new culture is indicative of new aims. Scientists working in the field of nanotechnology are directed toward application and production. Nanotechnology redirects the aims and goals of the contributing fields purposefully; the literature about nanotechnology funding put out by the NNI is clear about this.

The European Union has also been funding nanotechnology. EurActiv, a website dedicated to EU News and Policy explains:

> The technology stretches across the whole spectrum of science, touching medicine, physics, engineering and chemistry, and so is difficult to pin down to one discrete area... Research is expected to lead to advances in areas such as medicine, environment, manufacturing, communications and electronics... Described as 'a new industrial revolution', nanotechnologies have the potential to produce sweeping changes to all aspects of human society. Their use might be particularly beneficial in the areas of environment, communication, health and production.[13]

The United States is not the only country caught up in the excitement of the possibilities for nanotechnology and its great aims. So far, nanotechnology's aims have been encouraged and facilitated by funding, but its aims need to develop within the community of scientists and engineers who do the research. Already histories of the development of nanotechnology have worked to push the aim of nanotechnology, relying on Feynman's famous 1959 speech[14] to help emphasize the drive for application.

Feynman is used in these histories because of his great status as a scientist and because he is a Nobel-prize winning physicist who is well-known and honored. Feynman's speech is interesting and directs science in a new path:

> I would like to describe a field, in which little has been done, but in which an enormous amount can be done in principle. This field is not quite the same as the others in that it will not tell us much of fundamental physics (in the sense of, ``What are the strange particles?") but it is more like solid-state physics in the sense that it might tell us much of great interest about the strange phenomena that occur in complex situations. Furthermore, a point that is most important is that it would have an enormous number of technical applications... What I want to talk about is the problem of manipulating and controlling things on a small scale.[15]

By adding him to the history of nanotechnology, the shift in aim from pure work-to-understand science to technologically-driven work-to-use science is encouraged. Some have even suggested that the histories of nanotechnology serve a mythological function, shaping the aims of the field by employing a story that overlooks certain details to explain nanotechnology's role and supposedly inevitable development.[16]

Despite questions over whether Feynman actually influenced anyone other than Eric Drexler, Feynman has been named in most of the histories of nanotechnology.[17] Because Feynman's speech worked so well in presenting the intended purpose of nanotechnology, it is used. The identity of nanotechnology is aided in its use, but nanotechnologists need to work to further form their field by identifying someone closer to the field to honor. Towards the end of forming a lasting identity, a code of ethics needs to be developed.

Codes of Ethics

Codes of professional ethics are employed for a variety of reasons. Sometimes an incident occurs and professionals feel the need to reassure the public as to their position or to instruct novices in the field on how to behave properly. Codes can signal the solidification of a profession and strengthen the values of a profession. Ethical codes can be used to point to areas of caution or concern. Usually professionals within the field meet together to discuss the values they hold and how they want to express them. These codes also help define a profession so that it can separate itself from others performing the same service and protect against rogues, which is important in protecting against catastrophe.[18] Codes also buttress the ethics of individuals in relation to larger bodies in which they work, like university research centers and industry. By picturing themselves as nanotechnologists with a shared value system, individual nanotechnologists are in a better position to stand up to wrong-doing.

Nanotechnology research often is performed by diverse, multidisciplinary groups. A code of ethics for nanotechnology might be useful as a way to create dialogue about social and ethical implications among the professionals who work in the field. As scientists and engineers are trained and cultured differently within their respective disciplines, a code of ethics might prove useful in creating some common ground between fields. Listing areas of caution for the nanoscale might help researchers keep in mind the ramifications of the work. A code might serve to initiate dialogue within the nanotechnology community about professional responsibility and duty. Further, cementing an identity in this way is preferable to an identity formation in relation to funding sources. If nanotechnology is defined simply in terms of funding, cynicism among practitioners will become commonplace, which might lead to problems with proper practices in nanotechnology. If nanotechnology is about funding, the professional identity of those researching in the field will not act as a deterrent against improper behavior.

Developing a code might be particularly important in nanotechnology research. Catastrophes could occur, [19] and there has been public speculation over possible catastrophes in popular entertainment.[20] Even simply the public perception of a catastrophe (whether or not based in reality) can be a problem. A code can alert those in nanotechnology to the perils that might arise from working at the nanoscale and reassure the public that some thought about consequences and professional responsibility has been put in place. Ideally, a code could breed a sense of community that might promote responsibility – something imperative for those working with the dangerous or unknown.[21] Identity matters because situations will occur, and a community response determines how the situation will be handled. A code for nanotechnology might include values from both engineering codes and scientific codes of ethics, as both fields are working together on this scale. However, since these codes express different values and aims for science and engineering respectively, one cannot simply lift a code from chemistry and slap it on nanotechnology. More thought is needed to articulate a code focused on nanotechnology.

Differences in Codes

The codes of ethics in science and in engineering differ in certain systematic and discernable ways. Engineers tend to have more structure in their codes, and they also express concerns in different arenas than scientists do. Scientists are focused, perhaps rightly, on professional behavior in research, while engineers are bent on safety. Engineers have typically been more oriented towards minimization of public harms, while scientists are not directed to look at the public in such a way.

Many professional organizations for scientists have codes of ethics or codes or conduct for their members. Though having no legal force (except through malpractice law), these codes outline proper behavior in their fields. These codes serve as guidelines for professionals and students and reassurance to the public as to the aim of the profession. If the group that has the code is powerful or widespread, the violation of the codes can be devastating to a career. Codes and ethical norms have force when a community upholds them and regards their violation as awful.

The American Institute of Chemists (AIC) has a Code of Ethics that lays out twelve rules of conduct for Chemists and Chemical Engineers.[22] The AIC basically upholds fairness, honesty, and objectivity, while defining proper professional practice. Though this sounds vague, societies can make decisions based on the code as to interpretation and use. Codes are neither static nor uninterpretable, but they do provide stability and common ground.

The American Physical Society (APS) has no formal code of ethics as such, but they have “Guidelines for Professional Conduct,” which press that physicists are part of a community of physicists who must maintain the profession’s values.[23] These values include the good of the community, honesty, trust, and objectivity. APS also offers a “Statement on Integrity in Science” which explains that the APS has no formal code because it has felt no need because the “physics community has traditionally enjoyed a well-deserved reputation for maintenance of high ethical standards.”[24] This statement lists several types of misconduct that violate professional integrity, such as plagiarism, fabrication of data, submission of a paper to more than one publication, lack of impartiality in reviewing, or even slow response as a referee to delay publication of a manuscript. The APS “Statement on Integrity in Science” lists areas of concern mainly to an academic or research physicist, focusing on data, papers, and publishing – just like the codes we see in other science organizations. The focus of the code, namely who it addresses, is important and will be addressed later.

The American Society of Biochemistry and Molecular Biology (ASBMB) has a code of ethics which they break into three main categories: “Obligations to the Public,” “Obligations to Other Investigators,” and “Obligations to Trainees.”[25] Obligations to the public involve enhancing public interest, using funds properly, and following proper rules and requirements in research. Obligations to other investigators involve doing your experiments and reporting on them fairly and honestly, giving credit where due and keeping confidence when necessary, all the while disclosing possible conflicts of interest. Obligations to trainees involve advancing the trainee’s scientific and ethical research knowledge and recognizing their contributions.

Codes and guidelines published by scientific societies focus on research and academic integrity – concerns that are pertinent to the science community. Engineering codes take a different form. When engineers think of codes, they think of building codes and specifications for design,[26] but no code of ethics could ever be that specific and still be reasonable. The number one thing engineering codes emphasize is public safety. Public safety is probably of prime importance because engineers must be relied on so heavily by the public. Engineers build the structures and machines that people must be able to trust. Engineering codes also emphasize the importance of transparency in ones' work and calculation and the importance of professional development (both for oneself and in helping others). Like scientists, they emphasize fair and accurate reporting of data and disclosing conflicts of interest. Engineering codes also bring up intellectual property concerns.

Many of the current professional engineering codes are modeled after the Accreditation Board for Engineering and Technology's "Code of Ethics," with involves "Fundamental Principles," "Fundamental Canons," and "Suggested Guidelines for use with the Fundamental Canons of Ethics." Interestingly, engineering codes tend to have more structured layers than scientific codes, as you can see in the ABET Code of Ethics and associated documents versus the AIC Code of Ethics. In addition to these principles and canons, the ABET has published "Suggested Guidelines for Use with the Fundamental Canons of Ethics," which explains each Canon in more specific detail. Running for about seven pages, each numbered canon gets several alpha-numerical subpoints added below it – lettering a to o in explaining canon four about conflicts of interest and a to p in explaining canon five on fairness. These engineers are very detailed.

The American Society of Civil Engineers (ASCE) uses the ABET model, adding only environmental concerns to the first fundamental principle,[27] and the American Society of Mechanical Engineers (ASME) has 3 fundamental principles and 8 fundamental canons, though still following the ABET structure.[28] The ASME drops the ABET principle four concerning support for one's professional societies and changes around the canons. The ASME has "Criteria for Interpretation of the Canons," much in the way the ABET has "Suggested Guidelines." The biggest difference in ASME canons is canon number eight, which stresses the consideration of environmental impact.

The American Institute of Chemical Engineers (AIChE) has a code of ethics which every applicant to the group must sign. Though only less than a page long, this code highlights safety, responsibility, truthfulness, avoiding conflicts of interest, fairness, competence, and professional development. The IEEE Code of Ethics for engineers features ten items, upholding values similar to the other engineering societies (though no environmental concerns). However, their most interesting commitment is their number five, which is not explicitly written in any of the other codes. It reads: "to improve the understanding of technology, its appropriate application, and potential consequences." This IEEE point is one that might be very suitable for a nanotechnology code.

The Codes of Ethics for different societies differ as much as the focus of the societies do. Certainly, civil engineers, building outside, have to work around and work with the environment more than an electrical engineer would, so it makes sense that these societies would have differing foci when it comes to such things. The same goes for physicists and molecular biologists, as well as any other subdisciplines in science or engineering. Not all people within a profession know the codes of ethics associated with their discipline, but the values contained within the code are usually known.[29] In speaking with different scientists and engineers, I found that everyone had the basic ideas about what their profession held as valuable in ethics and that they try to impart these values to their students. In further questioning about nanotechnology, one scientist pointed out that nanotechnology and nanoscience are different from chemistry because of the hype factor; she said it is more crucial in nano-studies to stick to the reality of the lab and do more public outreach[30] because there is more public concern due to the hype that nanotechnology has right now.[31] One engineering professor pointed out that codes of ethics are useful, but not in the sense of legislating; they are useful in thinking about possible problems and bringing them out for discussion and consideration.[32] Codes of ethics serve a role in the development of a profession and a professional identity. By identifying the core values associated with practice, nanotechnologists will be able to better identify themselves and their practice within a larger context.

Code for Nanotechnologists

Two summers ago, I worked at a party supply store with a high schooler named Tom. Tom would always ask me questions about nanotechnology and discuss current developments in science; he was very up-to-date on science news. One day, Tom came into work, and he was indignant. He had been to a department store and had seen “nanopants.”[33] When he asked the store clerk about these nanopants, the clerk told him that the pants had miniature robots in them![34] The public understanding of nanotechnology is based largely based on sensational information and speculation from hearing very conflicting reports in the media.

Professionals working with the nanoscale need to be aware of the public’s perception when they make statements. The NBIC report, Drexler’s *Engines of Creation,* the NNI reports, and other documents that outline plans for the nanoscale have promised much. The NBIC Report, “Converging Technologies for Improving Human Performance,” tries to lay out the possibilities for human improvement with the advancing technologies associated with the convergence of nanotechnology, biotechnology, information technology, and cognitive science.[35] This reports talks about altering the “fabric” of society, initiating a “new renaissance,” and converging technologies being “a turning point in the evolution of human society.”[36] Eric

Drexler's well-written *Engines of Creation* easily moves from replication of DNA to molecular assemblers, tiny molecular machinery that can alter the structure of atoms, creating new and more desirable materials, literally turning trash into treasure.[37] The National Nanotechnology Initiative material is no less eager; at the beginning of one report, we are asked to:

> [i]magine a single area of scientific discovery with the potential to enable a wealth of innovative new technologies across a vast array of fields, including healthcare, information technology, energy production and utilization, homeland security and national defense, biotechnology, food and agriculture, aerospace, manufacturing, and environmental improvement.[38]

This hype for nanotechnology is dangerous in that the public's expectancy for the technology may be too great or only in the short-term. This could hurt the funding of such science and technology, as well as the reputation of such studies.

One of the reasons a code of ethics would be useful for nanotechnology is that it might alert those working on the nanoscale to the hype. Starting a dialogue within a community that includes scientists, engineers, business people, and others would be a good start to reducing the hype factor and educating the public. The hype factor in nanotechnology is only detrimental in the long-run. Nanotechnology is currently very two-faced in that it is on a basic research level, but we are told that it is going to solve all of our problems in the very near future. With nanotechnology, having some common values to agree on and point to may prevent problems and misunderstanding in the future. Researchers into nanotechnology would be best served in having dialogue with one another about values so that there can be some sense of common ethical ground among colleagues.

James Chiles, author of *Inviting Disaster: Lessons From the Edge of Technology*, was interviewed in the magazine *Mechanical Engineering*. In being questioned about the usefulness of codes of ethics in a complex company, he responded that:

> The engineering code of ethics would help people who were at the middle level, those who design and put the pieces together in the organization. If there's a code of ethics in place, those people would feel empowered as engineers to call a halt to a project or to say, "In my professional judgment, this doesn't meet the standards of work."… A code of ethics would read that the project you're working on has to meet certain industrywide standards. So it would allow engineers to say, "I've got to speak up, I've got to say something. I have no choice."….. It's easier to stand up if you're citing a code of ethics.[39]

With this in mind, I invite the International Association of Nanotechnology to deal with these issues and start some real dialogue on how they regard nanotechnology, perhaps including the general public in their discussion as well.

Writing a code of ethics for nanotechnology is both easier and harder than earlier professional codes. Codifying the ethics of nanotechnology will be easier because nanotechnology seems to be emerging from several already professionalized fields. Further, histories of nanotechnology have established nanotechnology's guiding aims from Feynman's "There's Plenty of Room at the Bottom" speech – whether or not researchers of nanotechnology actually knew of the document in the beginning.[40,41] Codifying the ethics of nanotechnology will be harder in the sense that there is still contention about how the field is defined and who is a nanotechnologist. Also, what makes this case more difficult is the debate that surrounds nanotechnology generally. However, there are some things that I think a code for nanotechnology should include. Here I present one possible code of ethics for nanotechnology.

Suggested Code of Ethics for Nanotechnology

My code is meant to spark discussion and thought on values and professionalization. Discussion and debate are healthy and desirable in the development of a code of ethics (and the development of understanding among colleagues). Codes should be carefully considered and amended to properly represent the values of the field. A code means very little if it is simply inherited without reflection on the issues and the values of the field. With that said, I present my code of ethics for nanotechnology, with comments on each section to explain myself.

(Preamble)

We, Nanotechnologists, realize our special position in science, engineering, and society. Nanotechnology's specialness is a result of the hype and attention the field has received, the complexity and scope of the subject matter, and the blurring of the fields of science and engineering. Our aims and position require a broader understanding of ethics and of the repercussions involved in pursuing any phenomena or application. Nanotechnology has a purpose in discovering underlying atomic properties and their manipulation for practical application to benefit the welfare of people. To this end, we are mindful of the impacts of our work, seeking to investigate, to help others understand, and to apply scientific research towards positive application. Our commitment to professional ethics and practice includes:

By starting with a preamble explaining why a code is necessary, nanotechnologists can have a common understanding of why the code is worthwhile.

(Code of Ethics)

1. Holding paramount the welfare of the public

- *a. by accepting responsibility in making decisions consistent with safety, health, and welfare of the public;*
- *b. by informing the proper officials and the public when there are risks to the public;*

The public needs to be recognized at the outset of the code because of all the public worry and hype about the field. By first stating in their code the importance of the welfare of the public, nanotechnologists recognize their responsibility to their fellow citizens of the world.

2. Engaging in public discourse on the subjects we study with public comments made on all matters of nanotechnology being made with care and awareness

a. by recognizing that science and engineering affect society;

b. by explaining without exaggeration;

c. by seeking public reaction and input;

d. by admitting when not all the answers are known;

Public discourse is important for nanotechnologists because of the hype I've discussed. Nanotechnologists need to be aware of how their work might affect society, seeking to understand what the public has to say. Part 2c is especially important. Nanotechnologists need not only to speak about nanotechnology to the public, but to seek out reaction from the public. Nanotechnologists need to be aware of and sensitive to the perceptions and beliefs that are out there concerning nanotechnology.

3. Promoting truth and exposing error, being transparent in calculation, representation and purpose

a. by remaining current on topics in the field on which one speaks;

b. by sharing ideas and information with colleagues and co-workers;

c. by maintaining complete and accurate scientific records;

d. by accurately depicting the phenomena and not intentionally using misleading material;

e. by pursuing honesty;

f. by following proper practices for publishing and presenting research;

g. by giving due credit to contributors and sources;

h. by seeking, accepting, and offering honest criticism;

This principle is a rather large one, but it will speak to scientists about their role in nanotechnology. Because of the funding associated with nanotechnology, it is important for nanotechnologists to remember the values of the professions from which they came. With nanotechnology, scientists and engineers still need to be aware of the responsibilities they still have. Part 3d is especially important here because of the images used in nanotechnology; the public (myself included) cannot tell what is real and what is imagined in these images. Nanotechnologists need to be particularly aware of how they depict the phenomena with which they deal and the plans they have for the future.

4. Improving the understanding of technology, its aims, and its repercussions

a. by imagining the possible outcomes and applications of the research;

b. by looking to the societal implications;

c. by seeking input from all classes of society;

d. by realizing the uncertainties in dealing with complex systems and showing humility in the face of complexity;

This particular principle is taken from the IEEE Code of Ethics. It is unique to that particular code, as far as I can tell, and it is a very good principle for a community that deals with high technology. Part 4b and 4c – and I added the parts – are really important to addressing the hype associated with nanotechnology. Once again, this code points nanotechnologists towards the public – to seek input from all groups of society. 4d has been added in response to the comments I received from one nanotechnologist who expressed, and the words "showing humility in the face of complexity" are hers, not mine.[42]

5. Avoiding conflicts of interest, real or perceived

a. by disclosing any possible conflicts of interest when they exist;

b. by rejecting bribery of any sort;

c. by entering only into agreements and contracts with openness;

This principle we see in some variety in most scientific and engineering codes of ethics. It is important to reemphasize this principle for novices in the field and as a reminder for more seasoned practitioners.

6. Keeping private any confidential information gained in work when the confidentiality is consistent with public interest and the law;

This was taken from the IEEE/ACM Software Engineering Code of Ethics, part 2.05. The idea of this principle is something typically seen in engineering codes of ethics, but scientists also need to be aware of the new responsibilities they might face, especially when working with engineers who may be under confidentiality agreements or entering into confidentiality agreements through the funding they receive.

7. Acting fairly in the treatment of others

a. by not acting in a discriminatory manner;

b. by working to encourage novices and trainees in the field;

c. by treating subordinates with respect;

d. by helping colleagues to develop professionally and supporting them in related matters;

e. by not in engaging unfair competition with others;

f. by seeking diversity in the scientific community.

We see statements of fairness in both scientific and engineering codes of ethics, but part 7f was added – and suggested to me by someone else – due to nanotechnology's hyped status. By seeking diversity in the community of science, concerns that reflect society are more likely to be voiced early in development of the technologies that nanotechnology promises. By adding part 7f, I was thinking specifically of nuclear technology. Nuclear power facilities are seen as very undesirable by those who live right next to them. People would rather live near coal-burning power plants than nuclear ones, despite the fact that coal-burning plants are often much more harmful to the health of the people living around them, because public perception of nuclear technology is so negative. Also, when undesirable technologies are located, they hurt the lowest income brackets. By having input from various backgrounds, nanotechnologists can work to ensure a solid future.

These things we pledge as nanotechnologists, for the welfare of the public, for the advancement of truth and society, and for our professional wellbeing.

The restatement of aims is a nice way to end a code; this is largely an aesthetic consideration on my part.

The primary values that should be emphasized in a code of ethics for nanotechnology are public good, honesty, and transparency, so these are the top things that are discussed in the code. I've looked at many Codes of Ethics in the course of working on this paper, but the three codes I have relied on the most to write my code are the IEEE Code of Ethics, the Chemist's Code, and the ABET Code of Ethics. These codes were looked at for their diversity of style, thought, and wording. The IEEE also had one unique principle that is reflected in my number 4.

Concluding Remarks

In thinking about nanotechnology, the analogous historical situation of science which first comes to mind is the building of the atomic bomb with the Manhattan Project. Science was explicitly directed to application in the case of nucleonics, in a way that we see now in nanotechnology. The development of the atomic bomb involved many players, like nanotechnology, and more than one nation. Because it was supposed to be secretly developed, the atomic bomb would also have great consequences for those who had no say in its development. Physicists who worked on the Manhattan Project have not gone without reflection on the societal concerns raised by their work, but there was no look into the societal implications by those not directly linked to the project. Citizens of the world were given no voice in a decision that had consequences to them. Perhaps it is here that the analogy breaks down because nanotechnology involves many applications and the Manhattan Project involved only one. Further, the bomb was developed for warfare, where only some of nanotechnology's applications are for military use. I think the analogy is still a good one; both sets of projects – Manhattan and nanotechnological – have (or have had) large consequences for the world and its citizens. Discussion about nuclear technology came only after the bombs were dropped, but nanotechnology's discussions can happen now, with nanotechnologists stepping up and confronting the hype the field faces and the reality of the applications their research may have.

I bring up the Manhattan Project not to frighten people, but to help further explain the aims for nanotechnologists. Current rhetoric has aimed scientists differently than they traditionally consider themselves. *Scientists working in nanotechnology are working towards the production of something.* Though perhaps not something as destructive as an atomic bomb, scientist and engineers working with the nanoscale need to be aware of their responsibilities. Engineers already have some sense and acknowledgment of how their work impacts humanity, as reflected in their codes of ethics. Scientists really only have an idea of how their work might affect their direct community. A new code of ethics for nanotechnology is the first step to adjusting to shifts of aim and directing professionals to the new concerns that the new aim brings.

This paper is not written to question the aims or motives of scientists. Most people do not want to cause harm to others. This paper is written to explain an area of concern – namely, the hype and uncertainty that nanotechnology is facing – and address this area of concern by suggesting a way for nanotechnologists to meet this concern. Codes of ethics often help students and younger professionals get an idea of the values that drive the profession. Codes of ethics help people keep in mind and have reference to areas of professional awareness. By introducing, discussing, and writing a code of ethics, nanotechnologists will be able to better address public concern and let younger professionals know where to be mindful.

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