Chapter 7
Nanotechnology's Future: Considerations for the Professional[1]

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7.1 Introduction

At a previous job not too long ago, a former colleague of mine was indignant when he came into work. He had been to a department store and had seen "nanopants."[2] When he asked the store clerk about these nanopants, the clerk told him that the pants had miniature robots in them! (Personal conversation, July 2003) Professionals in nanotechnology might need to clear up some misperceptions about nanotechnology. Nanotechnology holds many hopes, but first the field must face some reality.

Concerns have already been raised about toxicity of nanoparticles and environmental dangers. Products said to be using nanotechnology are already in the consumer market, from sunscreen to stain resistant pants. Nanotechnology could suffer great backlash if any incidents or tragedies occur. Having a strong code of ethics could aid understanding between nanotechnologists[3] and could help save time in response to any contentious situations. By developing a code of ethics, the field would have some group identity in which ethical dilemmas and questions of technology might be framed. Further, nanotechnologists could take the initiative in self-regulation, rather than be forced to meet governmental standards later.

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[1] This paper is excerpted from my Honors Thesis in the Department of Philosophy at the University of South Carolina, which was done under the direction of Ann Johnson and Davis Baird. I owe these two people great thanks for helping me think about things and organize those thoughts. This paper also benefited from conversations with people at meetings of the International Association of Nanotechnology conferences at the University of South Carolina, and discussions with Chris Toumey, Loren Knapp, and Kathryn Vignone.

[2] Nanopants—there are several different brands—have a stain-resistant coating that was engineered on the nanoscale.

[3] I use the word 'nanotechnologist' instead of 'nanoscientist' here because of the way the governmental structures, particularly the US National Nanotechnology Initiative, have emphasized nanotechnology, which they define as including both basic nanoscience and nanoengineering as they define the word nanotechnology. I take the word 'nanotechnologist' to encompass professionals working with a concentration on the nanoscale that come from both science and engineering backgrounds.

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Nanotechnology is currently the topic of research for a multidisciplinary group of people. Because of disciplinary diversity in nanotechnology, there is no one understood set of ethical norms to which these practitioners hold themselves. Scientists and engineers have different understandings of what ethics involves; even science sub-disciplines generate different understandings. To promote public trust and to foster understanding within the community, nanotechnologists need to have a code of ethics from which to work. Codes of ethics are usually an important part of the process of professionalization, but the fact that nanotechnologists come from such diverse backgrounds raises the question of how the field might form a disciplinary identity and create a code of ethics. I do not advocate a strong professional development, but forming some sort of loose coalition of professionals would help this emerging and exciting field.

This intent of this paper is to address the emerging field of nanotechnology and the problems that that are likely to assail it unless it develops a clearer professional identity. Right now, nanotechnologists come from many fields, working with different understandings of phenomena and of proper practice, and any identity of nanotechnology that researchers have comes largely as a result of funding, but there is much more richness in which an identity for nanotechnology could be formed. Nanotechnology can challenge the traditional hierarchy of the sciences and is unique in its aims of control and manipulation of the atomic scale. In order to ease frictions that might occur in attempting professionalization, I will describe the development of two professions and their respective identities with an aim at having some foresight as to the problems that might arise in disciplinary formation for nanotechnology (Section 7.2). After developing a model for forming a disciplinary identity, I will explain the role of codes and the differences of codes of ethics between professions, so as to aid nanotechnology in this development (Section 7.3). Finally, I will further explain the uniqueness of nanotechnology and develop a code of ethics based on its aim (Section 7.4). Though I believe practitioners of nanotechnology should be involved in the process of writing a proper code of ethics, this paper should be of aid to any professionals in embarking on such a project.

7.2 Professions and Development

Professions are not static entities. Subject to pressures and disasters and politics, professions develop and evolve for many reasons. Professions are very much a product of their time and place. The physician's role perhaps illustrates this most clearly. The role of a medical professional has changed radically over time and place—from shaman to limited healer to director of health to an overseer of condition and wellness. Throughout most of the time in Western society, a physician could do little to help someone and would only be called upon in the most dire of circumstances, if at all. Now, we see our personal physicians for any small ailment and even for yearly physicals. We see our physicians whether we are ill or not, something that is very different from previous times. But, the role of physician continues to change.

As medical doctors are becoming more specialized, nurse practitioners—trained in the field of nursing, not medicine—are often taking the place of primary care physicians, seeing patients for common ailments and administering treatment or directing them to specialists as needed. Medicine as a field is changing due to exterior forces, like the pharmaceutical industry and insurance policy, and interior forces, like the greater specialization and the use of medical enhancements.

This section outlines the development of three professions and examines how these professions developed their professional codes of ethics. The professions to be examined are software engineering and nursing. These professions, each from a different area of technical study, encountered different problems in forming their identity. Through looking at these three professions and their development, I will: discuss the barriers and difficulties in professionalizing; frame the development of ethical codes with special consideration of aim; and suggest an ideal model for professionalization. The cases of professionalization are not tidy, linear stories that give us a simple model to follow, but, from reflecting on the difficulties and highlighting certain properties involved in the professionalization of certain fields, the hope is that the process of identity formation can go more smoothly for emerging fields, like nanotechnology.

7.2.1 Software Engineering and Its Development

In 1968, the first software engineering conference took place. This conference was set to discuss the "software crisis," in which the computer industry was beset with trouble in constructing "large and complex software systems" (McClure, 2001) There were two such conferences, sponsored by NATO, to help solve this "software crisis." One met in 1968 in Munich and one in 1969 in Rome;[4] over 50 participants from industry and academia came to discuss the problem. In 1969, *Computer Decisions* published a short opinion piece by Franklin Kuo (1969) entitled, "Let's Make Our Best People into Software Engineers and Not Computer Scientists." His thesis should be apparent by his title: he observes that computer science departments "do not emphasize enough the practical aspects of computer systems design" (Kuo, 1969).

These calls for software engineering and software engineers were serious, yet they went unheeded for over two decades. The Software Engineers Association of Japan was established in 1985, but it would take until 1993 for enough interest to be generated in the United States. In 1993, both the IEEE Computer Society Board of Governors and the Association for Computing Machinery (ACM) endorsed motions to address questions of professionalizing software engineering (IEEE Computer Society, 2004). The IEEE Computer Society and ACM decided to work

[4] McClure, 2001. The Rome conference was on "Software Engineering Techniques."

together on this project, designating three task force areas for investigation: “Body of Knowledge,” “Ethics and Professional Practice,” and “Education” (IEEE Computer Society, 2004). By 1995, the Task Force on Software Engineering Body of Knowledge had started conducting a survey online to find out the educational background and knowledge of people who do software engineering. What they found was a variety of educational levels and experiences in the field (Task Force on Body of SE Knowledge, 1997). Also, there was no general consensus as to the knowledge that novices in the field should have (Task Force on Body of SE Knowledge, 1997). Gary Ford and Norman Gibbs (1996) of the Software Engineering Institute of Carnegie Mellon also reported a lack of uniform experience among software engineers in their technical report on “A Mature Profession of Software Engineering.” Ford and Gibbs reported that there were 13 undergraduate software engineering (SE) programs in the UK and 3 in Australia, though none existed in the United States.[5]

The educational background of those doing tasks of software engineering has varied a great deal. Though many have backgrounds in computer science, math, or computer engineering, some have no formal or college degrees in a related field. Diversity in educational background for those with degrees doing software engineering also varies, with programs in computer science varying as to the amount of exposure to software engineering a student might receive. With such a wide array of formal exposure to software engineering and no bachelor’s program existing on the subject until 1996 in the US, software engineers have had no one body of knowledge or experience. The survey of software engineers done in 1996 by the IEEE/ACM Task Force on Body of Software Engineering Knowledge showed that defining the body of knowledge that software engineers are using is difficult. With most respondents working in SE for ten or more years, one would expect more agreement as to what novices in the field should know. There were only five expected tasks items were agreed upon by over 70% of those surveyed, one of the tasks involving being able to name and describe six common computer peripherals. One other agreed upon task included being able to describe the fundamental data structures of hash table, linked list, tree, graph, stack, and queue—something most high-schoolers taking advanced computer science could answer. Defining the body of knowledge needed to do software engineering was not a simple task for the bodies that were pushing for the formation of a profession of software engineering. This was a challenge to the professionalization that was addressed by Ford and Gibbs in “A Mature Profession of Software Engineering” and by institutions, like Rochester Institute of Technology, that developed the first US bachelor’s programs in the area.

Developing a curriculum and standardizing knowledge helped the profession develop further, but it was a slow process that took years for the profession. Currently, the Accreditation Board for Engineering and Technology accredits

[5] Rochester Institute of Technology was slated to begin offering a bachelor’s program in SE, the first of its kind in the US, when Ford and Gibbs were published.

programs in software engineering, with six now-accredited bachelor's programs in software engineering in the US (ABET, 2004). Of course, six programs out of all the institutions in the US is hardly an impressive figure, but software engineering is on its way.

One aspect of professionalization in which software engineering has become well-developed is its code of ethics. Developed by the joint effort of IEEE and ACM and currently in version 5.2, the *Software Engineering Code of Ethics* has been accepted by groups in Australia and other places as *the* code of ethics for software engineers (Australian Computer Society Media Release, 2004). *The Code* has even been published in eight different languages (Australian Computer Society Media Release, 2004). *The Code* was published for viewing by the IEEE and ACM in version 3.0. After getting some feedback, the *Code* was updated until version 5.2 was approved by both the ACM and the IEEE Computer Society in 1999 (Gotterbarn et al., 1999). Alterations to the *Code* between versions 3.0 and 5.2 include reordering the eight principles listed and adding a shortened version at the front for quick review (Gotterbarn et al., 1999).

My selection of and focus on *Software Engineer's Code of Ethics* is not trivial. Software Engineering suffered from a crisis that could be analogized to the situation of nanotechnology. Software engineers were needed not to theorize about computer science, but to develop and implement good systems. Nanotechnologists are needed not simply to gather information about the nanoscale, but to use the properties therein to manipulate and create. Software engineers had a real challenge in developing their code of ethics because of resistance in the field, but they were able to organize and agree on the values of the profession. Nanotechnologists will also see some apathy among practitioners, but this can be overcome by commitment and willingness to involve the public.

Software engineering has been a tough field to professionalize because it lacks a seminal figure in its professional mythology. Without reference back to a single figure or plan that embodies the aims of the profession, a disciplinary identity will not easily be established. Nanotechnology already has some possible founding figures, but the stories around these figures and their relation to nanotechnology are contested.[6]

7.2.2 Professional Nursing and Its Development

Professional aims and mythological characters can play a strong role in the life of a profession. The profession of nursing is often traced back to Florence Nightingale. Though nursing existed before Florence Nightingale with nuns and untrained caretakers of the ill, her figure transformed nursing by taking an active role in patient care, a different role than that of the medical doctor or mere assistant to the

[6] I have worked on this problem in an unpublished paper, and Christopher Toumey of USC has written several papers on the trouble with Feynman as a founding figure in nanotechnology.

doctor. Nightingale's insistence that nursing is not a position subservient to the physician continues to be emphasized in nursing literature and frames discussions of nursing professionalism today. In *Prologue to Professionalism*, Louise Fitzpatrick (1983) writes:

> While the medical profession was busily placing the nursing role in a passive and subservient position, Florence Nightingale was carving a unique independent role for nursing. Miss Nightingale believed that "No man, not even a doctor, ever gave any other definition of what a nurse should be than this – devoted and obedient. This definition would do just as well for a porter. It might even do for a horse. It will not do for a nurse."

No nursing text is complete without reference to Nightingale as the founder of modern nursing. This consistent character of nursing has helped to shape the ethic and the identity of nursing.

She continues to provide guidance for the professional identity of nursing. In "Florence Nightingale: Yesterday, today, and tomorrow," nurses Karen Dennis and Patricia Prescott (1985) report that, in a study of nursing practice, nurses "addressed the same areas Nightingale had deemed to be important. Some of the particulars have changed because of the changing times, but the central themes remain." In researching this portion of this paper, I found a section of the library's nursing section practically devoted to Nightingale. Nursing has perhaps the most strongly defined character that has helped anchor and define the profession. Scholarship on Nightingale's works, life, and teaching continue to be pursued because of her prominence in creating the understanding of nursing that endures from her legacy (Dossey et al., 2005; Vicinus and Nergaard, 1990; Bullough et al. 1990).

There is one other prominent feature of the professional identity of nursing that I would like to highlight, namely the ethics of nursing and its development. Physicians have traditionally framed their professional ethic in terms of respect for autonomy, nonmaleficence (not harming others), beneficence (benefiting others), and justice (Beauchamp and Childress, 1994). This "principlism," as it has been called, seems very masculine in its emphasis on principles of action and is certainly a justice-oriented account of ethics. The profession of nursing has framed their ethic in a different way from this principlism, taking an approach more closely related to feminist and narrative accounts of ethics. Feminist accounts of ethics critique traditional accounts of ethics for approaching individuals outside of their proper context; we are not simply agents acting on principles. Feminist ethics focuses on shifting our focus from acting on principles to acting upon care, compassion, and within a context. Narrative approaches to ethics bring further focus to the context in which we experience dilemmas and are faced with ethical decision making. These approaches seem to cohere better with the way nurses see their role in patient care.

Originally, the ANA *Code for Nurses* put the purpose of nursing into the terms of principlism, but nursing was also influenced by the work of Lawrence Kohlberg and Carol Gilligan, and so, when nursing was being taught in classes, nursing was constructed in terms of applying patient care (Fry, 2004). Sara Fry of Boston College's School of Nursing even suggests that the theoretical frameworks taken from medicine actually hurt the development of nursing ethics. Nursing, with its necessary emphasis on daily care of patients, makes more sense within a framework of care-based (or feminist) ethics. Generally nurses are thought of as dealing with patients and responding to their needs better than doctors.[7] Writing on Nightingale points out that in her era and in our era, "the patient is the focal point of nursing care" (Dennis and Prescott,1985). Nurses are supposed to be responsive to their patients, working to provide the proper environment and care for each individual patient. The theoretical model of physicians simply fails to work for the professional situation of nurses. Interestingly, Fry, in her writing on nursing ethics, brings up the work of Carol Gilligan, a psychologist known for identifying the moral development of females, and Nel Noddings, a prominent feminist ethicist, in talking about developing a care-based ethic for nursing, explicitly challenging "theories [that] espouse a masculine approach to moral decision making and ethical analysis" (Fry, 1989).

Nursing developed its codes of ethics during the 1950s[8] and modeled them after the then-current ethical codes of physicians (Fry, 2004). Fry points out that these theoretical frameworks actually inhibited the development of nursing, but more recent contributions in the field have set out to enrich the nurses' view of professional ethics. The theories of medicine kept nurses from seeing their practice as independent and vitally important to healthcare. Nursing has become more attuned to the developments associated with care-based approaches to ethics in philosophy, and Fry has been among those working to bring these approaches into nursing ethics to more properly describe nursing practice. The ethics used for physicians are not those employed in everyday nursing practice. Fry (1989) argues that "what is appropriate to the practice of medicine or is argued as the moral foundation for the physician/patient relationship is not necessarily the case for the practice of nursing or the nurse/patient relationship." Fry and others have argued that caring provides a better foundation for professional nursing practice, that this is the ethical approach that actually reflects the practitioners' approach. They point to the contextual differences between medical practice and nursing practice and the misfit of biomedical approaches in their application to nurses.

The very prominent founding figure of professional identity and the discussion of ethics in nursing both demonstrate how this field has matured. Even its discussion of ethics invoked the name of Nightingale to aid in sorting out their aims of the practice. By separating themselves from medicine and by the use of this strong character, nursing has developed into a strong profession with a strong professional identity. Nanotechnology may encounter problems if it tries to simply adopt the ethics suggested by bioethicists to deal with bioengineering[9] or by environmental ethicists to aid the engineering professions. Nanotechnologists need to be wary of the simple borrowing of principles.

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[7] Though this may be disputed—there are certainly good doctors who do pay attention to patients—physicians are taught about body parts and disease patterns, not about patient care. There are many examples of how the medical profession desensitizes physicians to people.

[8] The International Council of Nurses developed its *Code of Ethics for Nurses* in 1953, revised in 1965, rewrote in 1973, and reaffirmed in 2000. The American Nursing Association developed its *Code for Nurses* in 1950 and revised in 1985 and revised in 2001 with interpretive statements.

[9] Matte Ebbeson suggested this very thing at USC's NanoEthics Conference, 4 March 2005.

7.2.3 Thoughts on Professional Identity

A strong professional identity relies on a conscious movement to develop a field, anchoring the field to a character and shaping practice through a set of values and goals. A common aim, often mythologized through a founding figure, is central to solid professional development, but will this bear out in nanotechnology? Professions are borne out of certain times and places, reacting to pressures and developments in their day. Software engineering needed (and might still need) to standardize the knowledge of the field. Nursing had to define itself as independent from the practice of the physician to succeed as a profession. What will happen to the emerging field of nanotechnology? What problems might this field face?

Currently, funding sources seem to define what nanotechnology is (and who researches it), but this type of forced identity will only lead to cynicism on the part of researchers.[10] Nanotechnology does seem to have a special aim with particular social ends and implications. It is a field that should form a distinct identity, one that is not so much separate from other sciences as it is a fusion of the ways of knowing, thinking, doing, and designing used in related branches of science and engineering. There is a great opportunity to develop these exciting ways of studying the nanoscale, and the time for a conscious shaping of the field on the part of nanotechnologists is now.

7.2.4 The Problem of the Founding Figure of Nanotechnology

Nanotechnology has two founding figures that are used in standard histories of nanotechnology, namely Richard Feynman and Eric Drexler (Baird and Shew, unpublished manuscript). Neither of these figures is actually very healthy for the development of the field. Feynman would be a really great character with his charisma and great academic credentials, but his contributions to nanotechnology are only in hindsight, and few researchers in the early days of nanotechnology had ever heard of his now famous 1959 speech to the American Physical Society by the title, "There's Plenty of Room at the Bottom" (Toumey, 2005). Eric Drexler lacks the charisma of Feynman, and, though he might be credited with popularizing nanotechnology and with introducing the ideas that shape the aim of nanotechnology, many researchers in the field have tried to distance themselves from Drexler because his popularization of nanotechnology created unrealistic expectations (Toumey, 2005). The figure not as often mentioned in the general histories of nanotechnology that Christopher Toumey suggests might make the best founding figure is Gerd Binnig, co-inventor of the Scanning Tunneling Microscope (1981) and the Atomic Force Microscope (1986), instruments that strengthened the reference

[10] Ann Johnson, personal conversation, 9 February 2005.

to Feynman speech (Baird and Shew, 2004). This move might be useful to help nanotechnology form a stronger and more narrative identity. Since nanotechnologists rely on instruments to get them to their area of study, the inventor of a few of the field's instruments would not be a poor founding figure. In addition to considering the narrative identity of the field, nanotechnologists would be smart to start discussing the shared values of the practitioners.

7.2.5 The Problem of an Ethical Code

Due to nanotechnology's interdisciplinarity, developing a code of ethics to express the aims and values of the field may cause friction. Because of the different ways of understanding ethics in science and engineering, a code of ethics for nanotechnology would allow for a greater coherence of approach in the field. Though one may argue that a profession cannot be formed around nanotechnology in the same way a profession could be developed a century ago because disciplinary boundaries are already in place, a code of ethics can work to inform a heterogeneous research group about the values they corporately hold. In the same way the IEEE Computer Society and the ACM set up an explorative committee to look into developing software engineering into a field of its own, the American Chemical Society and the International Association of Nanotechnology[11] and other nanotech-oriented groups have an opportunity to start exploring the identity of nanotechnology to prevent cynicism and to promote professionalism among researchers. There are many benefits to developing a code of ethics that could help nanotechnology develop its professional identity. By fostering communication among practitioners, a code of ethics project might work to help this mixed group work together toward an objective. How will these professionals work together, given their different backgrounds? By looking at the values some of the contributing professions hold, perhaps we can see how these different professionals might from an appropriate code of ethics for nanotechnology.

7.3 Codes of Ethics

Codes of professional ethics are employed for many 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

[11] Information about this association of those interested in nanotechnology can be found at http://www.ianano.org.

can be used to point to areas of caution or concern. Usually, in making a code, 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.[12] 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 wrongdoing.

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 (Hirshler, 2004; Amato, 2004; Weiss, 2004), and there has been public speculation over possible catastrophes in popular entertainment.[13] 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. 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.

[12] This "protection against rogues" can have an exclusionary effect, which can be negative for some groups.

[13] Michael Crichton's *Prey* and the 1995 movie *Virtuosity* (among others).

7.3.1 Codes of Ethics between Professions

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.

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,[14] 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*, which 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 if you compare the ABET *Code of Ethics* and associated documents versus the American Institute of Chemists *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.[15] Running for about seven pages, each numbered canon gets several alphanumerical subpoints added below it – lettering 'a' through 'o' in explaining canon four about conflicts of interest and 'a' –through 'p' in explaining canon five on fairness. These engineers are very detailed.

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[14] Sarah Baxter, personal conversation, 24 March 2004.

[15] ABET Code of Ethics.

The American Institute of Chemical Engineers (AIChE) has a code of ethics which every applicant to the group must sign. Though 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."[16] This IEEE point is one that might be very suitable for a nano-studies code.

The codes of ethics for different societies differ as much as the foci 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.[17] 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 nano-studies, 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[18] because there is more public concern due to the hype that nanotechnology has right now.[19] 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.[20] 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.

7.4 Developing a Code of Ethics for Nanotechnology

Codes of ethics signal the seriousness of a group of professionals to think about their impacts and goals. The emergence of professional organizations and professional codes of ethics are an important part in the development of a discipline or

[16] IEEE Code of Ethics.

[17] Interviews with scientists and engineers, March–April 2004.

[18] She pointed to USC's Citizen's School of Nanotechnology as one example of beneficial public outreach.

[19] Cathy Murphy, personal conversation, 18 March 2004.

[20] Sarah Baxter, personal conversation, 24 March 2004.

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?

7.4.1 Aim of Nanotechnology

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 distinction made between 'nanoscience' and 'nanotechnology' on the basis the goals of inquiry versus the making of something, 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.[21] 'Nanotechnology' is not simply nanoengineering, nor is it 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. Therefore, the use of the term 'nanotechnology' shall be regarded as an umbrella term for the investigation on or of the nanoscale, combining the aims of both fields.

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."[22] The NNI wants to "fuel innovation" by "improving fundamental understanding," "focusing on applications," using multidisciplinary collaboration, and encouraging "technology transfer" (National Science and Technology Council, 2003).[23] 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 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:

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[21] National Nanotechnology Initiative. NNI Budget by Agency.

[22] From the home page of their website: www.nano.gov, and from the NNI Supplement to the President's FY 2004 Budget, and from other materials on the NNI.

[23] For a further discussion, see Johnson (2004).

> 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.
>
> (National Science and Technology Council, 2003)

A new culture in nanotechnology is indicative of new aims. Scientists working in the field of nanotechnology are directed toward application and production. Engineers in nanotechnology are perhaps doing work already considered part of its construction, but the research can be more basic and the science less understood. 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 (2005), 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.

The US 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. One way of discussing goals and values is to organize around the creation of a code of ethics.

7.4.2 A Code for Nanotechnology

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 (Roco and Bainbridge, 2002). 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" (Roco and Bainbridge, 2002). 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 (Drexler, 1986). 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.
> (National Science and Technology Council, 2003)

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.

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 mostly consists in research, 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.

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" lecture—whether or not researchers of nanotechnology actually knew of the document in the beginning (Feynman, 1959). 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. However, there are some things that I think a code for nanotechnology should include, despite possible debates in the future.

A code of ethics for nanotechnology needs to include a focus on honesty in the representation of data and results both in the public arena and within the community. Right now, the public is being to believe that nanotechnologists are working to create tiny robots, but this perception may lead to disappointment and disaster for nanotechnology as a field. Nanotechnologists need to know what the professional expectations are for their field, and they can work to have these defined by communicating with each other and the public. In nanotechnology, the public arena and engagement with the public are particularly important because of the newness and the hype of the field of nanotechnology. Scientists usually have to answer to other scientists, but, in this case, it might be beneficial to both the field and the public for a broader and more public dialogue on the nature of the field and on the duties of someone working in nanotechnology.

Before any mention of honesty is proper in the code, nanotechnologists should first address public safety because of the fear factor associated with popular representations of nanotechnology in the media. Because of the aims toward application that we find in all the funding and founding documents of nanotechnology, the public will be receiving the outcomes.

7.4.3 Suggested Code of Ethics for Nanotechnology

Discussion and debate are healthy and desirable in the development of a code of ethics (and the development of an understanding among colleagues). Codes should be carefully considered and amended to properly represent the values of the field. Practitioners in the field of nanotechnology need to be the ones creating the code. A code means very little if it is simply inherited without reflection on the issues and the values of the field. My code is meant to spark discussion and thought on values and professionalization and is not meant for immediate adoption.

(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 and the explicit discarding of the pure/applied distinction between 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; and*
   (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 precision*:
   (a) *By explaining without exaggeration*;
   (b) *By seeking public reaction and input; and*
   (c) *By admitting when not all the answers are known.*

Public discourse is important for nanotechnologists because of the hype I have discussed. (2b) 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*;
   (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 truth and goodness*;
   (f) *By following proper practices for publishing and presenting research*;
   (g) *By giving due credit to contributors and sources; and*
   (h) *By seeking, accepting, and offering honest criticism.*

This principle is a rather broad 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. (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; and*
   (c) *By seeking input from all classes of society.*

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. (4b) and (4c)—and I added the parts—are really important to addressing the hype associated with nanotechnology. Once again, this codes points nanotechnologists toward the public in order to seek input from all groups of society.

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; and*
   (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 proprietary information gained in work when the confidentiality is consistent with public interest and the law.*

This was taken from the Software Engineering *Code of Ethics* Section 2.05. The idea of this principle is something typically seen in engineering codes of ethics, but some 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 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 engaging into unfair competition with others; and*
   (f) *By seeking diversity in the scientific community*.

We see statements of fairness in both scientific and engineering codes of ethics, but (7f) was added—and suggested to me by Ann Johnson—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 (7f), I was thinking specifically of nuclear technology. Nuclear power facilities are seen as very undesirable by its neighbors. 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 an aesthetic consideration.

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 have 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 (4).

7.5 Conclusion

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. 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. Public discussion about nuclear technology came only after the bombs were dropped, though insiders prepared numerous reports on future implications, but nanotechnology's public 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.

Current rhetoric has aimed scientists differently than they traditionally consider themselves. *Scientists working in nanotechnology are working towards the production of something*, and they need an awareness of their position. 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.

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