Ethics in the NanoInformation Age

Rosalyn W. Berne, Phd. [1]

Abstract

Nanotechnology research is rapidly moving towards the development of new information technologies, made possible by drastic reductions in the size of devices from the micro down to the nano scale. As with any such radical new technological development, there are likely to be enormous material and economic benefits to be enjoyed. But also, unanticipated ethics issues to be resolved and crucial societal consequences to be addressed. It is important that engineering students are given opportunities to reflect on such social and ethical implications of the coming nano-information age, and that they are equipped with the intellectual tools with which to process the meaning and significance of these implications. This paper presents an analytical model developed by H.T. Tavani as one particularly useful tool for helping students to process ethics issues in information technology. It points out that while very useful, most analytical models were not designed for extrapolating into the technological future. The paper suggests that as a supplement to a model such as Tavani's, the pedagogical use of science fiction is a very effective way to deeply engage the engineering student in the imaginative process which is necessary for thinking about the nano-information future.

The Coming Age of Nanoscale Information

The information age as we usually think of it, networked computers, the Internet, DVD-ROMs, is already behind us. The information era we have now entered is occurring at the nanoscale. In fact, not only do we now treat DNA as a platform for encoding information, but we are also trying to adopt this scale in our new storage devices and computer chips. Though information continues to be exchanged on a worldwide macro-scale, the devices used to transmit and store massive amounts of information are headed towards the nanoscale. For example, in 2002 IBM researchers finished building and operated the world's smallest working computer circuits using an approach in which individual molecules move across an atomic surface like toppling dominoes.

The commercialization of these computing devices would mean a total redefinition of information processing, and with it, the increasingly ubiquitous nature of information. This may spark some ethical concerns, signified by the problems inherent in our ability to have information circulate invisibly around us, inside us, or virtually anywhere we might imagine. But changing the nature of storage, processing and retrieval of information is once again changing the nature of human communication, as well as our relationship to information itself.

In order for engineering students, researchers, policy makers, funding agencies and others to be wise about the potential ethical and inevitable societal challenges to come as a result of this current evolution in the information age, they will need to have an understanding of the meaning and significance of nanotechnology's rapid emergence into redesigned, new forms of information. And, they will need a tool for ethical understanding. This paper contends that pedagogical tools are essential for preparing students for thinking critically about the social and ethical implications of the coming nano-information era. An analytical model developed by H.T. Tavani is an excellent example of a good teaching tool for helping students to process ethics issues in information technology. However, it was not designed to extrapolate into the nanotechnology future. Supplementing the teaching of this kind

[1] Technology, Culture and Communication, University of Virginia School of Engineering and Applied Sciences, 351 McCormick Road, Charlottesville, VA 22904

of model with study of science fiction resolves the inadequacy, by giving students a tool by which to imaginatively engage the ethical and social implications of the newly emerging information age.

Key Terms and Developmental Phases

To begin, let us be clear about the definitions of key words being used in this paper.

1. CyberTechnology, from Herman Tavani's *Ethics and Technology* [Tavani, 2] refers to a wide range of computing and communications devices, from stand-alone computers to "connected," or networked computing and communications technologies. This includes hand-held devices, personal computers, and mainframe computers. The Internet and Local Area Networks are examples of cyber-technology.

2. Cyber-ethics examines ethical issues that cut across the spectrum of devices and networked communication systems comprising cyber technology, from stand-alone computers to networked systems.

3. Nanoscaled technology is defined as the ability to work at the molecular level, atom by atom, to create large structures with fundamentally new molecular organization. It is concerned with material and systems whose structures and components exhibit novel and significantly improved physical, chemical and biological properties, and that enable the exploitation of novel phenomenon and processes, due to their nanoscale size. The report of the United States National Nanotechnology Initiative states that such new forms of materials and devices "herald a revolutionary age for science and technology, provided we can discover and fully utilize the underlying principles" [(Initiative, 1].

Tavani marks four phases in the development of cybernetics:

Phase I. 1950's–1960's with stand alone machines, where artificial intelligence and database privacy issues emerge.

Phase II. 1970's-1980's with minicomputers and PC's interconnected via privately owned networks. Issues in this phase include those of phase I, but also involve intellectual property, software piracy, and the exchange of records.

Phase III. 1990's to the present, with the Internet and World Wide Web, issues now also concern free speech, anonymity, legal jurisdiction, virtual communities, etc.

Phase IV. Present to near future with the convergence of information and communication technologies with nanotechnology research and genetic and genomic research. Issues now include concerns over artificial electronic agents with decision-making capabilities, biochip implants, nanocomputing research, genomic research, etc.

Tavani Method of Cyber Ethics

Tavani offers his method of cyber-ethics as a comprehensive one, which can be employed to adequately guide analysis of cyber ethics issues through each of its developmental its phases. That method has three steps. The first is to identify any practice involving cyber technology or a feature of that technology that is controversial from a moral perspective. Hidden features or issues that have moral implications are disclosed and assessed for their sociological implications, in light of relevant social institutional or socio-demographic groups. If there are ethical, normative issues that are professional in nature, they are accessed in terms of existing codes of ethics for relevant professional associations. Step two: if after identifying the professional issues there remain any other ethical issues, one would analyze those by clarifying concepts and situating them in the relevant context. Any conceptual muddles involving policy are addressed, and then the analysis moves on to Step 3. In step three, one or more ethical theories is applied to the situation, reaching a position, and then that position by evaluating it against logical /critical thinking.

I offer the following example of using the Tavani model. A young engineer signs on with a firm that has a clear policy about the distribution of span email. One day his friend sends him a sexually illicit video clip which he finds very funny. Momentarily forgetting about company policy, the young engineer sends it on to a few of his friends in and outside of the company. Using the Tavani model, we first identify any professional ethics issues of concern in this action. In this case, it was against the company policy that the young engineer had willingly signed on to, and therefore his act was professionally unethical. This issue would be relegated to the relevant professional association. Step Two: to identify any remaining issues. There are at least two remaining issues. For one, the clip was funny at the expense of degrading women from whole persons to sexual objects. For another, because of its graphics, it was morally offensive to a number of people who received the email as it was passed on exponentially by the friends and acquaintances of people receiving it. Step Three: These two issues are analyzed using ethical theory. A position on the case is reached as a result of that analysis and is justified in light of the theory used. In this case, the principle of respect for persons applied to justify the engineer's culpability in the case. The case is about the unintended consequences of information technology (a new concern) as much as it is about human behavior (an ancient concern). The technology itself invites certain kinds of behavior that are otherwise not possible. The action of sending an email is not in itself a problem. The problem comes with the content, but even more so, with the technology which makes possible the rapid and expansive flow of information.

The Coming Age of NanoInformation Technology

Nanosystems hold the promise of immense performance possibilities over earlier technologies, because of their reduced size and energy requirements, and especially because of their ubiquity. Nanocomputers may render current encryption schemes obsolete, and be capable of supporting networks storing massive information about individuals and monitoring their whereabouts and condition in real time. Ralph Merkle envisions nano-computers as having "mass storage devices that can store more that 100 billion bytes in a volume the size of a sugar cube." And, that these computers will be able to function a billion times faster than today's desktop computers. Clearly there are beneficial applications of such systems, but also concerns about privacy and erroneous or malevolent actions by the proprietors of these systems, whether corporate, government, or individual. What are the responsibilities of practitioners to assure that systems are used for the good of the people, not the bad? What new safeguards to protect personal autonomy might be needed?

Combinations of electrical, biological, and mechanical nanoscale technologies will yield new devices and require different professionals to work together. What ethical principles will guide these diverse groups? What will they learn from each other about the ethical questions of other disciplines? What new ethical issues will result from these interactions? What concerns arise with electrically- or mechanically-aided or monitored body parts and, conversely, biologically enhanced computing and mechanical devices?

Malevolent or accidental creation of nanoscale devices that cause either intentional or random harm may be a special concern of nanotechnology because, as pointed out by Joy, there is the possibility that such nanodevices/nano-organisms could be made in small laboratories without massive investment or large government or corporate involvement. How real is the possibility that unforeseen organisms could be created and "escape" into the population with bad results? Can self-replicating devices; fueled by readily available matter, multiply with dire consequences? Are there particular ethical guidelines that would minimize the likelihood of such accidental occurrence, or collective standards and safeguards to reduce the potential for misuse?

Advanced technology within the semiconductor industry is already happening at the nanoscale. Ratner and Ratner write that advanced prototype models that reduce circuit size substantially are now available. Nano-electronics and computer technology are aiming for improvements in miniaturization, speed and power reduction in information processing devices. The Semiconductor Industry Association roadmap projects that by approximately 2016 there will be critical feature sizes as small as 9 nanometers, well into the realm of fully nanostructured devices. According to MIT computing scientist Ray Kurzweil, the development of molecular computers that use DNA as the basis for quantum computing would mean computers that are able to compete with and surpass the full range of human capabilities. And that point is only a few decades away.

How can we possibly access the ethical issues, or the cyber ethical issues of devices we are fully unable to see or even detect with unaided human senses? How might we think about and prepare for ethics concerns, which may

emerge with nanoscaled cyber technology? I suggest that Tavani's system would work very nicely in the classroom for teaching about ethics and an existing cyber-technology. However, as we move into the Tavani's fourth phase of cyber-technological development, particularly into the age of nanoscaled information systems, the Tavani model doesn't work as well. How do we help students to think critically about the moral issues associated with technologies which do not yet exist? The only way is through engaging the imagination.

Imagination in Phase Four Ethics Assessments

Should we even bother with teaching students to analyze technology ethics issues which may be ten to twelve years in advance of their actual development? Joseph Wezenbaum argues that computer science research should not even be done if it may have unforeseeable side effects. Unfortunately, the precautionary principal he calls for is no longer possible in the National Nanotechnology Initiative. The proverbial horse is out of the gate and running fast. At this point, we have no choice but to find ways of seeing, understanding, and preparing for a technological development that is already underway. Now is the time to teach students how to think about the future information age, because they are still in a position to make choices about how we might use and develop the technologies, which have yet to emerge in the marketplace.

The assessment model Tavani proposes helps with cases of information technology which have already made their presence felt. To teach ethics issues about technologies of phase four, the information age of nanoscalded devices and converging technologies, I suggest that Tavani's model be augmented with an additional element of analysis; active engagement of the imaginative process.

Freeman Dyson said that there are only two ways to predict the progress of technology: economic forecasting and science fiction. The problem he saw with economic forecasting is that it is good for only ten years forward. Science fiction he found to be a more useful guide, but only because it doesn't pretend to predict. It only tells us what might happen. Dyson concluded that both miss the mark—economic forecasting misses the most important developments of the future because it has too short a range and fiction because it has too little imagination! But science fiction does employ some imagination, enough, at least, to be a creative source of reflection. Science fiction as pedagogy helps students to assess issues of futuristic technologies; their consequences and effects on the social, spiritual, practical and moral elements of our lives. Tavani's model includes disclosure of any hidden or opaque features or issues that have moral implications. Futuristic cyber-technologies that might emerge through nanoscaled research are opaque by nature, because of the inaccessible dimensions of distant time and of nanoscaled space. The imaginative process gives us one possible access to those dimensions. More importantly, the imaginative process provides a reminder to the student of engineering or of technology ethics, that we humans are the creators of our technologies, and therefore, totally capable of directing and controlling our destinies with them. Lacking awareness of this fact is perhaps the most robust inhibitor of ethical reflection and assessment about phase four information technologies.

Fictional accounts of nanoscaled technology such as Neil Stephenson's, *The Diamond Age*; Michael Crichton's, *Prey;* short stories by Greg Bear, Kathleen Ann Goonan, Greg Egan, and Steven Baxter; and films such as *Minority Report* and *The Matrix*, can be used in the classroom to help engage the process of moral reflection about the future. Such engagement is only possible when students thinking moves out, into the untamed world of the imagination. For example, in Stephenson' *The Diamond Age*, books are obsolete, and information is transmitted only through nano-electronics. Someone uses a nanoscaled device to create a technology called a "Primer". This device is read, like a book, but which responds in real time to the fantasies and desires, fears and imaginings of it reader. The primer writes the story as the reader proceeds to read it, by responding to the queries the reader poses to it. Nell, the child protagonist in *The Diamond Age*, is particularly vulnerable to the book's responsive writing as it senses her physical poverty and her emotional needs. In due time, the book begins to "know" her better than she knows herself, and becomes her companion, confident and ultimately, her savior in the face of real threats to her life.

I offer the following excerpt from the *Diamond Age* as an example of material that can stimulate imaginative consideration of highly futuristic information technology ethics, in the engineering classroom:

> "Open it," he said.

"How?"

"Harv leaned toward her, caught the upper-right corner under his finger, and flipped it. The whole lid of the thing bent upward around a hinge on the left side, pulling a flutter of cream-colored leaves after it. Underneath the cover was a piece of paper with a picture on it and some more letters. One the first page of the book was a picture of little girl sitting on a bench. Above the bench was a thing like a ladder, except that it was horizontal, supported at each end by posts Thick vines twisted up the posts and gripped the ladder, where they burst into huge flowers. The girl had her back to Nell; she was looking down a grassy slope sprinkled with little flowers toward a blue pond. On the other side of the pond rose mountains like the ones they supposedly had in the middle of New Chusan, where the fanciest Vicky's of all had their aestival houses. The girl had a book open on her lap.

The facing page had a little picture in the upper left, consisting of more vines and flowers wrapped around a giant egg-shaped letter. But the rest of the page was nothing but tiny black letters without decoration. Nell turned it and found two more pages of letters, though a couple of them were big ones with pictures drawn around them. She turned another page and found another picture. In this one, the little girl has set aside her book and was talking to a big black bird that had apparently gotten its foot tangled up in the vines overheard. She flipped another page. The pages she'd already turned were under her left thumb. They were trying to work their way lose, as if they were alive. She had to press down harder and harder to keep them there. Finally, they bulged up in the middle and slid out from underneath her thumb and flop-flop-flop returned to the beginning of the story.

'Once upon a time,' said a woman's voice, 'There was a little girl named Elizabeth who liked to sit in the bower in her grandfather's garden and read story books." The voice was soft, meant just for her, with an expensive Victorian accent..." [5]

Here we have a wonderfully rich presentation of a technological device, which has completely altered our human relationships with books. What does it mean to read a Primer? What does it mean for the acquisition of knowledge, for the sense of story, for the sense of self? What does it mean for the nature of the human imagination? What goods have come from the Primer? What have we given up in exchange for the immobile, printed text, which was a primary source of knowing for thousands of years? Why, in the Diamond Age, was the Primer illegal, and considered by some to be a threat to the established social structure? What happened to books? Is this a future we might judge to be a utopia? Why? How might we imagine tracing the history of technological change and development from obsolescence of the book to elicit creation of the Primer?

Conclusion

When given opportunities through science fiction, to move beyond ideas of present material reality, into the domains of the imagined future, engineering students can work with ethics questions of future nano-information technology in creative and active ways. From their engagement with science fiction, they can move back to real time and the actual development of nanoscaled devices, to ask where it is we wish to go with these technologies, and how we wish to use them. Most importantly, the imaginative process can better equip them to engage reflection over such issues such as what we take to be our most cherished values and beliefs, and how those values and beliefs might be impacted by the technologies we are creating. By bringing this imaginative process of reflection into the engineering classroom, we to help students reflect more deeply upon the ethics of phase four developments in the emerging nano-information, cybernetic age.

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Rosalyn W. Berne

Rosalyn W. Berne is Assistant Professor of Technology, Culture and Communication in the University of Virginia's School of Engineering and Applied Sciences. Her primary research is focused on nanotechnology ethics. She is also interested in mythical and religious elements of newly developing technologies. She uses narrative interpretation and rhetorical analysis to understand the ethical frameworks of nanoscaled science and technology, strong AI, robotics and quantum computing. Professor Berne received a NSF CAREER award to study ethical issues in the development of nanotechnology. She has recently written the book, Nanotalk: What Scientists and Engineers say about Ethics, Meaning and Belief in the Development of Nanotechnology. She earned B.A. and M.A. degrees in Rhetoric and Communication Studies, and a Ph.D. in Religious Studies (Bio-Ethics) from the University of Virginia. Her previous positions at UVA include Executive Director of the Olsson Center of Applied Ethics and Director of Admissions at Darden, and UVA Assistant Vice President of Administration. She also served as Head of Tandem Friends School.