2006-914: IMPROVING ETHICS STUDIES THROUGH A SPIRAL THEMED CURRICULUM IN BIOLOGICAL SYSTEMS ENGINEERING

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Improving Ethics Studies through a Spiral Themed Curriculum

Abstract

To enhance ethics training during the undergraduate career, engineering ethics material should be presented throughout the engineering curriculum. The Departments of Engineering Education and of Biological Systems Engineering at Virginia Tech aim to implement ethics throughout a four-year program by utilizing a spiral curriculum, that is to continue revisiting the same subject material with increased difficulty at each occurrence. This is one of the goals of the Department Level Reform (DLR) project at this university, funded by the National Science Foundation (NSF). The two departments have started to compile a library of ethics case studies related to Biological Systems Engineering, particularly Bioprocess Engineering, along with different ways to implement these ethics case studies. The preliminary work was performed as part of an undergraduate research project during summer 2005.

As initial work, genetically modified products were chosen as the main topic because it includes several key ethical issues. Sustainability can be observed when students review the genetic modification of major food crops, such as corn and soybeans. Students may study how different countries view genetically modified products while looking at the labeling laws found in each country. Intellectual property can be studied when looking at the patenting of specific genes and the idea of the terminating gene. Animal rights can be discussed when looking at different transgenic animals and how they are used once produced. The aforementioned issues may be addressed by including ethics training into the Biological Systems Engineering curriculum through existing labs and projects. These ideas may be incorporated in the form of a class discussion, a posting to an electronic portfolio, an online discussion, an assignment of a research project, and questions as part of a write up.

Background and spiral approach

At Virginia Tech, engineering intents enter the General Engineering (GE) program and have a common first semester; GE students are required to take a first semester, introductory engineering course, which is offered by the Department of Engineering Education (EngE). One of the main objectives of the course is: Having successfully completed this course, the student will be able to demonstrate an understanding of professional ethics and application to real-life situations. Hence, the freshman year is an opportunity to introduce students to professional ethics, which becomes a foundation for ethical training received in upperclassman years. Because the 1200+ entering freshman students who are enrolled in the common engineering course will enter one of twelve different departments after their first year of studies, the ethics instruction given by EngE faculty must be broad enough to serve a wide audience.

Some of these 1200+ students will 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 NSF. The goal of the

DLR project 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. [1] 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.

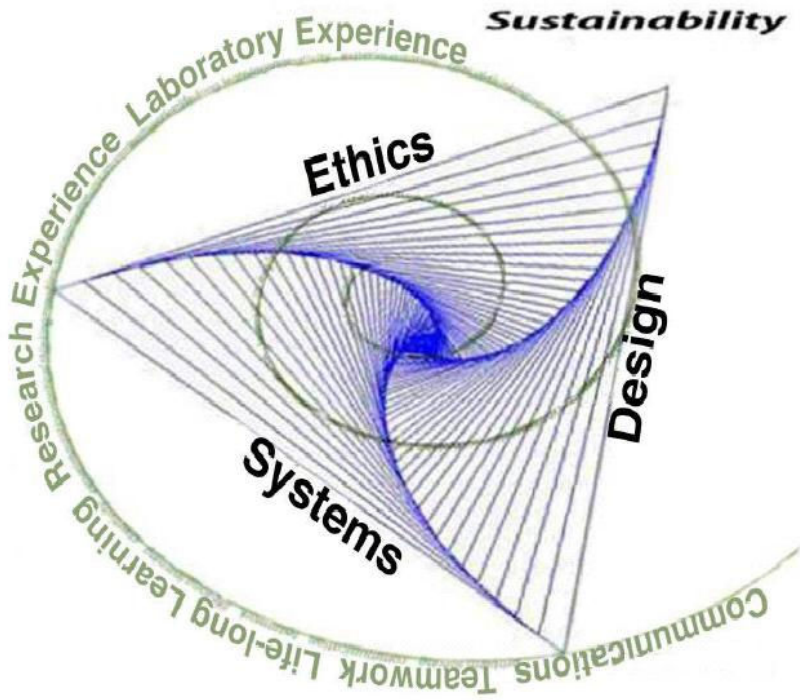

Figure 1. Schematic of a spiral theme based curriculum. Ethics, systems approach and engineering design will be revisited with increasing difficulty at each level or run.

In support of this approach, the two departments have started to compile a library of ethics case studies related to Biological Systems Engineering, particularly Bioprocess Engineering, along with proposed methods of implementing these ethics case studies. The preliminary work was performed as part of an undergraduate research project during summer 2005 by BSE undergraduate student Christan Whysong.

Freshman year

In fall 2005, significant changes were made in the delivery of ethics materials in the first semester engineering course. Freshman students watched the National Institute for Engineering Ethics' Incident at Morales video, which introduced ethics concepts such as public health, making tradeoffs, and differences in international laws. In addition, students read a chapter consisting of explanations of basic moral theories and a few classic engineering case studies

from Holtzapple and Reece's Concepts in Engineering.[2] The three main moral theories students studied were utilitarianism, ethical egoism, and rights ethics.

Students also reflected on ethics as part of an electronic portfolio assignment. This electronic portfolio is owned by the student while he/she is enrolled at this university. BSE intends to use electronic portfolios to encourage students to reflect on and maintain a record of their educational experiences. Lastly, students worked in teams to perform research and present ethics related material within the context of recent concerns and events related to natural disasters such as hurricanes, tsunamis and earthquakes; this presentation assignment is presented in a companion paper.[3] This basic ethics instruction creates a foundation for ethics instruction that occurs in the upperclassman engineering curricula.

BSE sophomore year: case studies

The main idea of a spiral curriculum is to continue revisiting the same subject material with increased difficulty at each occurrence. At a sophomore level, students will revisit the basic moral theories they learned in their freshman year and have the opportunity to learn more. Students may consider how utilitarianism can apply to the genetic modification of herbicide-resistant crops and how rights ethics can apply to the labeling of foods potentially containing allergens. The moral theory of prima facie duties may also be introduced at this level. Below is more information on these case studies.

Although the fundamental moral theories presented freshman year show students how ethical decisions can affect different groups of people, students must also be presented with basic methods of analyzing ethical examples that are observed. Two proposed methods for analyzing ethical problems are line drawing and flowcharting. Line drawing is performed by sketching a horizontal line. At the negative side of the line, the student writes an unambiguously unmoral situation while an unambiguously moral situation is placed at the positive end. The student then fills in the given example and analyzes whether the example is more positive or negative. To create a flowchart, a student analyzes each possible decision that could be made in a given example. The student can then readily see the consequences of each decision.[4]

Weed overgrowth is a concern for farmers in large-scale crop production and much work has been done to produce herbicide-resistant plants. When an herbicide-resistant gene is inserted into the crop, the herbicide can be applied to the entire field, allowing for the termination of the weeds but leaving the desired crop unaffected. This genetically modified crop has the potential to save the farmers money because they can spray the entire crop field with herbicide instead of spending more money on time to spray single areas while gingerly avoiding the crop. Herbicide-resistant versions of soy, canola, corn, sugar beet, and cotton have been achieved by inserting a gene from the bacterium *Agrobacterium tumefaciens*.[5]

The herbicide-resistance genetic modification of crops effectively produces crops that are stronger than the naturally occurring ones. One must be concerned, then, about the precious balance that nature maintains and how the altered crop may accidentally cause ecosystems to adjust in unpredictable ways.[6] People who are opposed to this kind of crop modification are

afraid the stronger crop will outgrow and overtake the unaltered version, making it impossible for the unaltered crop to sustain itself, leading to the extinction of the natural plant.

There is a wide mistrust of genetically modified, or transgenic, crops. The public wants to know that the food consumed is safe and will not harm consumers or the environment. A major concern in question is allergens. Since genetically modified foods are relatively new, there is still much to be learned about how the individual genes inserted into the different crops will affect the person consuming them. For instance Pioneer Hi-bred, a company located in the United States, developed a process for incorporating a methionine-producing gene found in Brazil nuts into soybean plants. The company performed experiments on the altered soybeans to analyze allergens. The tests showed the possibility that the consumption of the soybean plant could trigger an allergic response in people sensitive to the nut. When presented with this information, Pioneer Hi-bred decided not to sell the genetically altered soybeans.[6]

Pioneer Hi-bred could have decided to produce the genetically altered soybeans, but label them instead. Labeling laws are a controversy and vary from country to country. Labeling laws in the United States are relaxed with the exception of labeling added known allergens. Labeling regulators report they do not feel labeling is necessary because they do not foresee any problems with the genetically modified foods, but some believe they do not pass labeling laws because they fear the labels will scare the public away from the genetically modified foods.[7] Europeans, however, have much less trust for genetically modified foods than Americans. The European Commission has even instated mandatory labeling guidelines through prolonged public and political pressure.[8] Within the last few years Japan made the labeling of genetically engineered foods mandatory.[9]

The different labeling laws in each country also affect the trade of genetically modified crops. If the United States is producing herbicide-resistant corn and wants to sell it to Spain, it probably will not be allowed to because Europe has strict labeling laws, unlike the United States.

BSE sophomore year: course implementation

Currently, BSE sophomores are required to enroll in a fall semester introductory course which includes an oil extraction laboratory. Students are presented with raw cottonseed and instructions for grinding and extracting cottonseed oil. The procedure exposes students to vegetable oil production, yield calculations and waste product disposal. It was proposed to have the students consider cottonseed that has been genetically modified, for example cottonseed that has been made herbicide-resistant. The students would be asked how they believe the oil extraction procedure and oil would differ upon the use of genetically altered cottonseed, whether they believed the oil needs to be labeled any differently than the natural cottonseed oil, and whether the waste should be treated any differently. To compound their freshman course studies, the students could be asked to draw a flowchart and use the basic line drawing method to show the decision making process for labeling the genetically modified cottonseed oil and the potential outcomes. After having students consider these questions individually, the instructor would lead a structured group discussion during class to allow the students to hear different views. To assist

in the observation of different views within the class, several students would be asked to share their flow charts and line drawings with the class.

BSE junior year: case studies

At a junior level, students revisit the basic moral theories they learned in their freshman and sophomore years and have the opportunity to expand on these. Students may observe utilitarianism, rights ethics, prima facie duties and ethical egoism by studying genetically modified animal products such as pigs and dairy cattle. The moral theory of virtue ethics may also be introduced at this level. The following is more information on these case studies.

Genetic engineering also occurs in animals raised for consumption. In the mid-1980's the Beltsville research facility, operated by the United States Department of Agriculture, worked to increase the growth rate of pigs by incorporating a gene coding for human growth hormone into the genome of the pig embryos. These pigs, known as the Beltsville pigs, created negative press when they developed spinal deformities and severe arthritis, became cross-eyed or blind, and were impotent.[8]

Although similar transgenic animals would contribute to the food production and perhaps to the profits being made in the industry, one must decide whether it is worth the pain and suffering of the animals at stake. Regulation of these animals rests within different organizations and varies depending on what country the animal is in. In the United States the Animal Welfare Act protects all experimental farm animals. In Britain the Animal Scientific Procedures Act of 1986 protects work performed with transgenic animals. However, licenses are awarded when the benefit to the human population far outweighs the suffering of the animal.[8]

Similar to the Beltsville pigs, dairy cattle are commonly injected with bovine growth hormone (BST) which is important for increasing milk production by between 15 and 25 percent.[8] The BST injections sometimes create a serious udder infection called mastitis in cows. This occurs when the udder becomes painfully inflamed, is detected by the observation of pus on the udders, leads to discolored milk, and is typically treated with antibiotics.

BSE junior year: course implementation

Currently in the spring of the junior year, students are required to take a unit operations course and laboratory. One of the labs performed is the heat exchanger lab. During this experiment students are presented with a tube heat exchanger and observe the temperature changes that take place when different liquids are run through the apparatus. One of these liquids is cow's milk.

It was proposed to present students with basic information about BST injections in dairy cows and how they can affect the animals and then ask them several questions related to this information. Students could be asked how they felt about the increase in mastitis in cows when BST is used to produce more milk, if they believe BST injections should continue to be given, and which milk they would choose to purchase if given the choice between naturally occurring milk or milk produced using BST injections. Students would be asked to prepare individual

answers to these discussion topics and then engage in an online discussion consisting of no more than three students.

Use of online discussions has already been piloted in food processing, a senior level course. In the food processing course, each group agreed on a common time to meet online and discuss instructor specified questions for at least 30 minutes. Each group turned in a copy of its transcript to the professor. A grading rubric was provided before the discussions were held, and these hard copies were evaluated as such. Students were mainly graded on their input to the discussion. Major benefits to this assignment include having students perform real time research into the provided topics, more free conversation without the presence of a professor, and a hard copy which can be graded and saved for future program assessment.

For the unit operations course, a similar online discussion is proposed. Each group would turn in a transcript of its online discussion, which would be analyzed using an instructor generated rubric. It is possible that the grading rubric might differ from an assessment rubric. For example, the grading rubric might involve level of student engagement by number of responses, length of responses, etc while an assessment rubric would not only look at how many times each student responds and the quality of such responses (meaningful statements versus fillers such as "Yeah", etc.) but also use of facts versus opinions, mention of ethics terminology, level of critical thinking, etc..

In addition, the students would use the flowcharting method to analyze these questions. As a concluding assignment, the students would create an entry in their electronic portfolios, discussing their individual feelings about the use of BST, the flowcharts they created, and how their viewpoints changed after online discussions with their peers and the creation of flowcharts.

BSE senior year: case studies

At a senior level, students revisit the basic moral theories they learned in their freshman, sophomore, and junior years and have the opportunity to learn more. Students may apply ethical egoism, virtue ethics, and utilitarianism by studying the patenting of genes, specifically the terminating gene. The following is more information on this case study.

Genetically modified foods provide the chance for improved food quality and quantity. They also provide the chance to increase the amount of money being earned during crop production and sale. Just as toys or machines can be patented to a specific company or person, in some places it is possible to patent specific genes so that no one else can use or do work with them without special permission. With much debate, the first living organism, a genetically altered oil-degrading bacterium, was patented in 1980. The patent was only allowed when the Supreme Court considered it to be man made because it did not exist naturally.[9] Some companies obtain patents to block anyone else from profiting from a specific gene, however there are a few companies who provide royalty-free licenses which allow others to work on their patented genes, furthering the development in their research area.

One gene that has become popular to patent is called the terminating gene. The gene is typically incorporated into a crop that has been genetically modified to benefit the farmer. Unfortunately

the technology surrounding the gene enables farmers to grow their crops but not recover the seeds to be planted for the next growing season. The gene alters the crop so that the seeds can not germinate, forcing farmers wishing to grow the crop to purchase new seeds every year in order to continue growing the genetically engineered crop. This practice provides customers to the companies, creating a "monopolists dream."[7] Instead of using the genetic modification of the crop to produce an improved food supply, the gene increases the farmer's dependence on the producing company.

BSE senior year: course implementation

This is a good opportunity for students to revisit the concepts related to intellectual property. Patents are briefly touched upon in the freshmen introductory engineering course as well as in the sophomore year. This case study provides another opportunity to expand on patent law right before graduation.

In order to enable senior level students to use accumulated ethics knowledge to analyze a provided situation, it is proposed to include a combination of online and classroom ethics discussions. For example students would be presented with the example of a developing country which has decided to grow corn as its major crop. The country must decide between two companies in purchasing its corn seed to initialize its crop. The first company, Bob's Corn Company, sells naturally occurring seed. The second company, Grasshopper Maize Producers, sells corn seed that has been genetically modified to be herbicide-resistant, however this genetic modification does not allow for the capture of seed to be reused with the next growing season. This would force the country to buy seed every year from Grasshopper Maize Producers. Students would be asked to individually analyze the provided situation using either the flowcharting method or the line drawing method. Each student would determine which company the country should purchase corn seed from and if the herbicide-resistant corn should be labeled any differently than the natural version when sold. The student must then identify what moral theories he/she used to form his/her conclusions. Once decisions are made, students would split into their online groups and hold an online discussion describing the different thinking processes used and the different decisions made. At the discussion conclusion, a summary should be written describing the difference in decision making procedures students used. The conclusion and discussion transcript would be submitted to the professor for evaluation. The faculty member would conduct a classroom discussion that would allow students to further reflect on their discussions, to hear additional viewpoints by other classmates, and to hear concluding remarks from the professor.

Assessment

The Departments of Biological Systems Engineering and Engineering Education are only beginning to implement this ethics training through a spiral themed curriculum so it will be essential to orchestrate an assessment plan for future evaluation. The proposed assessment plan currently includes an analysis of focus group interviews, online surveys, online discussions, classroom discussions, and electronic portfolio entries. For the last two years, the Department of Engineering Education has started to collect data regarding student perceptions of engineering

ethics training in the freshman year; these studies will be expanded to include BSE students in their upperclassman years.

Future work

Future work includes piloting the preliminary case studies and assessing the effectiveness of the introduction of said case studies in Bioprocess Engineering at this university. In addition, additional case studies will be added to the case studies described in this paper.

Acknowledgements

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