



Learning About the Societal Impacts of Nanotechnology Through Role Playing

Kurt Winkelmann

Department of Chemistry, Florida Institute of Technology, Melbourne, Florida

A classroom activity introduces students to the ethical issues related to nanotechnology. Students play the roles of business owners, school administrators and local residents as they debate real life issues which include the use of nanotechnology for (1) collecting consumer shopping data, (2) enhancing campus security through increased surveillance and (3) manufacturing nanodevices despite potentially adverse effects on the environment. Each student receives an assigned role for one of the three scenarios and researches the topic. During the debate and in a written assignment, the student provides facts to support the character's viewpoint. Students also reflect on the topics themselves (not as their characters). Each debate lasted about forty-five minutes and included participation from the audience. Student comments taken from the written assignment and a video recording of the debate provide evidence that this assignment successfully encouraged them to critically think about how nanotechnology can affect their lives. The assignment was inspired by the television show, "Nanotechnology: The Power of Small."

Keywords: Ethics, Societal Impacts, Class Activity, Undergraduate.

1. INTRODUCTION

Many nanotechnology educators and researchers worry that practitioners of this field are not fully engaging the public in a discussion of the potential benefits and risks related to nanotechnology (Jacobs et al., 2010; Schuurbiens et al., 2009). In fact, this is a longstanding concern (Roco & Bainbridge, 2001a; Cobb & Macoubrie, 2004; Bhushan, 2004). A lack of communication between scientists and the general public can lead to diminished support for nanotechnology research funding, a lack of interest in nanotechnology among students in STEM fields and unwarranted fear when people learn that, unbeknownst to them, many consumer goods already contain these strange, new nanomaterials.

Educating students in the STEM disciplines about the social implications of nanotechnology can improve this situation in several ways (Barakat & Jiao, 2010). An understanding of ethical issues helps students better appreciate the significance of nanoscientific topics learned in class. Those who become researchers can thoughtfully consider the potential implications of their work as it advances, allowing them to steer the research towards improving society and avoid unintended outcomes. Understanding its impact on society can help students intelligently discuss nanotechnology with the many people in their lives who

are not scientists or engineers, including family members, friends and classmates.

Opportunities for students to understand how nanotechnology will affect their lives are increasingly common thanks to the availability of new curriculum materials. Many universities, including University of Montana, Cornell University, Cal Poly State University (San Luis Obispo), Arizona State University, University of California Santa Barbara and the Illinois Institute of Technology, host centers with missions to study the social dimensions of nanoscience and technology, including public policy and ethics. The academic discipline of nanotechnology ethics is robust enough to support a peer reviewed journal, *NanoEthics*, (Springer) and the field continues to evolve (Ferrari, 2010). These scholars disseminate their work to research scientists, educators and the general public. The most recent solicitation by NSF's Nanotechnology Undergraduate Education (NUE) in Engineering program requests proposals with the goal of improving students' understanding of "the societal, ethical, economic and/or environmental issues relevant to nanotechnology." (National Science Foundation, 2012) Background for case studies and role playing exercises (Roco & Bainbridge, 2001b) and examples of case studies for teaching ethics in science (*On Being a Scientist: A Guide to Responsible Conduct in Research*, 2009) are available.

Case studies provide an interactive means for students to learn about ethical dilemmas encountered by scientists and engineers. Issues such as the lack of regulation of nanomaterials raise ethical concerns that are somewhat unique to the field of nanotechnology and are suitable for case studies (Barakat & Jiao, 2010). In a case study, each student in a group takes on the role of a character involved in the scenario. Characters and events in the case study can be based on actual historical events or fictional. Role playing helps students appreciate the perspectives of others (Schuurbiens et al., 2009). Unlike most scientific and engineering topics they learn, realistic ethical issues do not have clear-cut answers. Participation in role playing activities helps students accept and become comfortable when confronted with such ambiguous situations (Smith, 2005). Well designed case studies can provide a rich experience that students remember and can draw upon in the future when they are faced with their own real ethical challenges (Thiel et al., 2011).

Nanotechnology: The Power of Small (2008) is a video recording of a role playing exercise broadcast on public television in the United States. Journalist John Hockenberry led a panel discussion of nanotechnology with scientists, journalists and policymakers. Panelists include Harvard chemistry professor George Whitesides, Carie Lemack, co-founder of Families of September 11, and Mr. Barry Steinhardt, the former Director of the ACLU Program on Technology and Liberty. Instead of simply asking their opinions of how nanotechnology might affect our lives, Mr. Hockenberry directed several panelists to role play characters involved in a fictional scenario that involves nanotechnology. For instance, siblings decide whether to implant a small computer chip in their father who suffers from Alzheimer's disease. Thanks to nanolithography, the chip contains enough data processing power that the family could locate their father in case he wanders off and potentially endangers himself. Other discussion topics addressed security and privacy, health-care technology advances and the environmental impact of nanotechnology. Some panelists did not play roles but instead provided background information for viewers to put the scenario in context. Video clips available on the Power of Small website provide more case studies.

In the spring 2012 semester, this author designed an activity based on the format of *Nanotechnology: The Power of Small*. Students role played characters serving as panelists in one of three scenarios while their classmates participated as the audience. Each student researched his or her role beforehand and wrote a reflection essay after the debate. Excerpts of the debate and samples of students' writings demonstrate that this activity engaged students in a meaningful discussion of nanotechnology and its impact on their lives.

2. ACTIVITY DESCRIPTION

The panel discussion activity is the most recent addition to Florida Tech's Introduction to Nanoscience and Technology laboratory (Winkelmann, 2009; Winkelmann, Mantovani & Brenner, 2008). This one-credit course is offered to freshmen students majoring in science or engineering during the spring semester. During most of the semester, students learn about nanomaterial synthesis (e.g., ferrofluids, thin films and carbon nanotube catalysts) and characterization (e.g., operation of scanning tunneling and atomic force microscopes). Since introducing the course in 2004, the instructors have tried different non-laboratory based activities to help students develop presentation skills, study a particular nanotechnology topic in more depth or learn about the relationship between nanotechnology and society. Activities occurred during the last week of the semester so that students would be already aware of many technical aspects of nanotechnology. In different years, students listened to guest lectures from scientists in local industrial and government research labs, participated in formal debates, and gave presentations to the class. Debates, writing assignments and presentations focused on topics related to experiments completed earlier in the semester. Course evaluations showed that students were generally uninterested in these activities compared to the course's laboratory sessions.

The activity described here creates opportunities for students to practice their presentation skills (albeit in an informal discussion), perform literature research of a nanotechnology topic and learn about the societal impacts of nanotechnology. Notable differences between role playing and the other class activities of past years are that the discussion topics are more relevant to students' lives, the discussion and debate are more informal and students are promoted to reflect upon their views before and after the activity. In addition, the writing assignment, due several days after the role playing panel discussion, and the debriefing session immediately after the discussion allow students to reflect upon their experience researching the topic and participating in the debate. Reflection has been shown to improve students' critical thinking and ethical decision making abilities (Thiel et al., 2011; Martin et al., 2011; Hammond, 1990).

Learning objectives for this activity for the student are

- (1) finding information related to the discussion topic from reputable sources,
- (2) constructively and actively participating in the panel discussion, and
- (3) reflecting upon his or her viewpoint held before and after the ethics discussion.

Evaluating the quality of sources that the student provides in the reflection paper determines the student's ability to reach the first goal. Students can achieve the second learning outcome in a variety of ways. They should behave

in a manner consistent with the character background provided in the assignment. They provide facts learned from sources to support opinions and contribute in a way that advances the discussion. Students should attempt to persuade other panelists having different viewpoints. As an audience member, each student should participate in post-role playing discussion sessions. Faculty instructors rated each student according to these criteria for achieving the second learning objective during the activity. Finally, content of students' reflection papers determines if they achieve the third goal of reflecting on their viewpoint held prior to the discussion and afterward.

The class was divided into three groups of six to eight students. Each group discussed one of the topics described below and in more detail in Appendix I of this article.

Scenario 1. Radio frequency identification (RFID) chips embedded in merchandise packaging can provide information to retailers about how their customers shop. Should a college student participate in such a program, allowing retailers to collect data about his shopping habits in return for a monthly stipend?

Scenario 2. A recent crime wave around campus worries the college administration and local residents. One solution put forth by the town's police department is to install small surveillance cameras around campus and monitor them. Thanks to advances in electronics miniaturization, the cameras can collect a great deal of information about everybody, both the innocent and criminals, and store an almost unlimited amount of data. Should the college install these cameras and share the data with local police officers?

Scenario 3. A team of students patented the technology to create a nano-thin coating for cell phones, laptops and other electronic devices that protects against water, bacteria and scratches. The students formed a company which is becoming very successful. They want to build a production facility in partnership with their university. Others raise concerns that the nanoparticles used in the coating could pollute the environment around the school where the facility is planned. Should the university support this new production facility?

Scenario 1 is based on a discussion in *Nanotechnology: The Power of Small*, (2008) with only minor plot changes. Scenario 2 is also taken from the same source, although the setting and related details were changed to a college campus. The third scenario is loosely based on WaterBlock, a real product developed by the company HzO and debuted at the 2012 Consumer Electronics Show (Miller, 2012). All character descriptions used for role playing are fictitious and any resemblance to real people is entirely coincidental.

Scenarios are consistent with best practices for designing science or engineering ethics activities. There is no right or wrong answer that solves a problem—only actions that lead to different, often unknown, outcomes. Since ethical issues are best addressed prior to pursuing a course of action rather than afterward, each scenario begins with

characters addressing the ethical dilemma before taking a concrete action (Barakat & Jiao, 2010). Characters hold opposing views so as to increase the emotional content of the scenarios, leading to increased student learning (Thiel et al., 2011). The author chose currently relevant ethical issues for students to consider rather than more speculative topics based on science fiction (Smith, 2005). This decision was based in part after considering criticism of how “if . . . then . . .” ethical issues are framed (Nordmann, 2007; van de Poel, 2008). It should be pointed out that although each scenario casts the ethical issue as whether the use of nanotechnology is beneficial or harmful to the characters, alternative options could have been considered. For example, a scenario could ask students to make ethical judgments on *how to best use* a particular nanotechnology, rather than whether to use it.

Thiel et al. found that emotionally rich content of a case study can increase students' knowledge of the case study and improve their ability to apply lessons of the case study when making other decisions. The descriptions of characters used in the present study include motivations, relationships with other characters and points of view that enrich the activity beyond simply a discussion of policy options (Thiel et al., 2011).

When designing this activity, the author chose realistic but fictitious scenarios based at the students' university, rather than actual events presented in the news, for several reasons. Real events become dated. This is especially true in a field such as nanotechnology, where scientific advances and new products are rapidly introduced. For instance, an engaging ethical dilemma based on the use of a particular type of nanoparticle in cosmetics become less instructive if toxicology tests demonstrate that the nanomaterial is safe to use. Scientific discoveries might also render fictitious scenarios moot but, in that case, the instructor is free to modify the background to make the scenario sufficiently relevant. With the easy availability of news through the internet, another concern is that students could learn of the outcome of an ethical decision before the activity. This would bias their view of what the “right” answer should be. Students participating in this activity should have a greater emotional connection to scenarios based at their own school, involving characters much like themselves and their friends, enhancing the emotional aspects of this activity. Their familiarity with the setting and details of the story reduces the amount of background information that the instructor must provide.

Each written scenario included two or three citations to news stories and some keywords relevant to the discussion topic. These helped students begin their research, which required them to find at least two additional articles. The assignment's instructions provided tips for finding high-quality information sources, including a link to a YouTube video explaining how to use the library's online databases to find sources. Students were told to provide copies of their sources when they turned in their reflection essays.

Four weeks prior to the debate, each student received instructions for the activity, a one-paragraph description of the character's viewpoint and scenario background. Each student was allowed to add details to his or her story but could not change the character's basic viewpoint. Characters had unique perspectives and each panel contained equal numbers of supporters and opponents. A student received only his or her own character story and the list of characters on the panel. Students could anticipate who on the panel might support or oppose their views but did not necessarily know what each participant was going to say. While students could share their background stories with each other prior to the activity, they were not encouraged to do so. All material provided to students is contained in Appendix I of this article.

All three panel discussions took place in a single class session, scheduled for the last session of the semester. The panel discussion and reflection essay each accounted for 20% of the student's grade. Students were graded on their individual effort, not on the overall performance of the panel. The rubrics used by the instructors for judging the panel discussion and the reflection essay provided in Appendix II.

Within the classroom, panelists sat at a separate table that faced the audience, which included other course instructors and their classmates. The moderator, played by the author, introduced each scenario so that the audience could follow along with the panelists' discussion. Convening the panel and the audience's presence was part of the story. For instance, student participating in Scenario 2 were part of a public meeting organized by the school administrators to discuss the problem of crime in and around campus. Panelists introduced themselves and briefly stated their positions on the issue. The moderator then directed questions to each panelist, asking them to provide more details about their views. Panelists were encouraged to ask each other questions but not interrupt each other. The moderator would ask a panelist specific questions if he or she was not contributing and he steered the conversation back to the main topic if it got sidetracked. Otherwise, the moderator let the panelists control the discussion. Each panel was scheduled for twenty minutes, although more time was provided, as necessary. At the conclusion of each session, he asked panelists to reach a consensus.

Following each panel, the audience asked questions and voted on the proposal. Finally, the moderator told participants to stop acting in character. Students briefly discussed their own views of the issue and commented on their role playing experience. This debriefing is helpful because it allows students to reflect on their own performance and share their own feelings, which they would not be able to do if their character held a different viewpoint (Sims, 2002).

Some changes were necessary in order to adapt the *Nanotechnology: The Power of Small* discussions to a

class discussion. First, no students served as information experts. All panelists were expected to have some basic knowledge of the scenario's nanotechnology topic and the moderator would provide any additional technical information as needed. This allowed all students to focus on the societal issues rather than technological details, making each student's role equivalent. As mentioned previously, some topics were changed so that they would be more relevant to students' lives. Scenarios avoided politically contentious issues. For instance, anti-terrorism measures discussed in *The Power of Small* were changed to policies to fight ordinary crime. The audience participated in the class activity whereas the audience was largely silent in the TV series. This change helped keep students in the audience interested in the activity and gave the opportunity for audience participation to be a component of the student's grade. The author did not know the students' personal views on these discussion topics beforehand. In order to avoid a situation in which all or most panelists agree with a single viewpoint, the instructors assigned opinions to students as part of their character background. It is likely that the participants in *The Power of Small* show were assigned roles that were consistent with their pre-existing views.

3. RESULTS AND DISCUSSION

Students performed this role playing ethics activity in the Spring 2012 offering of the course. All students take this class as an elective. Demographics of student participants are as follows.

- Gender: 5 female, 17 male.
- Academic major: 12 chemical engineering, 3 biochemistry, 3 physics, 1 civil engineering, 1 aerospace engineering, 1 mathematics, 1 molecular biology.
- Academic year: 17 freshmen, 4 sophomores, 1 junior.

Imbalances in the demographic categories are expected. Florida Tech's undergraduate freshman population is 75% male. One of the course instructors is an advisor to many chemical engineering students and he effectively promotes the course to his advisees. Because of its introductory nature, the course is offered to freshmen only though instructors may allow upper level students to enroll. One student could not attend the activity but did turn in a reflection essay. Two students did not turn in their essays but did participate in the discussion.

Of all the learning objectives, students failed most often to demonstrate their success in finding and turning in their articles from reliable sources. Nine students did not provide a list of references with their essays, although that requirement was included in the instructions for the assignment. Eleven students did provide a list of references, though most did not provide copies of the articles as instructed. Instructors deemed almost all of the provided references as being from trustworthy news sources. These included newspapers such as *The Guardian* and

The New York Times, news magazines and websites like CNN, Time and Forbes, and technology magazines and websites, including Popular Science, How Stuff Works, Nanowerk and CNet. Three students used information found in research conference proceedings, *IEEE Transactions*, and *Nature*. Instructors viewed the omission of references as an oversight by students rather than a reflection on the difficulty of finding sources. The vast majority of references that students did provide were acceptable, indicating that there is not a lack of reliable information about their research topics. In the future, the instructors will emphasize this part of the assignment.

In contrast, instructors graded students' participation in the ethics discussion very high using the grading rubric found in Appendix II. The rubric lists five criteria for evaluating a student's performance: making intelligent comments (5 pts), playing the character role (4 pts), supporting opinions with facts (5 pts), trying to persuade other panelists (4 pts) and participating as an audience member (2 pts). No student received less than 50% credit for any single rubric item. The average total score for students was 17.8 out of twenty possible points, equivalent to an average grade of 89%.

Students can be judged on both the quality and quantity of their comments made during the activity. Their discussions can be compared to those viewed in *Nanotechnology: The Power of Small*. Of the three scenarios in the class activity, the first one (voluntary RFID monitoring of a student's shopping habits) was most similar to a discussion presented in the TV show. During that discussion, student panelists were concerned about malicious hacking of the RFID system resulting in identity theft and disclosure of personal information to retailers. The written character profiles provided to students mentioned these concerns but the students expanded upon them during the discussion, relying on information gained from their research. Although the instructors modified the scenario plots which served as the bases of the second and third panels, the general topics were still the same (security and environmental protection). Students raised doubts about the value of greater security and its effect on personal privacy in Scenario 2 and they were concerned about the lack of regulation of nanomaterials used in consumer products and their eventual release into the environment. All of these concerns were expressed by their "expert" counterparts in the TV show. The amount of participation by students was greater than expected also. The instructors originally scheduled each scenario for twenty minutes. Instead, students engaged in meaningful discussions for twice as long before the moderator asked for concluding remarks. Due to short breaks between panels and the moderator's introductory remarks prior to each panel, the activity lasted the entire 2 hr 30 min class session.

Students discerned facts from opinions when performing their research then they evaluated which course of

action they preferred when writing the reflection essay. Many decided by weighing the pros and cons of possible outcomes (a utilitarian or egotarian ethical framework, see below). These actions indicate students were critically thinking about their views of nanotechnology (Angelo & Cross, 1993). As an example, a student researched the environmental impact and the financial benefits of nanotechnology for Scenario 3. In his reflection essay, he wrote:

"I was originally strongly in favor of having a nanotechnology research facility built on campus. The fact that there have not been many studies about the safety of nanotechnology is slightly disconcerting. So, ultimately, I would still be in favor of the research facility, but I would have some concerns about the safety of the student body."

A second student explained how research and the debate affected her views about constant police surveillance on campus.

"My opinion going into the debate was that surveillance would improve the campus crime and would create a safer environment. I personally did not have any ethical issues with the government storing data about me, because I know I have nothing to hide because I do not commit crimes. As I completed research I became a little more uncertain of the effectiveness of the cameras to prevent crimes and capture criminals, because research showed only an 18% improvement."

Both examples are typical of students' reflection essays and show that they found and used fact-based sources to learn about the issue, then used that new information to reconsider their views about nanotechnology.

While all students adequately performed their character roles, some incorporated mannerisms and costumes to make their characters more authentic. An example of this occurred during Scenario 1, in which Pete and Irene discuss whether to allow their son, Jack, to participate in a program that uses RFID chips to monitor his shopping habits. Pete and Irene's mild discussion turned into a full-fledged family argument. After Irene tells Jack that she supports this program and tells him to sign up, Pete exclaimed, "You know, you don't always get to make the decisions in this relationship." Harold, Jack's uncle, considered RFID chips to be an invasion of privacy and told Jack, "Don't listen to my little sister, Irene. She's always been kind of crazy." Irene tells Harold to stop being a conspiracy theorist. These three students were friends so they took each other's remarks as jokes, as they were intended. Although the substance of their dialogue did not add to the quality of the discussion, it did provide some comic relief and realism. Students elaborated on their characters' backgrounds and a few even spoke using accents which were not part of the character description. A student playing the role of an elderly woman dressed in a wig and

shawl while another student dressed in a suit for her role as a high-ranking university administrator.

Audience members noted good performances by panelists as being enjoyable parts of the activity in their reflection essays. Several students specifically mentioned a debate that occurred during Scenario 3 between Dr. Carnegie, a university administrator in favor of building a new nanomaterial manufacturing facility, and Ms. Davis, a local resident and opponent of the plan. Unlike the comments between Irene, Jack and Harold, Dr. Carnegie and Ms. Davis debated the technical issues related to nanotechnology and its potential impact on the environment. One audience member commented, "I appreciated the heated debate between Dr. Carnegie and Ms. Davis. It was highly entertaining." Another student remarked that the discussions felt like, "a formal meeting where professionals were presenting their opinions on a controversial topic."

Near the end of each discussion, the moderator asked panelists to reach a compromise. Students were not told beforehand that they would have this opportunity. Their responses showed how well they integrated a persuasive offer from panelists who disagreed with them into their own characters' point of view. In the first scenario, the family agreed to allow Jack to shop with the RFID-implanted card if retailers provided a higher level of data security and did not share the information with other businesses or the government. On the other hand, students in the second panel held strong and very different views of the benefits of using miniature video cameras to increase campus security. Despite several attempts by the moderator and one panelist, the two sides could not reach any compromise. In the third panel, a local businessman who initially opposed building a new electronics coating facility near campus changed his mind, providing a 4 to 2 vote in favor of the plan—a victory for the company. Reaching a compromise was not necessary but the process helped show how much effort students would make in order to persuade each other. In all three cases, students tried to either reach consensus on a new, more moderate proposal or change each other's views with appeals based on facts or emotions.

Audience members demonstrated that they actively followed the discussion by posing many questions to the panelists. Audience members did not perform any research of the other panel topics. However, comments in the reflection essays showed that audience members already possessed views of the underlying issues based on their own life experiences. All students contributed to the question and answer session with the panelists. The last task for each scenario was a conducting a vote of the audience members. A slight majority said they would not participate in a voluntary RFID shopping program as described in the first scenario. A perceived lack of cybersecurity and the accidental release of personal shopping information

were the main reasons put forth by those in opposition, while the group in favor of the program acknowledged those risks but were willing to take the chance. A similar ratio of students voted to support the presence of police-monitored video cameras on campus (Scenario 2). In this case, the majority was willing to accept the intrusion of police video recording their movements on campus because they thought they would be safer. After viewing the third scenario, an overwhelming number of audience members endorsed the construction of a manufacturing facility that would employ students and generate revenue for the university. Students cited their concern over future tuition increases, which would be prevented if the school received income from the new facility. Two students objected to the proposal because of concerns about the effect of the nanomaterials on human health and the environment.

The reflection essay assignment prompted students to describe their views of their scenario before and after the activity and also describe their views of the other two scenarios which they viewed as audience members. Table I summarizes the students' views before and after viewing or participating in each scenario. Numbers in the columns do not add up to 19 (the number of students who participated in the discussion and turned in reflection essays) because some students did not adequately respond to this portion of the assignment. For instance, a few wrote that they did not change their mind but failed to indicate their point of view. Those students were not included in the table below. Note that these are the views of students, not their characters that they role played.

Among panelists, six students changed their views about their topic. Scenario 2 caused the greatest change—opinions of three of the panelists changed from favoring the use of surveillance cameras for campus security to opposing them. No panelists for this scenario become more favorably inclined. One panelist in scenario 1 became more supportive of RFID technology while one panelist changed his mind to opposing it. In scenario 3, one panelist initially supported the plan to build a manufacturing center near

Table I. Number of students showing constant or changing views of three scenarios.

	Scenario 1	Scenario 2	Scenario 3
Panelist's opinion of			
Nanotechnological solution			
No change (more favorable)	5	2	5
Change to less favorable	1	3	1
Change to more favorable	1	0	0
No change (less favorable)	1	0	1
Audience opinion of			
Nanotechnological solution			
No change (more favorable)	5	4	5
Change to less favorable	2	1	1
Change to more favorable	0	1	0
No change (less favorable)	2	5	1

campus but changed her mind to oppose it after researching the topic. In total, one panelist became more supportive of nanotechnology as a solution to the problem while five panelists became more opposed to the use of nanotechnology. Most panelists did not change their minds based on what they learned while researching and discussing their topic.

Opinions of audience members shifted even less frequently. This seems reasonable since they were only exposed to the discussion of the topic and they did not perform any research on the topic themselves. Students did change their minds in five cases, four adopting less favorable views of nanotechnology and one student changing his mind to have a more favorable opinion. While most students did not change their views as members of the audience or panel, many did report that the activity exposed them to new opinions that they had not considered. Therefore, students did achieve the learning goal of learning about and considering alternative opinions for the use of nanotechnology.

Results described in Table I show that changes in students' opinions were not evenly distributed. Nine panelists or audience members became less inclined towards using a nanotechnological application to solve the problem described in the scenario while only two students became more supportive. This disparity may be due to the fact that the overwhelming majority of students were already favorably inclined towards nanotechnology before the activity. Few were initially opposed to the scenario topics so there was a smaller population of students who could change their minds.

When asked to describe the best aspect of the ethics activity, the overwhelming majority of students said it was enjoyable or fun and most agreed that the debate was interesting or educational. Many students cited the exposure to alternative and new points of view as a positive experience. The most common complaint was the prevalence of speculation about nanotechnology rather than specific facts in the press. One student summarized this by writing:

"I was frustrated to find that there is a significant amount of speculation about upcoming technology, and I have realized that much of it may never occur. I would relate this to people in the 1960s speculating that we would be living like the Jetsons by now. I found that it can be difficult to try and find unbiased articles about emerging technologies because not all of the facts have been established yet."

Based on this quote and other similar responses, it appears that students were looking for definitive answers to guide them as they tried to solve the ethical dilemma and found more uncertainty and hype than expected. Their reaction is consistent with other studies that indicate students prefer unambiguous situations with a right and wrong answer (Smith, 2005). Two students disliked the occasional confrontational nature of the discussion. One

student feared public speaking and the second student felt he lacked enough research information to share. Two students also wished there was more time for them to contribute and hear from other students.

Reflection essays showed that students learned more about nanotechnology than just the nanotechnology application related to their assigned scenario. Students cited their surprise at learning about the economic growth and job opportunities in the nanotechnology sector as well as uses for nanotechnology for solving crimes, its existence in consumer goods and scientists' uncertainty about its health effects. Their most common statement was that they had never considered the ethical issues related to technology before this activity.

The instructors did not focus on ethical frameworks which students might use to determine the best course of action. However, it is worth considering some of the possible ways students might view each scenario and the ethical decisions they must make. Incorporation of ethical frameworks into the post-debate discussion and reflective writing could further improve the activity. Descriptions of ethical systems such as those described here can be found in many introductory books about ethics, such as *Fundamentals of Ethics for Scientists and Engineers* (Seebauer & Barry, 2001). The brief descriptions of various frameworks provided below are not meant to be comprehensive.

Scenario 1 deals with a young adult's voluntary loss of privacy rights in exchange for potential economic gain. For this program, parents must consent to their child's participation. This raises the issue of how old a person may be before being allowed to make ethical decisions for him or herself. The student playing the child's role pointed out during the debate that he was legally an adult and should be allowed to make his own decisions.

Most students who said they would use the RFID when shopping expressed views consistent with egoism—determining the course of action that provides the most benefits for one's self. Many students expressed some concern for their loss of privacy by using the RFID but they felt the loss was minimal and less important than the financial gains. Students playing the roles of store owners urged those opposed to the program to consider how businesses and others might benefit. This could be considered an appeal based on utilitarianism, the view that the correct ethical decision will lead to the maximum good with the least harm. (The difference between egoism and utilitarianism is that the former is concerned only with the agent while the latter considers the consequences for everybody who is affected by the decision.)

The second scenario, concerning the use of advanced security cameras for campus safety, led many students to assert their right to privacy. This view is consistent with a rights-based ethical framework which treats the respect for human rights as superseding any potential benefits gained by violating those rights. Students who researched the

background information for this scenario noted that some studies found that the benefits of increased surveillance were not as great as anticipated and would not be worth the expense. Once again, they were employing a utilitarian framework to reach a decision.

Students discussing whether to build a new nanotech coatings research and production facility near campus used many of the ethical frameworks mentioned previously, especially utilitarianism and egoism. In their reflection papers, students participating in this scenario wrote about the potential environmental harm that could result from the nanomaterials used to make the coatings. In most cases, students viewed the potential financial windfall for the university (with subsequent lower or stable tuition) as being of greater value. As an example, one student wrote, "I supported it [the new facility] as long as there are adequate regulations put in place." Some ignored the environmental concerns and focused on the benefits for themselves while other students included their peers among those who would benefit.

4. CONCLUSIONS

This paper describes an ethics activity for students and its successful implementation in a spring 2012 introductory nanotechnology course. Students role play fictional characters who discuss the ethical issues related to realistic uses of nanotechnology. Most students failed to follow directions for citing the articles they read as background research for the activity. However, almost all students did accomplish the second and third learning objectives by participating in the discussion and reflecting on their viewpoints of the ethical issues presented. Overall, results of this activity demonstrate that students in an introductory nanotechnology course enjoy and learn from a discussion of nanotechnology ethics. Students were initially overwhelmingly in favor of using nanotechnology applications to achieve societal goals but approximately one third of the students viewed such solutions with less enthusiasm after reflecting on the issue.

APPENDIX I (STUDENT HANDOUTS)

Our last activity in Introduction to Nanoscience and Technology is a discussion about how nanotechnology might affect your lives. This will take place in the conference room on the second floor of the Olin Physical Sciences building at 6 pm on April 23. You will also write a short essay related to this discussion which is due Friday, April 27. Your performance in the discussion and your writing assignment will determine 40% of your final grade in the course.

Three groups of students will study a different ways that nanotechnology can affect your lives. To make the discussion more fun and interesting, you will play the role of a

character closely involved in one of the issues. Each group member will receive a description of the scenario you will be discussing, some references for additional reading about the nanotechnology topic and a summary of your character's interests and motivations. For instance, you could play the role of a police officer interested in using nanotechnology collecting DNA evidence at a crime scene while another classmate is a privacy advocate concerned about the police having samples of innocent people's DNA.

Each member of the group will research the topic to gather information that supports their view of the issue (or refutes the views of other group members). You should understand the basic nanotechnology aspects of the issue but you will also need to debate how that nanotechnology *should* be used. If a detailed technical question arises during the discussion, I will help you answer it. Note that some of the scenarios you will discuss occur in the near future so some current technologies may have evolved and improved.

You may not agree with the opinion of your character but you do need to convincingly assert the character's views. Each group will discuss their topic in front of an audience of other classmates and instructors. The audience and the instructors will grade your performance. We will conduct a vote among the audience members before and after the discussion to see if any audience members changed their minds.

I will provide a few articles which give some background information about your group's nanotechnology topic. These may not explain everything you need to know and are not necessarily even the best sources. They are good sources and can serve as examples of sources you should find for yourself. You need to find at least two more high quality articles which can help you understand and articulate your character's views of the scenario. These sources should help you *justify your character's opinion* with data or well reasoned arguments.

For this assignment, high quality sources can be found by searching for peer reviewed articles, news from major world newspapers, and articles from major news publications such as Time magazine or CNN.com. Although these articles may occasionally have factual errors, they are among the more accurate sources of information. Avoid blogs entries, discussion boards and websites like Yahoo Answers. If you have a question about a source, just ask me. You will need to download or print copies of all sources that you use for the assignment and turn them in with your written essay. Librarians can help you find articles.

Your written essay should be at least a page long, double spaced, 12 point Times New Roman font. The faculty instructors will grade you on the quality of your responses, not the length of your essay. It should answer the following questions:

What aspects of the research did you like and which aspects of research did you dislike?

What aspects of the discussion did you like and which aspects of the discussion did you dislike?

What did you learn from this assignment?

Was anything you learned unexpected?

What was your opinion of this issue you researched when you started the assignment?

Did your opinion change as you performed the research?

Did your opinion change as you participated in the discussion?

If you changed your opinion, what facts or ideas caused the change?

Did you change your mind about the other two topics discussed by other students while you were in the audience? If so, what was your original view and what was your view afterwards?

You will turn in a copy (either electronic or printed) of each good reference source that you used to prepare for your group's discussion.

Scenario 1: Shopper Helper or Shopper Watcher?

A major technology company is beta-testing new radio frequency identification (RFID) chips in the stores of a nearby mall, Wal-Mart and other major local retailers. Your town is the first community selected to participate. Consumers volunteer to receive a free RFID reader that looks like a credit card. It fits inside your wallet or purse. Packaging for all items in the store contains RFID chips. The reader you carry detects when you enter a store and then approach, linger around, handle and eventually buy any RFID-tagged item. It then transmits that information using a wireless network set up in the stores. This helps retailers and malls more effectively target customers and help companies know immediately which items interest shoppers. There may be other advantages also.

Some people are concerned about privacy, such as a store tracking them and monitoring their shopping. Others are worried about data security. In addition, it is not clear how much the company is charging the retailers for this service so prices of items may increase a little bit.

The company wants to get a lot of young consumers to use this service so they are giving away the readers to students and even pay them \$25 per month of use, assuming the student visits the mall or other participating store at least once a week. In order to sign up for the program, anybody under 21 years old must have a parent to sign the consent form.

This issue attracted the attention of an Orlando TV station. They broadcast a technology-themed talk show on Saturday morning. The show's host invited Jack, his family and other people involved in this potential RFID program to discuss this issue.

Discussion topic: Should the parents of Jack, a student, allow him to sign up for this program?

Keywords: Nanotechnology Ethics, RFID (Radio Frequency Identification), Privacy, Consumer Monitoring, Data Collection, Data Security.

Roles:

Jack, a student

Irene, Jack's mother

Pete, Jack's father

Harold, Jack's uncle

Ms. Brenda Claiborne, owner of Game Trader, a video game store in the mall

Mr. Antonio Freeman, owner of a small video game company who sells games in stores like Game Trader

Mr. Patrick Wagner, financial analyst of technology companies

Background Information Sources:

<http://www.nanowerk.com/news/newsid=15389.php>

http://www.forbes.com/2005/11/23/rfid-nano-wolfe-in_jw_1123soapbox_inl.html

<http://books.google.com/books?id=DIkt1w4LuvkC&pg=PA210&lpg=PA210&dq=rfid+nanotechnology+ethics&source=bl&ots=7dojKQR6n1&sig=cqTXDxdYCF6ZM7eBN3A9Ekhhx0c&hl=en&sa=X&ei=yHxrT7DNHcicgQfG6vSJBg&sqi=2&ved=0CEAQ6AEwAQ#v=onepage&q=rfid%20nanotechnology%20ethics&f=false, pages 192-204, 207-211>

<http://electronics.howstuffworks.com/gadgets/high-tech-gadgets/rfid.htm>

Student 1a: Your name is Pete, and you are Jack's father and Irene's husband. He is an 18 year old freshman student. Jack is trustworthy and a good son. He found out about this program through advertisements in the school newspaper and wants to sign up. Jack likes the idea of making money just by shopping. However, you work at a nearby juice factory where the supervisors just implemented a similar RFID tracking system for the bottling line workers. The RFID chips are placed on the hard hats of each worker. The system tracks everybody's movements, which is pretty annoying to you and your coworkers. You don't want your son tracked in the mall too. Besides, the factory's network sometimes gets signals messed up and records the wrong location for people. You are reluctant to allow Jack to sign up for this program.

Student 1b: You are Jack's mother, Irene and the wife of Pete. Jack is an 18 year old freshman student. Jack is trustworthy and a good son. He found out about this program through advertisements in the school newspaper and wants to sign up. Jack likes the idea of making money just by walking around the mall. Both you and Jack noted that he wouldn't even have to buy anything. As the person who buys most of the groceries and other household items for the family, you want to join this program too because you recognize its benefits to shoppers. Why not let a computer know which video game Jack wants to buy? It is just like recommendations that you see when shopping at Amazon. This can be one more way that technology makes the time-consuming task of shopping easier and saves money.

Student 1c: You are Jack, an 18 year old freshman. You noticed an ad in the *Crimson* about a company will pay you to shop. You just carry around a card that communicates with RFID chips in products and transmits the data to stores. Professors in your engineering seminar mentioned this technology and you don't see any problems with it. ISPs, car navigation systems and cell phone providers can track what you do and where you go already. This is just a little more specific but it pays you and could even encourage stores stock the less popular video games that you like. You really want to sign up for this program.

Student 1d: You are Harold, Jack's uncle and Irene's brother. You review new consumer technology for a popular CNet blog. New, invasive technology bothers you but not as much as the willingness of people to blindly accept it in their lives. You are concerned about the vulnerabilities of this technology that nobody is thinking about. Who would see this data and what would they do with it? Consumers may not want anybody to know that they were shopping for certain personal items. How secure is the data and the network that is used to collect it? This could put the privacy of many consumers at risk.

Student 1e: As Brenda Claiborne, the owner of the new Game Trader store in the mall, you want to know what your customers are looking at. Game Trader sells new and used games for all game console platforms. You stock hundreds of games and so far, business is pretty good. Lots of people browse your selection—too many for you to keep track of what games they are browsing. Your biggest problem is that they look but then go home and order the game from Amazon. If you knew which games they were looking at, you could very quickly price them more competitively or talk with customers and get them to buy while they are in the store. A technology that provides more information would help you compete with bigger retail chains. You want to show Jack's parents how this technology can benefit Game Trader customers like him.

Student 1f: You are Antonio Freeman, the owner of a small video game company, Magnifico Games. As a new, small player in the video game market, you have trouble competing with the latest edition of Halo a new zombie apocalypse shooter game. The rights to some of your games have been purchased by major gaming companies so you know your other games would be successful if only you could get more of them on store shelves. Store owners are reluctant to take a chance on a small company like yours since they can't afford to waste shelf space on games that don't sell. RFID technology can demonstrate to retailers that people really are interested in your products. Overall, letting small game companies have more visibility will improve competition and the quality of all video games. You want to explain how this new technology will companies like Magnifico Games develop the products that stores sell.

Student 1g: You are Mr. Patrick Wagner, a financial analyst who studies technology companies like Reliable Tracking,

Inc. (RTI), the corporation that developed this new generation of RFID technology and is beta-testing it in your town. You believe this technology will work as RTI advertised but you wonder about the cost of program, including manufacturing the RFID chips and readers, installing the equipment in stores, teaching retailers how to operate and maintain it, and collecting and analyzing the data. There's also the challenge of explaining how it works to the public and how this technology benefits them. Although RTI may benefit from being the first to sell this technology, RTI will also have to deal with any unforeseen problems by itself. You don't know if it is worth it.

Scenario 2: Safe and Secure and Recorded

Unfortunately, the university is experiencing a crime wave. Criminals have vandalized cars, broken into a dorm room (thankfully, nobody was home), stolen computers from the library, sold drugs near campus, assaulted students, and driven off after two collisions with bicyclists. Local police and campus security caught one student who sprayed graffiti on a car but all other crimes remain unsolved. Everybody is worried and conversations all over campus focus on this issue. Parents of students are concerned about their children's safety. Students no longer refer to the town as "Melboring" but under the circumstances, that's not good. Local residents comment that the extra crime coincides with the university's increased enrollment. Maybe that's just a coincidence, they say, or maybe not.

Residents want something done. Now. The local Police Department wants to install very small video cameras around campus and town to catch these criminals and deter future crimes from occurring. Unlike the bulky security cameras that are now used in some buildings, these new cameras are so small that it's hard for a criminal to even know the cameras are there. The cameras send their audio and video recordings through a secure wireless network to a central server where police or campus security can review the data in real time. Although they are small, their advanced computer processors record more than just movies. The software can detect a car on the road, measure its speed or show that it ran a red light, and take a picture of the driver and license plate. Facial recognition software allows police to track and monitor suspicious people. The images are screened against a database of students and known criminals to identify the person immediately. Microphones can overhear conversations which police and security officers will monitor. It's not too much an exaggeration to say that these cameras would be everywhere on campus and can monitor everything.

This cutting edge technology is expensive. Of course, so is the loss of tuition from students leaving school because they feel unsafe. The City Council has offered to help pay for the cost of setting up the campus-wide security system which will save the university a lot of money. In return, the

Police Department wants the school to allow it to monitor the data from cameras on campus and integrate it with their own system.

To some students and most local residents, this sounds like a great way to improve the security around campus. Those who are not committing crimes do not have anything to worry about if a policeman watches them. Others are uneasy about the intrusion of local police on campus. Maybe there is another anti-crime program which is less expensive and does not intrude on everybody's expectation of privacy or focus on just students.

Due to the contentious nature of the issue, the school's administration has convened a town hall meeting. They want to know what the campus and local community think about the university starting in this security program. The Police Department is in favor of this program.

Discussion topic: Should the university join this security program?

Keywords: nanotechnology ethics, privacy, safety, security, computer technology, video recording, nanolithography, data storage, data mining

Roles:

Sgt. Dale Connor, police officer

Gary, local homeowner and crime victim

Arnold, student who lives off campus

Paul, resident and bicyclist

Steve, commuter

Dan, member of university's Student Services Office

Dr. Carolyn Faulk, university administrator

Dennis, student who lives on campus

Background Information Sources:

<http://www.guardian.co.uk/nanotechnology-world/the-future-of-computing-power-from-dna-hard-drives-to-quantum-chips?newsfeed=true>

<http://www.eetimes.com/electronics-news/4211151/IBM-debuts-CMOS-silicon-nanophotonics>

http://articles.baltimoresun.com/2012-03-10/business/bs-bz-vorbeck-materials-innovation-20120309_1_lithium-ion-batteries-graphene-aa-batteries

Student 2a: You are Police Sgt. Dale Connor, a twenty-year veteran the police force and resident. Until very recently, this used to be a really safe community. You have never seen a series of crimes your town is experiencing right now and you don't have any idea why it is occurring. You hope that the university installs these new cameras and that they allow the Police Department to monitor them. With these cameras, you could apprehend criminals who flee onto campus, since they can hide in the Botanical Garden. Your department and the school's campus security have a very good working relationship and have cooperated in several occasions to promote student safety. If the school needs financial assistance to purchase the cameras, you think it would be wise for your department to help. You've been a police officer too long to jump to any conclusions about how much of this problem is caused by students.

One thing you do know is that cameras would help catch whoever is causing the trouble.

Student 2b: You are Gary, owner and resident of a home located a block away from school. Except for complaining about an occasional party at a house rented by students, you've never had to interact with the police. That is, until two weeks ago. You heard a noise in your backyard at night. It sounded like it came from your shed and when you looked outside, you saw two young men taking your lawn equipment. They ran away when you turned on your porch light. Nothing was stolen and it was too dark to see the thieves but you called the police anyway. They told you that a pair of young men had been seen in the area before, jumping over fences into people's backyards. You like being near a university but you might change your mind if students start causing trouble. You welcome any ideas that the police have to prevent this type of crime in the future. You think that cameras would help prevent this type of crime.

Student 2c: You are Arnold, a student. Most nights, you walk to your Crane Creek apartment after studying on campus or working at the library. You haven't been the victim of a crime but your roommate almost was. Three guys started following him as he walked down the street at night. He ran to your apartment safely but it certainly scared him. You are thinking about finding a place closer to campus to live next year. Living closer to friends and work would also cut down on the number of times that neighborhood watch patrols stop to ask you what you're doing out at night. Residents should stop bothering hard-working students and help the police catch the bad guys. Overall, you think the cameras would help since they show you minding your own business and they would catch the criminals.

Student 2d: You are Paul, but you might as well be called the Invisible Man because drivers around town don't seem to notice you riding your bike on the edge of the road. You live and work in town and over the years you have had several close calls with cars driving past you or making a turn right in front of you. It is a good thing that you see them because they are not looking for you. One of your friends in the local bicycle club got hit by a car and the driver didn't even stop to see if she was hurt. You generally like students—lots of them enjoy biking like you do but you notice that absent-minded drivers seem a lot more common when fall classes begin. You are not too worried about the rash of crimes that you read about in the paper but cameras around campus might remind young drivers to watch as they turned onto local streets.

Student 2e: Your name is Steve and you definitely oppose these cameras around town. You drive to Hugh's Research Labs everyday but you and your friends live in another town. These crimes are terrible but they don't affect you. What does worry you is that the school might install cameras that catch drivers who speed along the highway. You

don't want to admit that you speed all the time but everybody does it, right? Cameras along the road would be a big inconvenience for your daily commute. You have heard about other communities using cameras at intersections to catch people running red lights. Some people say that they are illegal. You sure hope so because tickets could get expensive for you.

Student 2f: You are Dan, a staff member in the university's Student Services office. A lot of your work focuses on helping students deal with problems off campus. Students might have a dispute with their apartment landlord or neighborhood residents might complain about students making too much noise. Sometimes, the student is at fault, other times people are trying to take advantage of students because they are young and living away from home for the first time. You are definitely concerned about the recent crimes because some involve student victims. You hate to see members of the university family hurt. However, you also think a lot of residents are picking on the school. You've argued with your neighbors about who is responsible for these crimes. They assume that if the criminal is young, that means he is a student, as every young man around here go to college. The truth is that nobody knows who is committing these crimes. Why don't they install cameras around town instead?

Student 2g: Your name is Dr. Carolyn Faulk, a school administrator concerned about the wellbeing of students and how to best address this crime problem. Even with help from the local government, these cameras will cost a lot to maintain, not to mention hiring extra security officers to watch the recordings and work with the local police. You hope that this upcoming town meeting will give you the opportunity to share your ideas for anti-crime programs that other communities have successfully employed.

Student 2h: You are Dennis but to most people, your name is Cortana57416—that's your login name for the online gaming guilds that you belong to. You are a student and are proud to say that you consume more bandwidth than anybody else in your dorm. While you enjoy your technology for entertainment, you strongly disapprove of using it to spy on people. You've read about some of the crimes around campus on discussion boards. It makes you wonder why people can't travel in groups and not wander around at night. Don't they know you can get pizza delivered? Everything a student needs in on campus anyway. The university would be better off not installing these creepy cameras and just letting students stay in their dorms and take classes online. You don't want cameras watching you and you would consider transferring to another school if they installed them. These have got to be illegal if "privacy" means anything. What's next, a camera in each dorm room to make sure students do their homework?

Scenario 3: The Biggest Thing to Happen at the University Since Football

A group of university students recently took a trip to the Consumer Electronics Show, not to see all the new gadgets and phones but to demonstrate their own product. As part of a senior engineering design project, they developed a nano-thin coating containing several different types of particles to extend the useful life of electronic devices. They began a startup company, Panther Electronics Protection (PEP), which applies their NanoSafe coating to a laptop, phone, MP3 player, etc. The device's screen remains scratch-free, bacteria don't grow on its surface and the device becomes waterproof so you don't have to buy a new one every time you spill a little coffee on it.

PEP performs this service locally and employs six other college students. The startup appears to be very successful—its office is always busy and expanding. PEP is even in negotiations with Motorola to license this proprietary NanoSafe technology. Because NanoSafe was first developed at the university, the school receives 20% of all profits, which could mean millions of dollars. Researchers in many fields, from defense contractors to public health officials, are very interested in applying this technology in their work. Due to its current and potential success, PEP has attracted venture capital to build a larger factory and research lab located on campus to handle their growing business while still being close to the school and students who inspired the company.

Despite all the positive attention this story is receiving, a few people have raised objections about the new PEP lab. They worry that this coating material may not be safe. According to them, nanomaterials are not rigorously tested. PEP admits that the coating eventually wears off, requiring periodic reapplications. Could the material be absorbing into people's skin, dissolving in the water or evaporating into the air? PEP is silent about this, claiming that it would infringe upon their trade secrets related to NanoSafe's formulation. With no answers from PEP or the school, a small group of students, faculty and local residents have picketed each morning this week outside of the PEP office. They want to raise the public's awareness of their concerns.

Sensing that this protest could become more popular and distract the media's attention from the new research lab or jeopardize potential licensing contracts, PEP wants to meet with the community and address any concerns that people have about their business.

Discussion topic: Should the university allow PEP to build on campus?

Keywords: nanotechnology ethics, environmental safety, economic benefits of nanotechnology, consumer electronics, health effects of nanomaterials, regulation of nanotechnology, thin films, antibacterial nanotechnology, waterproof film, scratch resistant coating

Roles:

Dr. Marcus Carnegie, school administrator

Sam, university student and PEP employee

Ms. Ruth Anne Davis, local resident

Professor Charles DeWalt, university professor and protester

Ms. Kate Carlson, PEP founder and university alumnus

Raymond, university student with financial concerns

Mr. Greg Salvador, manager of cell local phone store

Background Information Sources:

http://www.nytimes.com/2008/05/21/science/21nano.html?_r=1&em&ex=1211428800&en=87de3ed7193ffbf9&ei=5087%0A

http://www.nanotechproject.org/publications/archive/nanotechnology_consumer_products/

<http://www.popsoci.com/science/article/2011-04/study-finds-common-silver-nanoparticles-are-deadly-microbes-critical-plant-growth>

Student 3a: You are Dr. Marcus Carnegie, Chief Development Officer for the university. Your job is to solicit donations from alumni and university supporters. This includes businesses which may donate money for student scholarships or to name buildings. PEP is such a great success story for the university: student geniuses create an invisible coating that makes a cell phone indestructible! You've received calls from national and international newspapers and broadcasters who want to visit the university for on-the-scene reports about PEP. That exposure will help attract new students and raise the university's reputation as a science and engineering school. The new research lab will be a centerpiece of a future technology center that helps faculty and students market their research, employs dozens of student research assistants and attracts industrial partners. The revenue from PEP's license agreements alone could help the university keep its tuition from rising for the next five or ten years. Of course, PEP must follow all government safety and health rules—you don't support breaking any laws—but you want everybody to remember how lucky the university is to have PEP. Maybe if PEP is successful, other nanotech firms might want to work with the university too. You've heard about the bright future of nanotechnology and you want the university to be a part of it.

Student 3b: Your name is Sam, a very bright and hard-working student who has been with the PEP research team from the beginning. You are studying electrical engineering while continuing to work for PEP. After graduation, you hope to get a highly paid, full time position there. You cannot reveal how the NanoSafe coating is made but you can say that all individual ingredients are safe for the environment and people, especially when considering that the coating requires such a small amount of material. You follow all the required protocols for disposing of chemical waste as you apply the coatings. Your cell phone and iPad are coated with this stuff and you wouldn't use it if you

didn't think it was safe. As far as you know, there's nothing dangerous about the PEP coating. You want to make sure they understand that. Besides, whatever affects PEP affects your future.

Student 3c: Your name is Ms. Ruth Anne Davis. You live in one of the houses across the street from the science building. Luckily, your house is not one of those which PEP is purchasing to demolish to make room for this ugly new building. It always seemed quaint to live next to a little college but now it is not a "little" college anymore. They get famous and the first thing they do is start messing up your neighborhood. All these new gizmos and doodads seem pretty neat to your grandchildren but you don't need any of them or any of the nano-whatever-it-is. You do feel safer wearing the emergency response bracelet that your daughter gave you last year. Just in case you fall or have a heart attack, it calls the hospital all by itself so you can get help quickly. It's very convenient and helpful, nothing like all these radios and telephones that kids walk around with these days. Anyway, you saw an episode of Sixty Minutes in which they stopped a company from polluting the air around a factory. You don't know if PEP is doing that but you are going to the library to find out. Maybe you can stop them from ruining your neighborhood.

Student 3d: You are Professor Charles DeWalt, a faculty member at the university for forty-five years. The things that today's students do really impress you. "Nanotechnology" wasn't even a word when you began working here and now a few of them started their own company. Back in the eighties, you worked with NASA engineers to design materials for the Space Shuttle. Some projects required you to work with hazardous chemicals for rocket fuels and fire-retardant foam insulation. It was only because the materials were so necessary that NASA was even allowed to use them. Over the years, you've experienced some unusual health problems—nothing severe but unpleasant none the less. There's no firm evidence that these materials caused your health issues but since then you have always encouraged students to avoid exposing themselves to dangerous chemicals, just to be safe. This concern for safety led you to join the protest outside of PEP's office. You are happy for their success but you want to make sure that they are protecting the student research assistants and the general public from harm. Since they won't tell you what's in NanoSafe, you are a little suspicious.

Student 3e: Your name is Ms. Kate Carlson, a chemical engineering alumna of the university, leader of the original student research team that developed the first nanothin coating that led to the founding of PEP, which you now serve as CEO. It has always been your dream to own a company that creates a product which lots of people enjoy. You and your employees have worked tirelessly to market NanoSafe and it is now paying off. PEP is on the cusp of becoming really profitable with major technology firms interested in licensing NanoSafe. You and all your employees could become very successful soon but you need to

remain careful. Public perception of your product is most important. Some consumers will not support companies which are not social responsible. While you believe that PEP's nanocoating does a lot of good (cell phones last longer so you buy fewer replacements), what matters is how consumers feel about it. You don't want these protests to create problems so you are very willing to listen. If there's anything you can do to make people feel better about the new research lab, it is worth it.

Student 3g: You are Raymond, a freshman student at the university. You think the nanothin coating developed by PEP is pretty cool and you want to get your iPod treated with it. What makes you really interested in this issue is the idea of the university holding its tuition under control for a few years. You were barely able to get enough student loans to cover tuition this year. If it keeps going up, you might have to transfer to another school. Sure, the environment is important and nobody should get a rash from holding their NanoSafe-coated cell phone but you hope the protesters don't go overboard with their objections. Your college career is on the line. You are attending this meeting to provide a voice for students in a similar financial situation and let people know about the economic benefits of this new research lab.

Student 3h: You are Greg Salvador, owner of cell phone kiosks at several nearby malls, including the one in town. Your family runs a profitable business by selling inexpensive cell phones to young teenagers. The technology is so cheap that your customers consider them almost disposable. You sell a few high end models also but most of your sales are to kids a phone and accessories for less than \$50. Your daughter attends the university and she told you about this new coating technology from PEP. It sounds like it could affect your business. You've talked with your customers and many say that they are replacing a phone with a damaged screen or one that got wet. You lose customers if they get a coating of the PEP stuff that makes their phones last longer. Some people are making a big deal about the jobs that this new research lab will create in town. You want people to know that it has bad consequences too. If the research lab gets cancelled because of environmental issues, that would be fine with you.

APPENDIX II (GRADING RUBRICS)

Panel Discussion Rubric

Rate each student panelist on his or her ability to:	
Make intelligent comments	___/ 5 pts
Play the character role	___/ 4
Support opinions with facts	___/ 5
Try to persuade others	___/ 4
Pay attention when in the audience	___/ 2
Total grade	___/ 20 pts

4.1. Report Rubric

- (1) (2 pts) What aspects of the research did you like and which aspects of research did you dislike?
- (2) (2 pts) What aspects of the discussion did you like and which aspects of the discussion did you dislike?
- (3) (3 pts) What did you learn from this assignment?
- (4) (3 pts) Was anything you learned unexpected?
- (5) (2 pts) What was your opinion of this issue you researched when you started the assignment?
- (6) (2 pts) Did your opinion change as you performed the research?
- (7) (2 pts) Did your opinion change as you participated in the discussion?
- (8) (2 pts) If you changed your opinion, what facts or ideas caused the change?
- (9) (2 pts) Did you change your mind about the other two topics discussed by other students while you were in the audience? If so, what was your original view and what was your view afterwards?

Acknowledgments: The author wishes to thank Andy Stanfield at the Florida Tech Center for Teaching and Learning Excellence, for his advice in designing this activity. The author acknowledges the support for developing this project provided by the Camille and Henry Dreyfus Foundation through a 2008 award from the Special Grant Program in the Chemical Sciences and by the National Science Foundation through a 2009 award from the Nanotechnology in Undergraduate Education (NUE) in Engineering program (award #0939355).

References and Notes

- Angelo, T. A., & Cross, K. P. (1993). Assessing skill in analysis and critical thinking. *Classroom Assessment Techniques* (2nd ed.), San Francisco, CA: John Wiley & Sons.
- Barakat, N., & Jiao, H. (2010). Proposed strategies for teaching ethics of nanotechnology. *NanoEthics*, 4, 221–228.
- Bhushan, B. (2004). Social and ethical implications of nanotechnology. In *Springer Handbook of Nanotechnology*. New York, NY: Springer-Verlag.
- Cobb, M. D., & Macoubrie, J. (2004). Public preceptions about nanotechnology: Risks, benefits and trust. *J. Nanoparticle Res.*, 6, 395–405.
- Ferrari, A. (2010). Developments in the debate on nanoethics: Traditional approaches and the need for new kinds of analysis. *NanoEthics*, 4, 27–52.
- Hammond, K. J. (1990). Case-based planning: A framework for planning from experience. *Cognitive Sci.*, 14, 385–443.
- Jacobs, J. F., van de Poel, I., & Osseweijer, P. (2010). Sunscreens with titanium dioxide (TiO₂) nano-particles: A societal experiment. *NanoEthics*, 4, 103–113.
- Martin, L. E., Stenmark, C. K., Thiel, C. E., Antes, A. L., Mumford, M. D., Connelly, S., & Devenport, L. D. (2011). The influence of temporal orientation and affective frame on use of ethical decision-making strategies. *Ethics and Behavior*, 21, 127–146.
- Miller, M. (2012). CES 2012: Want all your mobile gear to be water-proof? HzO can do it. *ZDNet*. Retrieved from <http://www.zdnet.com/blog/mobile-gadgeteer/ces-2012-want-all-your-mobile-gear-to-be-water-proof-hzo-can-do-it/5397>.

- NanoEthics. (2012). Retrieved from <http://www.springerlink.com/content/1871-4757/>. *Nanotechnology: The Power of Small* (2008). Retrieved from <http://powerofsmall.org/>.
- National Academy of Sciences, National Academy of Engineering, Institute of Medicine. (2009). *On Being a Scientist: Responsible Conduct in Research* (2nd ed.). Washington, DC: The National Academies Press.
- National Science Foundation. (2012). Nanotechnology Undergraduate Education (NUE) in Engineering. Retrieved from <http://www.nsf.gov/pubs/2012/nsf12534/nsf12534.pdf>.
- Nordmann, A. (2007). If and then: A critique of speculative nanoethics. *NanoEthics*, 1, 31–46.
- Roco M. C. & Bainbridge, W. (Eds.). (2001). Social science approaches for assessing nanotechnology's implications. In *Societal Implications of Nanoscience and Nanotechnology*. Retrieved from <http://www.wtec.org/loyola/nano/NSET.Societal.Implications/nanosi.pdf>.
- Roco, M. C. & Bainbridge, W. (Eds.). (2001). Societal implications of nanoscience and nanotechnology. Retrieved from <http://www.wtec.org/loyola/nano/NSET.Societal.Implications/nanosi.pdf>.
- Schuurbiers, D., Sleenhoff, S., Jacobs, J. F., & Osseweijer, P. (2009). Multidisciplinary engagement with nanoethics through education—the nanobio-RAISE advanced courses as a case study and model. *NanoEthics*, 3, 197–211.
- Seebaure, E. G. & Barry, R. L. (2001). Dealing with different ethical systems. *Fundamentals of Ethics for Scientists and Engineers*. New York, NY: Oxford University Press.
- Seebaure, E. G. & Barry, R. L. (2001). Dealing with different ethical systems. *Fundamentals of Ethics for Scientists and Engineers*. New York, NY: Oxford University Press.
- Sims, R. R. (2002). Debriefing experiential learning exercises in ethics education. *Teaching Business Ethics*, 6, 179–197.
- Smith, J. H. (2005). Topics and cases for online education in engineering. *Sci. Eng. Ethics*, 11, 451–458.
- Thiel, C. E., Connelly, S., Harkrider, L., Devenport, L. D., Bagdasarov, Z., Johnson, J. F., & Mumford, M. D. (2011). Case-based knowledge and ethics education: Improving learning and transfer through emotionally rich cases. *Sci. Eng. Ethics*, 1–22.
- Winkelmann, K. (2009). Practical aspects of creating an interdisciplinary nanotechnology laboratory course for freshmen. *J. Nano Educ.* 34–41.
- Kurt W., James M., & James B. (2008). Interdisciplinary lab course in nanotechnology for freshmen at the Florida Institute of Technology. In Sweeney, A. E. & Seal, S. (eds.), *Nanoscale Science and Engineering Education: Issues, Trends and Future Directions* (pp. 269–291). Stevenson Ranch, CA: American Scientific Publishers.
- van de Poel, I. (2008). How should we do nanoethics? A network approach for discerning ethical issues in nanotechnology. *NanoEthics*, 2, 25–38.

Received: xx Xxxx xxxx. Accepted: xx Xxxx xxxx.