Integrating Ethics into a Research Experience for Undergraduates

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Abstract – **A regular weekly seminar on engineering ethics has been part of an ongoing NSF-sponsored Research Experience for Undergraduates initiated in 2003. The seminar has always featured active student-centered learning centered on applying ethical principles to daily situations in education, research and the engineering profession. In summer 2004, students were further challenged to consider and investigate and present about how ethics relates to their summer research project. In the seminar, topics include introduction to ethical frameworks, professional codes of ethics, academic/research integrity, and sustainable engineering. The methods used in the class include brief slide shows reviewing key points, interactive case studies (written and video), an ethics game involving many short cases, and student presentations linking ethics to their research projects. This paper reviews the processes and techniques developed over the three years of the program.**

Index Terms – engineering ethics, sustainability, undergraduate research.

BACKGROUND

The Research Experiences for Undergraduates (REU) program is supported by the National Science Foundation (NSF) and supports active research participation by undergraduate students in any of the areas of research funded by the NSF. There are hundreds of REU sites at universities around the United States, with 158 in engineering alone as of 2006. REU projects involve students in meaningful ways in ongoing research programs or in research projects designed especially for the purpose.

The Electrical Engineering REU Site at the Pennsylvania State University's University Park Campus was awarded for five years beginning in 2003. The program supports 14 students each year for research in electrical engineering. The REU site is designed as a nine-week summer experience. Students have an opportunity to participate in a broad range of research projects that include both traditional and emergent interdisciplinary fields of electrical and electronics engineering. The program introduces participants to hands-on, cutting-edge research experiences especially designed for undergraduate students. Each student participant is paired with a faculty mentor to work on a specific research topic. In addition students participate in a number of group activities such as weekly research seminars and biweekly field trips to world-renown research centers. At the end of the summer program a mini research symposium is held to give students an opportunity to share their experiences. Students are selected nationwide with an emphasis on junior-level students outside of the University Park Campus that desire research opportunities. Current research collaborations with other universities are used to assist in attracting students from population groups underrepresented in research fields in engineering. This program seeks to broaden opportunities and enable participation of domestic undergraduate students in research careers in engineering.

One of the features of the EE REU summer program at Penn State is a one-hour weekly seminar on engineering ethics. Conceived in response to the emerging attention to ethics in the engineering curriculum, this topic has proven to substantially enrich the students' learning about the engineering profession, engineering research, and life as a student.

ETHICS IN CONTEXT

Ethics has been a part of engineering education in some programs for some time. After being incorporated into the Accreditation Board for Engineering and Technology's (ABET) engineering education outcomes beginning in 2000, it has become a topic that is of interest to all accredited programs. The past several years has seen a flurry of activity among educators.

There are numerous approaches to teaching engineering students about ethics. Some programs rely on specific courses wherein most of the content is ethics-related, some taught outside the engineering departments, and some within. Another approach is to integrate ethics topics into the engineering curriculum. This latter approach has been employed at the college level at Penn State and has been supported by summer in-house workshops for faculty members [1]. The author supports this approach because it helps reinforce to students, and perhaps to faculty too, that ethics is relevant to most of engineering practice.

At the 2002 Gonzaga Ethics Conference, Father Robert Spitzer, Gonzaga President, gave an inspiring presentation wherein he made a distinction between minimalist ethics and maximalist ethics. Minimalist ethics is proscriptive, giving direction about what not to do, like most of the Ten Commandments. While this is useful perhaps as a foundation

or a bottom line, it says little about making the most of one's life from the standpoint of doing good in the world, i.e. maximalist ethics. Much of the canons and rules of practice found in engineering codes of ethics are in the form of proscriptive statements, e.g. "Avoid deceptive acts." It is difficult to be inspired or passionate about doing no wrong.

Maximalist ethics, on the other hand, is exemplified by engineers who go beyond the minimum required of them to ensure that their projects do maximum good, and cause minimal harm, while meeting all of the other constraints of the project. Maximalist ethics is called for by the first canon of the National Society of Professional Engineers code of ethics: "Engineers, in the fulfillment of their professional duties, shall hold paramount the safety, health, and welfare of the public." [2] While safety has been in the focus of engineering for some time, considering how to practice engineering to provide for improved health and welfare clearly is a maximalist challenge. This canon is strongly connected to the concept of sustainability that calls for "meeting the needs of today without diminishing the ability of future generations to meet their needs." [3] Indeed, in the NSPE code of ethics, under Professional Obligations is the principle III.2.d: "Engineers shall strive to adhere to the principles of sustainable development in order to protect the environment for future generations." [2]

An example of maximalist engineering practice is the design of a pumping system for Interface, a major carpet manufacturer, for a new facility in Shanghai [4]. A consultant designed a system, with conventional means, that required a 95 horsepower pump. After considering the impact of the conventional design on energy use and resultant resource use and pollution production, Interface engineer Jan Schilman redesigned the piping system such that only a 7 hp pump was required, a 92% reduction. This was achieved in two ways, by using larger diameter pipes and by reducing the pipe length and number of turns. It turned out that conventional design wisdom results in relatively small diameter pipes and large horsepower pumps, and does not emphasize the placement of components to allow for short, straight runs. The conventional design process also ignores the resource and environmental consequences. Switching to large pipes allows the pumps to be smaller in power and size, thereby reducing their cost and offsetting the higher cost of the piping. Furthermore, the large pipe system uses drastically less operating energy, reducing resource use and the resultant pollution. By thinking outside the box and considering the moral implications of energy inefficiency, Mr. Schilman designed a system that did not cost more to purchase, saves enormously on energy cost, and reduces resource use and pollution production. And the job of moving the fluid from point to point is achieved.

Maximalist ethics is also exemplified by the phenomenon of green buildings, buildings that use less than half the energy and nonrenewable resources as other buildings, while providing beautifully daylit spaces that are healthier for workers and lead to greater productivity, often for little or no additional up-front cost. The result of applying a maximalist approach to ethics is to become a person of integrity and good character, with the satisfaction and fulfillment of having done a lot of good in the world, not just for one's employer, but also for the larger society of people and life in general.

OBJECTIVES

The overarching goal of the ethics seminars during the EE REU summer program is for students to appreciate the prevalence of ethical issues in engineering practice and the requisite need for moral imagination so that they can maximize the good that results from their work. Moral imagination is "an ability to imaginatively discern various possibilities for acting in a given situation and to envision the potential help and harm that are likely to result from a given action." [5] It involves at least two skills, one being able to imagine many possibilities and their consequences, a creative element, and the other being able to morally evaluate the possibilities, a more rational element (but not purely rational).

The seminars are successful if students recognize that most of what engineers do has ethical implications, and that it is these day-to-day choices that ultimately determine personal character as well as the overall benevolence of one's work. Many of our problems with technology can be described as the revenge of unintended consequences. Decisions that appeared to be good ended up having serious negative moral consequences. With better moral imagination, many unintended consequences can be anticipated and considered in the decision making process.

In addition to the overarching objective, there are several other learning objectives. Students should be able to:

- Explain, in everyday terms, some of the basic ethical philosophies and their limitations.
- Apply problem-solving processes for solving ethical problems.
- Make a well-reasoned argument for action in an ethical case.
- Work more effectively in a group.

TOPICS AND PROCESS

Each week of the nine-week summer REU session, the students meet for a one-hour technical seminar given by one of the research faculty. This is followed by an informal luncheon providing an opportunity for students and some faculty to socialize. A one-hour ethics seminar is conducted afterwards, usually led by the author.

The emphasis during these weekly seminars is on engaging the students in thinking about ethics and applying it to situations in academic, personal, and professional contexts. Several successful techniques have been developed and will be discussed in the next section in more detail. Much of the activity is based on selected case studies, thought through in

small teams, and discussed as a larger group. Students are encouraged to ask questions, justify their opinions, and critique arguments. The atmosphere is intended to be somewhat informal so that students are comfortable in sharing their thoughts.

This past summer marked the third year of the five-year project. Course topics have changed to adapt to student feedback and a developing sense of what is of most value. The planned outline for summer 2006 is in Table I. In the first week the seminar time is used to introduce everyone. In the final week, the ninth week, student have a day-long symposium where they present the results of their research projects.

TABLE I
WEEKLY OUTLINE

Week	Topic
2	Introduction; Types of Moral Problems; Academic Integrity
3	Shared Moral Values; Ethical Frameworks; Codes of Ethics and Their Application; The Responsible Conduct of Research
4	Sustainability: Principles, Life-Cycle Assessment, Environmental Impact
5	Happy Valley Values - The Game
6	Intellectual Property and Authorship
7	Student Presentations of Ethical Issues in Their Research - Round 1
8	Student Presentations of Ethical Issues in Their Research - Round 2

GETTING STARTED: WEEKS 2 AND 3

To set the class environment as one of active engagement, the first meeting starts with a case study called "The Take Home Exam," one of four on an excellent video prepared by Aarne Vesilind when he was at Duke University [6]. Each of the four cases on this video is acted out by Duke students and faculty and is accompanied by a written study guide with suggested discussion questions. The case is one of an engineering take-home exam where students are told their work must be their own. One resourceful student finds the exact problem and its solution in an old textbook in the library, and proceeds to copy it and turn it in as his solution. In talking with a friend who is in the same class and is having trouble with the exam, he tells her that she should look at this specific book in the library. He also makes her promise to not tell anyone else. She then proceeds to tell her roommate who puts off the exam until the last minute after a weekend of getting drunk. Then after the exam has been graded, a fourth friend, who did not do well on the exam, finds out that some students had the solution. He meets with the faculty member, tells him that some people found the solution, but refuses to name the students. The faculty member says there is nothing he can do without names, and the student wonders whether the professor was right in using a problem from an old textbook.

This case has an abundance of issues with which to engage. One way to start is to ask the students to list by character any ethical or unethical behavior, and then to discuss their observations. In all of the characters, there are both good and bad ethical behaviors, representing the classic dilemma of one moral principle in conflict with another. For example, the student who finds the text in the first place has to choose between being a helpful friend versus not violating the rule of doing your own work. He chooses friendship. The friend he shares the book's relevance with actually calls him an angel. This one case provides a chance to get students talking and thinking about ethics and academic integrity in a way that they can relate to as students.

Following this case in week two, a slide show is shown that states the goals of the workshops, defines ethics, distinguishes between minimalist and maximalist behavior, explains some motivations for ethical thinking, and introduces engineering ethics codes.

In week three, the class starts with students working in small groups to consider whether they have any moral values that they all can agree upon. Every group comes up with several such as respecting life, honesty, and justice. Thus they discover that even though exceptions may be made, there are some universal values. A slide is shown that lists eight shared moral values [7]: love, truthfulness, fairness, freedom, unity, tolerance, responsibility, and respect for life. The next few slides introduce three classical ethical frameworks, or approaches to thinking about ethical issues. The three frameworks are:

1. Consequence-based – assessing the net good that can result and picking the option with the greatest good.
2. Duty-based – doing that which you would want everyone to do.
3. Virtue-based – do that which a person of good moral character would do.

Examples are used to explain the reasoning of each framework, and each is followed with a list of some of the potential limitations. Connection is made between cost-benefit analysis, a common engineering tool, and consequentialism.

A video case is used to conclude this session that is related to research integrity [6]. It involves an environmental company intern who works with another colleague to analyze some environmental data on a stream. In the process, she discovers that key data was mistakenly never measured by the colleague, making all of the time and money invested in the data acquisition wasted. She decides to cover the mistake and use some assumptions to replace the data, but without making it clear that these were not actual measurements. Her supervisor congratulates her for a job well done, yet her colleague expresses reservations about the cover-up. Students are invited to devise other options for dealing with the missing data and to make recommendations for the best resolution.

SUSTAINABILITY: WEEK 4

An emerging ethical issue in engineering is the concept of sustainability. As mentioned before, the first canon of the NSPE ethics code calls for holding public health and welfare paramount. Sustainability serves to elaborate on this ethic and provide guidelines for engineering practice. There are several key points made:

- Engineering serves to benefit mankind, both current and future generations.
- Benefiting mankind requires that engineers understand a host of related issues such as economics, politics, ethics, sociology, and ecology.
- Long-term sustainability requires that man-made systems work in harmony and accord with natural principles such as zero waste, solar powered, diversity, and interdependence.
- Life-cycle assessment, examining material, energy, and pollutants at every stage of a product's life and subsequent reclamation, is a valuable tool to inform decision making.
- By the year 2050, a reduction in environmental impact on the order of a factor of ten is needed to approach sustainability.

This topic was added in summer 2004 using a slide show based upon a conference paper by the author calling for "life-centered design" as a new engineering paradigm [8]. All of the key points listed above, except for the last one, were included, and students were receptive to this discussion. In summer 2005, an additional section on impact and expected trends by 2050 was included to further motivate students about the magnitude of the challenge ahead in their lifetimes. This makes use of the IPAT equation [9]:

$$I = P\ A\ T \quad (1)$$

Where:

I = environmental impact
P = population
A = affluence, a measure of the per capita goods and services
T = technology, the environmental impact per unit of goods and services

By 2050, relative to 2000, population is predicted to increase by about a factor of 1.5, from 6 to 9 billion [10]. Worldwide affluence is expected to increase by a factor of 3 to 5 [11]. Furthermore, ecological footprint analysis indicates that we now exceed the Earth's sustainable capacity by about 20% [12]. Combining these figures leads to the conclusion that technology must improve by a factor of 5.4 to 9.0 just to reach a balance with sustainable capacity. Though daunting, this is presented to students as a major opportunity for innovation and entrepreneurship, for those who recognize and understand the problems.

At the conclusion of this session, students are given their ethics project assignment, which is to consider the ethical issues that are relevant to their summer research project, to investigate one or two of the issues, and to present to the class. They are encouraged to involve the class during this presentation. By the following week, they must prepare a brief proposal that explains the topic they are considering and demonstrating that they have found some resources to support the investigation.

ETHICS GAME: WEEK 5

To help reinforce the message that ethics issues are commonplace, and to provide practice at problem solving and argumentation, an ethics game has been developed. The game makes use of the Dilbert™ Ethics Game developed by Lockheed-Martin (out of print). The original game involves moving around a game board modeled on an office setting. Each team has a character and gets to move based on the answer they provide to an ethical case. Each case has a short description followed by four proposed courses of action, and one silly response attributed to Dogbert™. Each course of action has a point value assigned to it. Teams discuss which answer they think is best and why, then select an answer. The leader goes around the room asking teams to defend their answer. This allows for some interesting discussion about the "answers," both suggesting other even better ideas, and questioning the point value, or merit, of the answers. It seems that the competitive game situation encourages them to defend and argue their positions. Then they move around the game board the number of spaces assigned to the answer they chose. The teams collect tokens in the various rooms as they move about and the team with the most tokens at the end wins. The winning team is awarded small trinkets. One other feature of the game is wild card spaces that require a card to be drawn. The cards describe humorous examples of either ethical or unethical behavior, and tokens are awarded or forfeited.

Because the game seems to be successful in engaging the students, the author has been assigning students in other classes where the game is used to develop their own cases based on a student situation, including four possible courses of action, their relative point value (and why), and a funny fifth answer. These cases, along with other engineering situations, are being used by a team of undergraduates to develop a customized ethics game called Happy Valley Values (Happy Valley is a nickname for State College and Penn State). The relevant improvements include:

- Cases are more relevant to students and the engineering field. One limitation of the Dilbert™ Ethics Game is that the cases are more general and were meant for training corporate employees.
- The wild cards are based on student situations with frequent references to Penn State.
- The game board and characters are connected to Penn State, helping to reinforce the relevance of the issues.

Although the game is customized for Penn State, the intention is to prepare a thorough description of it, along with

downloadable resources, in a future publication so that other schools can adapt it for their students.

By using a game like this one, students can discuss about 5 to 6 cases in the course of an hour. They learn to work as a team, listening to other's opinions and reasoning while also having to explain their ideas. In the process of discussing amongst their team and listening to other teams' answers, they get to hear many other ideas, helping to enlarge their moral imagination. Cases can be selected to reinforce messages that are most important. Perhaps, most of all, the students enjoy the game.

INTELLECTUAL PROPERTY AND AUTHORSHIP: WEEK 6

For many of the students, the summer EE REU program is their first opportunity to work with faculty and graduate students on a research project. It presents a timely opportunity to address issues of intellectual property (IP) and authorship. The class begins with asking the students what they know about their IP rights. Many have not even thought about the topic prior to this questioning. This is followed with distribution of the student policy on intellectual property at Penn State, along with some official interpretations of the policy for undergraduates. Regarding the EE REU students, the official policy guidance is [13]:

> "If undergraduate students are working in a "scientific" lab,
> - if they are paid for the work, the IP belongs to University.
> - if they are doing it in a for-credit course, the IP is theirs.
> - if they are working for "experience," and they do not sign an IP assignment agreement, the IP will be theirs."

Because the students generally fall into the last category, they retain their IP unless they sign an IP agreement, which some do.

To introduce authorship issues, a Happy Valley Values case is presented, see the case in Figure 1. As this case is representative of the students' summer situation, it provokes some lively discussion. The fact that there is no standard for what merits being listed as an author causes student concern, but a general principle is developed that there must be some significant contribution. The best guidance is for students to discuss the issue with the faculty member and gain an understanding of their expectations. Another point is that being listed as a co-author implies some responsibility for the content, so co-authors should be provided an opportunity to at least review the paper and provide their consent.

If time remains, another case study called "The Thesis," is used [14]. This two-part case focuses on a graduate student, Jason, who drops out of a project which has to be completed by the faculty member, Nelson Nice. In the first part of the case, Jason contacts Prof. Nice a year later and explains he is enrolled at another university and would like a copy of the project final report to "see how things finally worked out in the project." The question is raised as to whether the faculty should send the report, which was never published. In the second part, the faculty does send the report and later discovers that the grad student had essentially used the report as his Master's thesis – with no reference to the faculty member. Several questions are raised at this point including what Prof. Nice should do; whether he could have done anything previously to prevent this; and what might he do differently in the future?

Happy Valley Values: Authorship

You are working as an undergraduate research assistant on a project that eventually results in a research paper that is submitted for publishing. The project team consists of a graduate student, a professor, and you. Even though you did not help write the paper, you were mainly responsible for collecting all of the data. You estimate that your time on the project was about ¼ of the total effort. The problem is that when the paper is published, you are not listed as a co-author. What should you do?

A. Contact the publisher and explain the situation.
B. Call up the professor and ask for an explanation of why you were not included as a co-author.
C. Just forget about it.
D. Send a letter to the department head and explain the situation.

Slacker: Use a picture of the professor on your dart board.

POINTS

A. [1 pt] This may bring attention to the matter but it is not the most direct route. It could also make unnecessary trouble if your contribution does not merit co-authorship.
B. [5 pt] Ultimately it is the prof's responsibility to ensure appropriate credit. It may be that the prof was unaware of your contribution, or that the role of data collection was not considered worthy of co-authorship (you should be acknowledged somewhere though).
C. [0 pt] Does not resolve your concern.
D. [2 pt] Better than A but could be embarrassing if your effort was not author-worthy.

FIGURE 1
AUTHORSHIP CASE STUDY FROM THE HAPPY VALLEY VALUES GAME

STUDENT PRESENTATIONS: WEEKS 7 AND 8

For the last two years, the last two weeks of the ethics seminar have been used for the students' presentations on their ethics topics. This concept was developed after reviewing student feedback from the first year of the program in 2003. Students requested less reading from a textbook, and more activities and participation. Plus they get a chance to apply the principles and ideas about engineering ethics in the context of their summer research project.

This feature of the ethics seminar has proven to be appreciated by the students. They get to interact with their peers about an area in which they have developed some competence. The breadth of topics is impressive as illustrated

in Table 2. Because of time limitations, the presentations are brief, eight minutes each.

TABLE II
SAMPLE OF STUDENT ETHICS TOPICS FROM SUMMER 2005

Nanotechnology: Is the risk worth the reward?
Obligation versus Compensation: A deadly combination
Ethics of Oxide Etching: What is good work?
Nanotechnology: Is Regulation in the Future?
Innovative Technologies and Defense
Reverse Engineering
Wireless Security in Industrial Settings
Do engineers need to consider the ethical consequences of the possible uses of new technology?
Science versus Religion
Wireless Devices and Ethics
Software Licenses

CONCLUSIONS AND RECOMMENDATIONS

After three years of developing the goals and content of these ethics seminars, the program is well developed and integrated with the summer research experience. The topics and exercises serve to accomplish the goals of the program. Students should recognize the prevalence of ethical issues in student and professional life, and be better equipped to deal with these issues.

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REFERENCES

[1] Litzinger, T. et al, "Learning and Teaching Ethics in Engineering: Preparing Engineering Faculty to Teach Ethics", *ASEE 2003 Conference Proceedings*, June 22-25, 2003.

[2] NSPE Code of Ethics, National Society of Professional Engineers, http://www.nspe.org/ethics/eh1-code.asp, April 13, 2006.

[3] World Commission on Environment and Development, *Our common future*, Oxford University Press, New York, New York, 1987.

[4] Lovins, A., Lovins, H., & Hawken, P., *Natural Capitalism – Creating the Next Industrial Revolution*, Little Brown and Company, New York, 1999.

[5] Johnson, M., *Moral Imagination: Implications of Cognitive Science for Ethics*, University of Chicago Press, Chicago, 1993.

[6] *Academic Integrity: The Bridge to Professional Ethics*, Duke University, Video, 1999.

[7] Kidder, R., *Shared Values for a Troubled World*, Jossey-Bass, San Francisco, 1994.

[8] Lau, A.S., "Life-Centered Design – A Paradigm for Engineering in the 21st Century," *ASEE 2004 Conference Proceedings*, June 20-23, 2004.

[9] Ehrlich, P.R. and Holdren J.P., "Impact of Population Growth", *Science*, Vol.171, 1971, pp.1212-1217.

[10] United Nations Population Information Network, http://esa.un.org/unpp/, April 13, 2006.

[11] Graedel, T.E., and Allenby, B.R., *Industrial Ecology, Second Edition*, Prentice Hall, 2003.

[12] Chambers, N., Simmons, C., and Wackernagel, M., *Sharing Nature's Interest: Ecological Footprints as an Indicator of Sustainability*, Earthscan Publications, 2000.

[13] Penn State Research Administration, *Guideline Rag12 Faculty Guidance On Student Intellectual Property Rights*, http://guru.psu.edu/policies/RAG12.html, April 13, 2006.

[14] Pritchard, M.S., Editor, *Teaching Engineering Ethics: A Case Study Approach*, Center for the Study of Ethics in Society, Western Michigan University, 1992. Found at http://ethics.tamu.edu/pritchar/thesis.htm.