AC 2007-2410: IMPROVING ETHICS STUDIES THROUGH A SPIRAL THEMED CURRICULUM: IMPLEMENTING ETHICS DISCUSSION AT THE SOPHOMORE LEVEL

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Improving Ethics Studies through a Spiral Themed Curriculum: Implementing Ethics Discussion at the Sophomore Level

Abstract

To enhance ethics training during the undergraduate career, engineering ethics material should be presented throughout the engineering curriculum. In continuation of the Department Level Reform (DLR) project, funded by the National Science Foundation (NSF), two departments at Virginia Tech aim to implement ethics throughout a four-year program by utilizing a spiral-themed curriculum. Preliminary work consisted of compiling a library of ethics case studies related to Biological Systems Engineering (BSE), particularly Bioprocess Engineering, along with different methods of implementing these ethics case studies. This work was presented during the 2006 ASEE Annual Conference and Exposition.[1] As the project moved to its second phase, the two departments have begun incorporating the library of ethics case studies in a designated sophomore course.

Initial work focused on genetically modified products because they incorporate several key ethical issues. A key theme of the spiral curriculum, sustainability can be observed as students review genetic modification of major food crops, such as cottonseed. Students may also study how different countries view genetically modified products while looking at labeling laws found in each country. Patents can be studied when looking at the patenting of specific genes and the idea of the terminating gene.

It was concluded the best method for incorporating ethics training into the BSE curriculum is to utilize already existing labs and projects by adding ethics material to them. Sophomores in BSE are currently required to take an Introduction to Biological Systems Engineering course in which they perform an oil extraction laboratory with cottonseed. As part of this laboratory, students were provided with a brief introduction to genetically modified products. They were then asked to consider potential differences that might occur in the production of cottonseed oil if genetically modified cottonseed were used as the raw material instead of the naturally occurring cottonseed as part of an informal written assignment and class discussion. For example, students were asked about labeling and marketing of the oil and if the production waste should be treated any differently.

Additionally, students completed a survey at the end of the ethics exercise to provide their feedback. Of interest was whether the students felt there was even an ethical issue present, the complexity of the thought process used when responding to the questions, students' openness to the discussion format, and the successes and challenges of implementing ethics material with this specific laboratory. A summary of these findings are presented in this paper.

Background and spiral approach

At an institution, 1200+ engineering intents enter the General Engineering (GE) program and have a common first semester offered by the Department of Engineering Education (EngE). Some of these students matriculate into the Department of Biological Systems Engineering (BSE). There exists a collaborative effort between some faculty of EngE and BSE, which is

funded under the department-level reform (DLR) program of the National Science Foundation (NSF). The goal of the DLR program between these two departments is to reformulate curricula within the EngE and BSE programs by using a theme-based spiral curriculum approach. The twentieth-century psychologist, Jerome Bruner, proposed the notion of a spiral curriculum in which basic ideas are visited repeatedly in an increasingly complex manner.[2] Figure 1 provides a visual description of the spiral curriculum being implemented by EngE and BSE faculty. One of the strategies used to teach themes of sustainability, design, systems, and ethics is the use of active learning in the form of hands-on activities. In the proposed reformulation, sustainability is the overall theme with ethics as one of the supporting themes for the spiral approach.

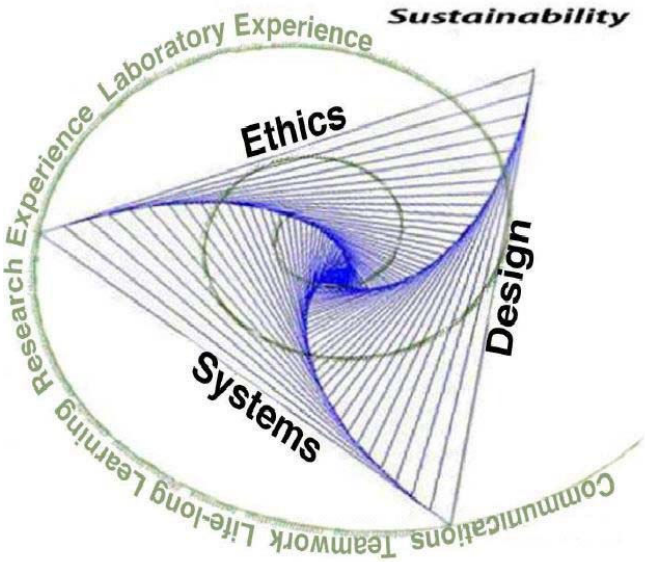

Figure 1. Schematic of a spiral theme based curriculum. Ethics, systems approach and engineering design will be revisited with increasing difficulty at each level or run.

In support of this approach, a library of ethics case studies related to Biological Systems Engineering (BSE), particularly Bioprocessing Engineering was developed. This library, along with different methods of implementing these ethics case studies were created as part of an undergraduate research project during summer 2005. The details from that work were presented during the 2006 ASEE Annual Conference and Exposition.[1] As the project enters its next phase, the two departments have begun incorporating the library of ethics case studies in a designated sophomore course in the BSE Department.

Freshman year: ethics instruction

One of the main objectives of the freshman introductory engineering course, taught by EngE is: Having successfully completed this course, the student will be able to demonstrate an understanding of professional ethics and application to real-life situations. During this course students watch the National Institute for Engineering Ethic's Incident at Morales video, which introduces ethics concepts such as public health, making tradeoffs, and differences in international laws. Students are required to read a chapter discussing basic moral theories and a few classic engineering case studies from Holtzapple and Reece's Concepts in Engineering.[3]

The three main moral theories studied are utilitarianism, ethical egoism, and rights ethics. Additionally students reflect on ethics as part of an electronic portfolio assignment and work in teams to perform skits acting out designated ethical situations. This introduction to professional ethics becomes the foundation for ethical training received in the upperclassman years.

BSE sophomore year: case studies

Initial case studies focused on genetically modified, or transgenic, products because they address several key ethical issues, including sustainability, labeling laws, and international controversy. Below is more information on these case studies.

Weed overgrowth is a major concern for farmers in large-scale crop production, leading to the production of herbicide-resistant plants. When a plant obtains an herbicide-resistant gene, the herbicide can be applied to the entire field, killing the weeds while retaining the desired crop. This genetically modified crop has the potential to save farmers money because they can spray an entire crop field with herbicide instead of spending precious money and time to tediously spray single areas to avoid the desired crop. The bacterium *Agrobacterium tumefaciens* has been utilized to produce herbicide-resistant versions of soy, canola, corn, sugar beet, and cotton.[4]

Crops that have been genetically modified to be herbicide-resistant have been considered a stronger crop than the naturally occurring ones. The balance nature maintains and how the modified crop may potentially alter the ecosystem must then be considered in implementing these altered crops.[5] People opposed to genetically altered crops are afraid the stronger crop will outgrow and overtake the natural version, virtually leading to the extinction of the natural plant.

The public wants to know the food it consumes is safe and will not harm the people who ingest it or the environment. As with any new area of biotechnology, positive and negative arguments can be made toward the use of transgenic crops. There is still much to be learned about how the individual genes inserted into different crops will affect the consumer, leading to a common concern in question: allergens. For instance, a company located in the United States, Pioneer Hi-bred developed a process for incorporating a methionine-producing gene found in Brazil nuts into soybean plants. The company performed tests on the altered soybeans to analyze allergen content. Results showed there was a possibility soybean plant consumption could trigger an allergic response in people sensitive to the nut. When presented with this information, Pioneer Hi-bred decided not to sell this particularly genetically altered soybean.[5]

Alternatively, Pioneer Hi-bred could have decided to produce the transgenic soybeans but label them. Labeling laws have become a controversy and vary depending on the host country. Labeling laws in the United States are relaxed with the exception of labeling added known allergens. Labeling regulators have reported they do not feel labeling is necessary because no problems with genetically modified foods is predicted. On the other hand, some believe labeling laws are not passed because it is feared labels will scare the public away from genetically altered foods. [6] In contrast, Europeans have much less trust for genetically modified products than Americans. The European Commission has even instated mandatory labeling guidelines through prolonged public and political pressure.[7] Within the last few years, Japan has also made the labeling of genetically engineered foods mandatory.[8]

Different labeling laws in each country also have the potential to affect the trade of transgenic crops. Because Europe has strict labeling laws, the United States may not be able to sell its herbicide-resistant corn to Spain.

Analyzing ethical case studies

Although fundamental moral theories are important, students must also be presented with basic methods for analyzing ethical situations which can be used as important tools throughout life. Similar to flowcharting, a concept map was introduced as one of these analysis tools. A concept map is a diagram connecting concepts with labeled arrows, in a branching structure and relationships between concepts are often expressed utilizing linking phrases. To create a flowchart or concept map, the student analyzes each possible decision that could be made given an example. The student can then observe the concept map to readily see the consequences of each decision.[9]

BSE sophomore year: course implementation

Currently, sophomores in BSE are required to enroll in an Introduction to Biological Systems Engineering course which includes the completion of an oil extraction laboratory. The lab exercise focuses on introducing systems concept (another spiral aspect, in addition to ethics and design) to the students through process flow, yield, and waste reduction aspects. A BSE faculty member introduces the lab material. Students then grind raw cottonseed, extract the oil, and refine the raw oil. The procedure exposes students to vegetable oil production, yield calculations and waste product disposal.

The main idea of a spiral curriculum is to continue revisiting the same subject material with increased difficulty at each occurrence. At the sophomore level, students revisited utilitarianism, ethical egoism, and rights ethics, three basic moral theories introduced at the freshman level. As a review students were asked to spend 10 minutes writing responses to the following five questions pertaining to their previous ethics exposure:

1.1. Define rights ethics
1.2. Define utilitarianism
1.3. Define ethical egoism
1.4. What else do you remember about ethics?
1.5. Identify possible ethics topics related to the BSE area.

Responses were collected to determine how much the students actually remembered from their freshman ethical experiences. The correct definitions were then discussed one week later in class.

Upon completion of the oil extraction laboratory, students are required to perform a formal write up, consisting of introduction, materials and methods, and results and discussion sections. Additionally, students were given a brief written introduction to genetically modified products, similar to the above case studies. They then completed an informal written assignment having them consider differences that might occur in the production of cottonseed oil if genetically

modified cottonseed were used as the raw material. The assignment included the following questions:

1. What, if anything, should be done differently (crop growth, oil production, selling oil, etc.) now that the genetically modified cottonseed is being used to produce the oil?

2. Do you think the oil needs to be labeled differently when marketed?

3. Do you think the cottonseed waste needs to be treated differently?

As part of the assignment, students were also asked to create concept maps which would identify possible scenarios for labeling transgenic cottonseed oil. Concept maps were expected to include at least one situation for labeling the oil and at least one situation for not labeling the oil. Positive and negative outcomes in each scenario, along with different perspectives (consumers, companies, etc.) should also have been considered. Students were given one week to complete the assignment.

Upon collection of the assignment, a graduate student from BSE led an informal class discussion regarding the potential ethical concerns of genetically modified products. The role of the graduate student was to provide discussion prompts and answer any questions students had. To begin the discussion, the students were asked to give their definitions of utilitarianism, rights ethics, and ethical egoism. They were then provided with a definition for each and asked to relate them to transgenic cottonseed oil production during the discussion. Throughout the discussion, students placed themselves in different perspectives (farmers, oil production companies, consumers, etc.) to analyze the situation. Additionally, two other case studies were presented to the class by the graduate student. These studies included the terminating gene which forces farmers to purchase crop seed from manufacturers every growing season and the genetic modification of rice to incorporate Vitamin A in an effort to reduce blindness in third world countries. Toward the end of the conversation students were asked, by a show of hands, whether they believed genetically modified products were an ethical concern, who would plant a genetically modified crop, and who would label cottonseed oil that had been produced with transgenic cottonseed. Other topics broached were differences in third world countries and when students would put themselves and their careers before the public safety. The goal of the discussion, lasting approximately 20 minutes, was to allow students to hear the varying views of their classmates.

The Departments of Biological Systems Engineering and Engineering Education are only beginning to implement this ethics training through a spiral themed curriculum so it is essential to orchestrate an assessment plan for future evaluation. The assessment tool utilized for this exercise was a survey which students spent ten minutes filling out after the class discussion. For questions 2.1 through 2.5, students were to circle the best response where:

1 is strongly disagree
2 is disagree
3 is no opinion
4 is agree
5 is strongly agree

2.1. I feel genetically modified products are an ethical concern.

1 2 3 4 5

2.2. I feel the class discussion format was beneficial.

1 2 3 4 5

2.3. I would like to see more discussions used in my courses.

1 2 3 4 5

2.4. I feel the use of concept maps is beneficial in analyzing the labeling of genetically modified cotton seed oil.

1 2 3 4 5

2.5. The topic of genetically modified products interests me.

1 2 3 4 5

2.6. What could be done to improve this exercise?

2.7. What did you enjoy about this exercise?

2.8. What are some other ethical topics related to BSE that you would like to learn about?

BSE sophomore year: assessment

Prior to submitting the ethics written assignment, students completed five questions pertaining to their previous ethics experiences. Responses to the first three questions were tabulated and recorded. As shown in Table 1, 25 students submitted complete questionnaires, with 60 % responding with the correct definition for rights ethics (Question 1.1), 44 % responding with the correct definition for utilitarianism (Question 1.2), and 64 % responding with the correct definition for ethical egoism (Question 1.3). Question 1.4 was an open ended question, asking the students to write what else they remembered about their previous ethics instruction. Common responses included the following:

- Ethics vary from person to person, especially with differing moral beliefs and approaches to analysis (6 students)
- Watching the Incident at Morales video (2 students)
- Honesty is important (3 students)
- Engineers follow a code of ethics (2 students)
- Not much or very little (4 students)

Question 1.5 asked students to identify possible ethics topics related to BSE. Common topics included:

- Environmental issues, including land development, natural resource and wild life management, sustainability, etc. (13 students)
- Food safety (3 students)
- Genetically modified products, including plants, food, and pharmaceuticals (16 students)
- Cloning (2 students)
- Animal rights, particularly related to product testing (3 students)
- Biopharmaceuticals (2 students)
- Don't know (2 students)

Table 1. Responses to preliminary ethics questionnaire.

	Question 1.1 (Rights Ethics)	Question 1.2 (Utilitarianism)	Question 1.3 (Ethical Egoism)
Number Correct (Out of 25 Responses)	15	11	16
Percent Correct	60	44	64

Students had one week to complete an informal written assignment having them consider the differences that might occur in the production of cottonseed oil if genetically modified cottonseed were used as the raw material. Students were to write short answers to three questions and create a concept map to be used in analyzing whether oil produced from transgenic cottonseed oil should be labeled. Students were able to use material provided in the handout about ethics case studies related to genetically modified products or could perform external research for the project, although it was not required. Of the 24 students who turned in the assignment, 15 students simply repeated the material provided in the hand out, while only two students performed outside research, and 11 students thought beyond the material given them (with or without external research). To be considered complete, assignments were to include positive and negative outcomes in each scenario along with different perspectives (consumers, companies, farmers, etc.) for labeling transgenic cottonseed oil. Of the 24 assignments submitted, 21 students discussed scenarios for labeling and not labeling the oil, 21 students included the positive and negative aspects for each, and 18 students included scenarios from different perspectives. At the beginning of the assignment there was a concern students had not previously been exposed to the idea of concept maps, so website links containing information on concept maps were provided to the students in the handout. Assignment analysis concluded 17 students understood the idea of a concept map in the analysis of this specific ethical situation.

One goal of the written assignment was to have students look into an ethical situation and use their concept maps and responses to form their own opinions toward the use of genetically modified products. Once assignments were collected, a graduate student from BSE led an informal class discussion concerning genetically modified products. This discussion allowed students to share their opinions toward the situation with their classmates. To begin the discussion, the class worked together to provide definitions for utilitarianism, rights ethics, and ethical egoism. Having completed the assignment, students were able to apply these moral

theories to transgenic products. Throughout the discussion, students utilized different perspectives, including that of differing countries, farmers producing cotton, consumers buying cottonseed oil, cotton seed manufacturers, and cottonseed oil manufacturers, to analyze the ethic case study. Students applied the different moral theories for each perspective and concluded money, individual careers, and public safety are key factors in which a person may consider in deciding what to do in a similar situation. The class also discovered their opinions toward the situation varied depending on which perspective students placed themselves into. As with any exercise, some students were more involved than others, but the discussion was an important learning tool. Through the discussion, students had the opportunity to learn about a topic that they may otherwise take for granted. It was also an eye-opening experience for some students as they were able to see not all of their classmates share the same opinions. This will prove to be imperative when they enter the industrial world and an ethical situation arises in the work place.

At the end of the ethics exercise, students spent about ten minutes answering eight questions. The responses to this survey were then utilized in the evaluation of the ethics exercise presented in this paper. Students selected the best answer for questions 2.1 through 2.5, where 1 was strongly disagree, 2 was disagree, 3 was no opinion, 4 was agree, and 5 was strongly agree. As seen in Table 2, responses to these five questions were tabulated and recorded. On average, the 26 responding students agreed (4.1 ± 0.7) genetically modified products are an ethical concern (Question 2.1), agreed (4.1 ± 1.0) the class discussion was beneficial (Question 2.2), agreed (4.2 ± 0.8) they would like to see more class discussions used in their courses (Question 2.3), had no opinion (2.9 ± 0.8) toward the use of concept maps being beneficial in analyzing the labeling of genetically modified cottonseed oil (Question 2.4), and agreed (4.1 ± 0.8) the topic of genetically modified products interested them (Question 2.5). Question 2.6 was an open ended question, asking students to write what they believed could be done to improve this ethics exercise. Common responses included:

- Cover a different topic (2 students)
- Did not understand concept maps (2 students)
- More (background) information on topic (8 students)
- Smaller group discussions (2 students)
- Nothing (4 students)

Question 2.7 asked students to identify what they enjoyed about this exercise. Common responses included:

- Hearing others' opinions (6 students)
- The topic: learning something new (5 students)
- The discussion portion (12 students)
- Class and department interaction (2 students)
- No response (1 student)

Question 2.8 asked students to identify other ethical tops related to BSE that they would like to learn about. Common responses included:

- Environmental Concerns, including land use, logging, habitat destruction, recycling, etc. (5 students)
- Pharmaceuticals, including biopharmaceuticals (5 students)
- Genetically modified animals (3 students)
- Not sure (2 students)
- No response (10 students)

Table 2. Results of end of exercise survey completed by students.

Question		Average (Out of 5)	Standard Deviation
2.1	I feel genetically modified products are an ethical concern.	4.1 (agree)	0.7
2.2	I feel the class discussion format was beneficial.	4.1 (agree)	1.0
2.3	I would like to see more discussions used in my courses.	4.2 (agree)	0.8
2.4	I feel the use of concept maps is beneficial in analyzing the labeling of genetically modified cotton seed oil.	2.9 (no opinion)	0.8
2.5	The topic of genetically modified products interests me.	4.1 (agree)	0.8

Lessons Learned

To enhance ethics training during the undergraduate career, engineering ethics should be taught throughout the engineering curriculum. As the DLR project moved into its second phase, BSE sophomores enrolled in the Introduction to BSE course took part in an additional ethics exercise. The exercise was part of an already existing laboratory and consisted of a preassignment questionnaire, written assignment, and an in class discussion. Additionally, to gather feedback, students completed a survey at the end of the exercise. The following are some of the lessons learned through the implementation of this ethics exercise.

While students were filling out the preassignment questionnaire, the written assignment, which included an introduction to genetically modified products, was handed out. Perhaps consequently, a large number of the students (16 out of 25) identified genetically modified products as a possible ethics topic related to BSE. To truly gain an understanding as to what the students feel are ethical issues related to BSE, the written assignment should be passed out after the questionnaires have been collected the next time this exercise is performed.

The class was provided with basic information about genetically modified crops in an effort to provide an introduction to students with no previous exposure to genetically modified crops. The main goal of the written assignment was to have the students critically analyze the situation and think outside of the material presented to them. However, of the 24 students submitting the written assignment, 15 students simply repeated the material provided to them in the hand out. When the exercise is repeated, it may be necessary to include a small research requirement with the assignment to further the students understanding of the topic, allowing them to think more about the topic and expand their responses and concept maps.

At the beginning of the ethics exercise there was concern students had not previously been exposed to the idea of concept mapping, so website links containing information on concept maps were provided to the class in the handout. However, assignment analysis concluded only 17 of the 24 students submitting assignments understood the idea of a concept map. Additionally, student responses to the survey were not overwhelmingly positive toward the use of concept maps in the analysis of labeling genetically modified cottonseed oil. Therefore, when the assignment is handed out, it may be advantageous to provide a brief verbal introduction to concept maps along with the website links already provided.

After completing the written assignments, students were easily able to provide definitions for utilitarianism, rights ethics, and ethical egoism when asked at the beginning of the discussion section of the exercise. Even more interesting is when asked for the definitions, students were automatically able to relate these moral theories to genetically modified products. Additionally, during the discussion students asked the graduate student questions about genetically modified products, specifically how much of the world's products are created from transgenic materials. It would be beneficial to know these statistics before entering the discussion. They may even provide a good introduction to the discussion.

At the completion of the ethics exercise, students completed an eight question survey. This survey lead to the conclusion students believe the class discussion format was beneficial and would like to see more class discussions used in their other courses. Other discussion formats which may be utilized include small group class discussions and small group online discussions.[1]

Future work

As the Departments of Biological Systems Engineering and Engineering Education are only beginning to implement this ethics training through a spiral-themed curriculum, it is essential to orchestrate an assessment plan for future evaluation. The use of a preassignment questionnaire and post assignment survey for this particular exercise demonstrated the need for a pre and post analysis tool to be utilized in future course implementation. Additionally, it would be useful to learn how the students perceive engineering ethics training and its importance to the industrial society, along with the way students' analysis of ethical situations changes after receiving exposure to engineering ethics training. To better understand students' perception to engineering ethics and training, Clancy et al. issued a 16 question survey before and after ethics training through case studies.[10] To better understand students' moral reasoning in analyzing ethical situations, Loui[11] issued the Defining Issues Test (DIT) before and after students watched the Incident at Morales video. To provide a better analysis of the implementation of ethics through a

spiral curriculum, the DLR project should turn to these previous studies in developing a tool to be issued before and after the ethics exercises.

As the DLR project moves into its third phase, EngE and BSE will begin incorporating the library of ethics case studies into designated junior level courses in BSE. This third phase will include the further implementation and assessment of developed case studies into the Bioprocessing curriculum. In addition, the ethics exercise described in this paper will be rerun with sophomores in the 2007 Introduction to Biological Systems and similar exercises will be incorporated into senior year courses during the fourth phase of the DLR project (2008). This continued implementation will provide the opportunity to look at a longitudinal study, tracking a single cohort through the BSE program. Additionally, student responses to questionnaires will be utilized to develop additional case studies which will be added to the library previously described.

Acknowledgements

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