Nanoethics, It is Not Small in Magnitude

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Abstract

This work in progress presents the implementation of nanoethics learning. The introduction of nanotechnology into an engineering technology program is explained briefly. The ideas of nanotechnology and ethical concerns are introduced in two courses (graduate and undergraduate.) This paper focuses on the on the nanoethics portion of the courses including assignments, readings, and class sessions. A set of questions for nanoethics is presented along with student's responses to these activities. While nanotechnology encompasses work at the scale of less than 100 nanometers, the ethical implications are not small in magnitude.

Introduction

Technological advances have increasingly impacted daily life; this demands close attention to ethical considerations. ABET recently adopted changes to program criteria to include "effective, efficient, sustainable, and socially responsible manner" [1], essentially emphasizing the need for ethical considerations in engineering and technology programs. Rather than being small in scale, the field of nanotechnology may actually amplify ethical concerns by orders of magnitude. The questions of ethics are the same when applied to nanotechnology.

Nanotechnology has the potential to affect (or already has) a vast number of industries including transportation and energy, agricultural processes, monitoring and food supply chains, medical prevention, diagnosis, treatment, and rehabilitation as well as nearly every academic discipline [2]. Equitable access to these technological advances is one aspect of the ethical concerns over nanotechnology. An international aspect became relevant in the realization of Moore's Second Law when the cost to build and maintain a nanotechnology fabrication facility became greater than the gross national budget of most countries [3]. Nanotechnology, with its amazing benefits (and drawbacks), is an opportunity for the riches of countries. A question arises, not IF but HOW will nanotechnology affect developing countries as well.

This paper describes the implementation of ethics centered activities in an undergraduate (ECET-32100) and graduate course (ENGT-57100) focused on nanotechnology at Purdue University. The courses have been taught since 2007 and 2009 respectively providing longitudinal data on student's perspectives and ideas. The application section of these courses and the fact that the graduate course has drawn students from a variety of disciplines has provided a variety of application-specific ethical concerns to be discussed and analyzed.

Nanotechnology in an Engineering Technology Program

Nanotechnology is not a discipline in itself but rather a merging of many disciplines at the atomic scale. Most nanotechnology initiatives came about through Electrical Engineering

programs by the downscaling of electronics from the macro to micro and now nanoscales. However, biologists, chemists, and physicists have been working at these scales for many years. The National Nanotechnology Initiative [4] created in 2000 provided opportunities for research and education of nanotechnology. It was just a matter of time before nanotechnology was to be introduced into Engineering Technology (ET) programs, particularly the Electrical Engineering Technology (EET) programs.

In 2006 the Department of Electrical and Computer Engineering Technology (ECET) focused a faculty search in the signature area of nanotechnology. The goal was to introduce this exciting field into the program including introductory course modules, undergraduate electives, graduate courses, and research projects. This paper reports results from an undergraduate ECET elective and a graduate course. Students participating in the graduate course range in technology majors such as electrical, mechanical, aviation, industrial, and computer graphics. Students form additional colleges at Purdue, including Engineering, Science and Agriculture, have also participated in the graduate course.

The topics of ethics is a continual discussion point throughout the courses. It begins in the introductory lectures with the downscaling of electronics meeting physical and financial limits. The cost of a single micro/nanofabrication facilities was estimated to be over $50 billion US in 2010 [3], severely limiting the number of countries able to participate in this area of technological advances. While the reduction on size, cost, and energy consumption of electronics such as cell phones and computers has made these technologies nearly worldwide, other applications are extremely limited. Water/air filtration, energy generation and personalized medicine have/will see significant impacts of nanotechnology. How many countries or individuals will have access to these life-saving technologies? In contrast, water and air contamination due to development and usage of nanotechnology products will spread throughout the globe regardless of economic conditions. Nanomaterials used in fabrics to resist stains or to enhance cosmetics are washed into the ground water. Alternatively, specialized nanomaterials can be used to collect and reclaim oil spills. The risk/benefit ratio for each country and worldwide is a key metric for ethical considerations. The ethical questions around the development, use, and distribution of these applications are the focus of a complete session of the course near the end of each semester.

Questions of Ethics at the Nanoscale:

The questions of ethics actually remain the same in nanotechnology as any other field. In a 2006 book, Foster [5] poses the questions found in Fig. 1.

⊡ Who is responsible for preventing and dealing with possible harm to health or the **environment**?
⊡ How can **intellectual property** rights be defined and defended when the boundary between nanoscience and nanotechnology is so ambiguous?
⊡ How can the **public's right** to know about technologies that may affect their lives be balanced against and **innovator's right** to protect trade secrets and against the cost of collecting and disseminating correct information?
⊡ What **priority** should be placed on developing new products and techniques that will be highly beneficial for some people, versus defending the interest of individuals and groups that may not benefit from them?

Fig. 1. Ethical questions posed for the application of nanotechnology [5].

Students are asked to consider the questions in relation to their newly developed knowledge in applications of nanotechnology and to develop additional ethical questions which might pertain to nanotechnology. Beginning as an individual effort (ethics assignment 1), students' horizons are broadened by pairing the students to develop common and contrasting ideas and then share with the entire class for another level of perspective. The second ethics assignment allows the students to focus on a country or region of choice for investigating the nanotechnology aspects, opportunities, challenges, and educational resources. This brings about a series of discussions on the impact nanotechnology has on countries with varying levels of access, capabilities, and interests. In preparation for the class session dedicated to ethics, the students are required to read several articles on nanoethics. During this session, the definition of nanoethics is discussed and what it really means at this scale. The nature of ethics in nanotechnology is described and stakeholders are identified. The Foresight Nanotechnology Institute [6] is introduced with their focus areas of interest. Additional resources with nanoethics concerns are also provided.

Students Response

Student response to this course is overall positive and exciting. Particularly undergraduate students' find the course to be interesting and different, certainly of the format but also the ideas and current impact nanotechnology is having on daily life. Undergraduate and graduate student suggest the focus on ethics for nanotechnology has increased their critical thinking towards equitable access for technology in general. Significant concern is expressed for equitable access to nanotechnology application in medicine, clean water, and air. Throughout the semester the students study a specific area of their own interest. During this session, the students tend to rigorously defend the ethical issues associated with their specific areas. For the course instructor, the responses, questions, and ideas are fascinating, leaving one to feel excited for the next generation of ET students to leave their impact on the world.

Discussion

Nanoethics is not ethics at a small scale. The questions are actually the same as any technology advances and are better addressed with the actual impacts of nanotechnology. The great advances due to nanotechnology provides many opportunities and challenges. How these are opportunities and challenges are implemented and/or negated are critical to the equitable access and distributed benefits of nanotechnology. This work in progress will continue through further offering of these

courses. New technological advances and associated incidents will provide additional topics of ethics discussion for many years to come.

References

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Biography

Dr. McNally is an associate professor in the School of Engineering Technology at Purdue University. She is a senior member of the IEEE and the chair for the Central Indiana Section of the Engineering in Medicine and Biology Society. Dr. McNally obtained her PhD in Electrical Engineering from Arizona State University in 1997 as a National Science Foundation Fellow. Dr. McNally's learning activities focuses on courses in nanotechnology and metrology. Her educational scholarship involves bringing these new technologies and concepts into all levels of the curriculum, including K-12.