Abstract

A number of authors have challenged engineering ethics educators to incorporate elements of what may be called “macroethics,” “social ethics” or considerations related to the field of science and technology studies (STS) in engineering ethics curricula. To respond to this call effectively requires reform of both content and pedagogy. A new advanced course on engineering ethics uses readings from philosophy, science and technology studies, and feminist and postcolonial science studies to examine questions that necessarily challenge foundational assumptions of engineering, which not only underlie all of what scientists and engineers undertake in their work, but also require the active involvement of citizens outside of science and engineering. Students encounter new visions for science and engineering that integrate a variety of ethical considerations that mean to address critiques encountered throughout the course. Pedagogies of liberation are employed in order to accomplish three outcomes. First, classroom responsibility shifts echo the lessons learned from STS around engineers’ responsibility properly contextualized. Second, a focus on critical thinking and creativity stimulate critiques of the classroom learning process as well as approaches to course material and ethics problems. Third, an orientation toward praxis grounds theory in real communities that generate problems addressed by ethics approaches, resulting ultimately in transformative action in collaboration with the community of origin. This paper describes course objectives, content, and pedagogy, and presents specific innovations that shift responsibility, stimulate critical thinking, and create opportunities for students to engage in praxis. Results of assessment are discussed, with a focus on the scaffolding required to assist engineering students in adjusting to new content and methods.

Introduction

As engineering has established itself as a profession, a defining and essential element of engineering education is professional ethics. Since 2000, the requirement to include ethics as part of an accredited degree has crystallized. However, now that more engineering curricula are taking ethics seriously, the question of what rightly belongs in an engineer’s ethics education is deservedly garnering more attention. Herkert offers a critique that typically, engineering ethics is thought of only in terms of “microethics” – the individual decision-making of the engineering professional. He reviews several calls made over the past three decades by scholars of engineering ethics to incorporate “macroethics” – which he defines as the ethics of broader collective and social decision-making about technology – as part of a complete engineering education. Indeed, the set of ethical problems that involve the collective action of engineers, or the collective action of society as a whole, are not commonly addressed in engineering curricula. To address macroethics takes ethics out of the arena of individual decision making and necessarily requires political and social analysis. To respond ethically to macroethics topics would require individual engineers to understand their organizational, cultural, and social contexts, and navigate these effectively, utilizing leadership and communication skills.
To these ends, Johnson and Wetmore call for the integration of concepts from Science and Technology Studies (STS). Specifically, they note that the idea of co-production – that society and technology co-produce each other in complex relationships of interaction – has important implications for engineering ethics. Specifically, they argue that understanding these more complex interactions between society and technology creates a situation in which engineers’ responsibility is understood differently. On the one hand, engineers have additional responsibilities if it is recognized that engineers aren’t simply making isolated decisions that follow logically from natural laws, but that social judgment comes into play far more often than many wish to think. On the other hand, engineers’ responsibilities are decreased in certain ways if it is recognized that other actors play important roles and share responsibility for certain decisions and outcomes.

Answering this call to incorporate social ethics, macroethics, or STS topics in the engineering ethics curriculum requires reform and innovation of both content and pedagogy. Clearly, the content needs to change when the questions posed are themselves new and different. The pedagogy also needs to change because the type of thinking required is new and different for traditional engineers. It is clear that with the more contained microethics problems, it has been possible for textbook authors to make analogies to ways of thinking in engineering, appealing to logic and problem solving; Harris, Pritchard and Rabins offer a typical example of this in their text, in which they present a flowchart of engineering ethics problem solving that looks very much like engineering problem solving and engineering design processes.

However, macroethics problems often do not fit as neatly into modes of engineering thought and require more crossing of disciplinary boundaries to adopt additional social science and philosophy methods of analysis. To do this undermines some foundational assumptions within the typical engineer’s worldview. Not only is there “no right answer,” (as students often learn in microethics cases as well), but also truth itself is subject to Foucauldian “effects of power.” If critical theory is incorporated in content (and it is difficult to avoid references to it in contemporary considerations of science, technology, and ethics on a macro scale), then drawing on critical pedagogy would naturally support student learning, because of the ways in which critical pedagogy draws upon and demonstrates ideas from critical theory. In particular, the concept of praxis – connecting theory and action – seems particularly promising for learning ethics in ways that support internalization of ideas leading to personal transformation.

This paper discusses one new course, Science, Technology, and Ethics, which innovates content and pedagogy toward this end of delivering macroethics as part of the engineering curriculum. The course was offered as an upper-level elective to seven students in a seminar-style setting. Because microethics topics are already covered as part of the core curriculum, this new course focused exclusively on macroethics topics. First, the content of the course is presented, followed by a discussion of pedagogies and course elements employed. Assessment data are presented and discussed, with some suggestions made for improving this course.

### Content

Before delving into course content, it is important to review the course objectives, which were for students to increase their ability to:
• Think critically about science, technology, and ethics, identifying and analyzing a variety of ethics problems. (f,h,j)
• Lead insightful discussions on science, technology, and ethics topics. (f,g,h,j)
• Conduct original research into a topic in science, technology, and ethics. (f,h,i,j)
• Effectively communicate in oral and written forms the findings of original research on science, technology and ethics. (g)
• Explain the complex relationships among science, technology, and ethics in current social contexts, and how these contexts inform and influence social choices about science, technology, and ethics. (f,h,j)
• Act creatively and reflectively in the world to address science, technology, and ethics. (f,i)
• Assess and direct your own learning, and reflect on that process. (i)

These map, as noted above, to f-j of ABET criterion 3 (a)-(k):
(f) an understanding of professional and ethical responsibility
(g) an ability to communicate effectively
(h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context
(i) a recognition of the need for, and an ability to engage in life-long learning
(j) a knowledge of contemporary issues

Questions and Themes. The course began with a screening and discussion of the Errol Morris non-fiction film, *Fast, Cheap, and Out of Control*, which profiles four men who are obsessed with their respective vocations as robotics professor, naked mole rat expert, topiary gardener, and lion tamer. Footage of interviews with the men is interwoven with stock footage from a circus, and from classic films including the 1936 film *Darkest Africa*, starring lion tamer Clyde Beatty. The film was an excellent vehicle for discussion drawing out course themes around technology and control, materialism and consumption, science and social inequality generally, and colonialism more specifically. The film touches on each of the main questions explored in the course:
• Who decides how science and engineering are done, who can participate in the scientific enterprise, and what problems are legitimately addressed within these disciplines and professions, on behalf of what communities?
• Under what conditions have science and engineering aided and abetted racist or colonialist projects?
• What are the roles of technology, culture, and economic systems in the drive toward bigger, faster, cheaper, and more automated production of goods, and what are the consequences for human relationships and for the environment?
• When technology provides means for control, for example in military, information, reproductive or environmental applications, what rights and responsibilities follow?

These wide-reaching questions not only underlie all of what scientists and engineers undertake in their work, but also require the active involvement of citizens outside of science and engineering. These are by no means representative or comprehensive of the full range of possible questions around science, technology, and ethics, but they provide opportunities for the kinds of analysis and insight required to frame and examine other questions.
**Readings.** In order to explore these questions, an eclectic and widely interdisciplinary list of articles was compiled from philosophy, science and technology studies, feminist and postcolonial science studies, and of course engineering and engineering education.

The course begins with a general introduction to issues in science and technology studies, deconstructing the alleged objectivity of science with Langdon Winner’s classic and accessible “Do Artifacts have Politics.” The article considers the bridges of Robert Moses on Long Island which were built low and hence prevented busses (and the “undesirables” who ride them) from reaching those communities, and the union-busting intentions behind the development of McCormick’s pneumatic molding machines. Accompanying this piece is Emily Martin’s “The Egg and the Sperm” which uses biology textbook material to make the point that science not only reflects and perpetuates gendered stereotypes in human reproduction, but also that scientists have trouble recognizing evidence to the contrary, and changing language to reflect new understandings. Finally Sandra Harding’s “The Political Unconscious of Western Science” connects the two articles and grounds them in theory and philosophy of science.

Background on science, technology and society continues with Warren’s “fruit bowl” approach to ecofeminist ethics, discussing how we discern appropriate ethics approaches for problems we face, and with Johnson and Wetmore’s plea to include considerations of science and technology studies in engineering ethics. McCutchen’s exposé of conflicts of interest in peer review and Geiger’s history of military backing of science and engineering research at universities completes the background unit.

The first topical unit revolves around the theme of “technology and control,” drawing on examples from military, information, reproductive, and environmental technologies. The potential for rich discussion abounds here, as students delve into the power dynamics inherent in control technologies – even those they may favor as a social good.

Next we take up the issue of science and social inequality, examining the issue of gender and race in science and engineering from two perspectives: one in which underrepresentation is seen as the problem, and one in which the problem is cast more broadly to examine the gendered and raced constructions of engineering in history. At this point students confront racist projects in science with three intense readings that cover the role of Nazi physicians in building a political ideology based in eugenics, the role of white and black public health professionals in the Tuskegee Syphilis Study, and the role of our own institution in supporting a physical anthropologist’s collection of Native American remains obtained in some cases from marked graves, and later participating in their repatriation. Again a reading from Harding serves to unify these cases studies with a theoretical perspective.

The next thematic unit deals with consumption and materialism, examining planned obsolescence over the last century, the engineering of fast food, and the privatization of the commons, including the Internet, Third World intellectual property, particularly indigenous medicine, seeds and other agricultural products, and the global water supply.

The final unit focuses on agency and resistance, ending with new visions for science and engineering that integrate a variety of ethical considerations that mean to address critiques.
encountered throughout the course. Forms of resistance including dissent of individual experts\textsuperscript{41,42}, collective dissent of professional societies\textsuperscript{43}, and citizen action\textsuperscript{44}. New visions of doing and teaching science in response to macroethical concerns are presented\textsuperscript{45-49}, along with discussions of teaching and doing engineering in ways that promote peace and social justice \textsuperscript{50-52}.

**Challenges posed by the content.** It may be apparent that at least some of the readings presented here, particularly those that draw either on philosophy or critical theory (or both), may be quite challenging for engineering students. If this material is important to their ability to act ethically as engineers, it is essential that students are exposed to it. At a minimum, the benefit to the student is their recognition of critical gaps in their education; at best, students will be motivated to gain additional background knowledge from outside research, from peers in other disciplines, or simply from the context of assigned readings. Additional challenges include students not being used to doing large amounts of reading, or readings of the type assigned, such that they may not think critically and bring good questions for discussion. Finally, the readings are challenging because they pose a threat to the world view many engineers hold, and can produce defensive reactions. These challenges are discussed more fully below.

**Pedagogy**

I argue that pedagogical changes are required in order to effectively deliver the kinds of content that places technology and engineering ethics in their proper social, political, and cultural contexts. For the most part, traditional pedagogies in engineering, whether they are “chalk and talk” lectures or more active approaches to learning, do not disturb some fundamental epistemological assumptions, specifically that the authority to determine what is true and untrue, correct and incorrect, lies with the professor and textbook. Questions posed by students (again for the most part) are directed toward clarification and elicitation of more knowledge from the authorities. That these epistemological assumptions go unchallenged is problematic because they represent a low developmental stage of critical thinking and reflective judgment\textsuperscript{53}.

While most of us who teach ethics recognize that there is more than one “right answer” to questions posed, the Fundamentals of Engineering Exam continues to offer multiple choice ethics questions, and some educators follow suit using the exam as justification belies this notion\textsuperscript{54}. Lockheed Martin’s use of Dilbert to teach ethics,\textsuperscript{55} implemented in some engineering classrooms\textsuperscript{56}, also utilizes a multiple choice format, although there is a designation of “grayness” for some answers. The recognition of multiple possible solutions may rattle some students, and likely does in fact begin to undermine some previous assumptions about the world. But to simply adapt traditional learning methods without questioning the underlying epistemological assumptions is to replicate the same power dynamics. The lesson students learn from the model of these power dynamics is that someone in authority over them determines what is ethical. Why wouldn’t they continue to look to bosses, legal departments, and others to tell them what is correct? Worse, why and how would they even think to question the conclusions reached by these others? How can we expect them to make the leap between recognizing responsibility and taking responsibility?

This brings to light a third problem, which lies in the assumption of traditional education that we can lead the horse to water, but we can’t make it drink; that is, we can teach students the codes,
maybe we can teach students to think critically, but ultimately they determine their actions and therefore there is nothing we can (or ought to) do about that. This separation of thought and action is problematic, especially when we pretend that the real-world ethical decision making in engineering begins after graduation, or maybe at internships and co-ops off campus. Returning to the horse analogy, we should not only lead them to water, we should not only encourage them to drink, but we should also – and most importantly – drink the water with them. Combining thought and action reinforces learning in most powerful ways.

**Why Pedagogies of liberation?**

Pedagogies of liberation (or liberative pedagogies) are inclusive of critical/radical pedagogies and feminist and postcolonial pedagogies. Darder et al. provide an introduction to critical pedagogy that discusses major influences from twentieth century educators, philosophers, and activists including Americans John Dewey and Myles Horton, Brazilians Paulo Freire and Augusto Boal, Europeans Michel Foucault and members of the Frankfurt School, and postcolonial and feminist critics of radical pedagogy such as bell hooks and Jennifer Gore.

Pedagogies of liberation are especially suited to teaching engineering ethics as described above because of the ways in which it is deliberately conscious of social justice issues, operationalizing ethical thought and practice in the classroom. First, the emphasis is placed on sharing power and shifting authority to students to enable them to “come into voice,” and claim responsibility as co-teachers in a community of scholars. This echoes the kinds of responsibility shifts we see when we move to an STS understanding of engineers’ responsibilities in a larger social context. It is true that engineers have certain responsibilities and duties based on their professional role in society, and at the same time other actors, including individuals, organizations, and society itself bear other kinds of responsibilities for decision-making about technology. When responsibility is contextualized and shared, a much richer and nuanced story emerges, both in the classroom and in the course content.

Second, pedagogies of liberation hold critical thinking as a fundamental outcome. Within the classroom, this stimulates creativity in the learning process, critiques of classroom activities and dynamics, challenges to course material and active exploration of ethics questions or problems. Students practice raising critical questions of peers and authority figures (as long as professors administer grades and institutional relationships persist, the playing field is never leveled).

Third, praxis, or reflective action, is another fundamental outcome of liberative pedagogies. Theory and action are not dichotomous but are brought together in the classroom and in the surrounding world. An orientation toward praxis grounds theory in real communities that generate problems addressed by ethics approaches, resulting ultimately in transformative action in collaboration with the community. Thus, students are not merely asked to think ethically but also to act ethically during the course, in ways that promise to create lasting transformation.

**Course Elements**

*Self-directed learning reflection.* The course begins with a reflection on self-directed learning, in which students review and revise the syllabus, identify additional individual objectives for
their learning in the course, suggest additional or alternative readings or activities, and reflect on their motivation for taking the course. After reading student work, the class collectively made changes to the syllabus reflecting class consensus. Making the syllabus open to this kind of critique shares power with students and acknowledges the choices professors make in putting together a syllabus, choices that are subject to question. At the end of the semester, students revisit their reflection and provide evidence of their achievement of course and individual learning objectives, and place this all in a larger reflective context. Clearly this assignment relates directly to the course objective around directing and assessing one’s own learning. Students’ additional objectives for learning (expressed in their own words, grouped thematically by the author) are shown in Table 1. Students tended to pick up on other course objectives and tailor them to personal interests with increased specificity.

<table>
<thead>
<tr>
<th>Table 1: Student Learning Objectives, fall 2007</th>
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<tbody>
<tr>
<td><strong>Case Study Analysis</strong></td>
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<tr>
<td>• Examine a variety of case studies, and determine and analyze who science, technology and ethics all come into play</td>
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<td>• Given a specific scenario, develop your own decisions and policies based on what you have learnt so far</td>
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<td><strong>Content/topical exploration</strong></td>
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<td>• Understand how ethics plays a role in activism and to what extent we should allow ethics to govern science and technology policies</td>
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<td>• Learn about the main science/technology/ethical concerns around the world and in the US</td>
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<tr>
<td>• To become more aware of the social and economic principles that govern the world inclusive of engineering</td>
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<td>• To be able to learn more about the way that issues of gender, race, and class intersect with issues in science, technology, and ethics</td>
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<td><strong>Critical Thinking</strong></td>
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<tr>
<td>• To be able to think critically about my own previous opinions in science, technology, and ethics</td>
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<td>• View topics relating to science, technology, and ethics from different perspectives so that all of the key issues at hand may be identified</td>
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<td><strong>Application</strong></td>
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<tr>
<td>• Use what I have learnt in this class related to science, technology and ethics and apply it to the situations I encounter in the future and presently encounter on a daily basis</td>
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<tr>
<td>• To be able to apply topics in science, technology, and ethics to a K-12 setting</td>
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<td><strong>Attitude</strong></td>
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<tr>
<td>• Maintain an intense curiosity, enthusiasm, and a willingness to challenge myself throughout this course</td>
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<tr>
<td>• Growing as an engineer, which means being creative, inquisitive, analytical, and detail oriented.</td>
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<tr>
<td><strong>Argumentation</strong></td>
</tr>
<tr>
<td>• Develop strategies for defending one’s point of view.</td>
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<tr>
<td>• Effectively support my position on an ethical issue</td>
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<tr>
<td>• Express ideas clearly and succinctly without losing any essential meaning</td>
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**Student-led discussion.** Because the course is taught as a seminar, the bulk of work rests on reading and preparation for each class discussion period. In the interest of sharing responsibility, students paired up to lead discussion most days, amounting to 5 class preparations for each student. Students turned in notes, which were graded, to evidence the level of preparation and development of discussion questions. The professor prepared for each course in order to assist the student discussion leaders. Of course, their peers did as well, especially as they realized that in a class of 7 students with two discussants, it is essential that others do the reading for class to be productive. Thus several goals of liberative pedagogies were achieved with this technique:
students became authorities as discussion leaders, leaders and peers alike took on more responsibility for learning, and a collaborative and supportive dynamic was established in which students understood what was being asked of the discussants for each class, and strove to participate fully. The collective ownership of and responsibility for the class was deeply felt by all. Course objectives were met related to explaining complex relationships among science, technology, and ethics in society, critical thinking, and leading insightful discussions. Student-led discussion proved to be a vehicle for creativity as well, as students experimented with different techniques in class, such as role-playing and the use of video clips to spur discussion.

**Video screenings.** As the class was scheduled immediately after lunch, it presented the opportunity to extend class time back into the lunch hour for the purpose of screening films related to science, technology and ethics. These were well attended, with students providing bag lunches, and accomplished an important pedagogical goal of building community, as well as supporting interdisciplinary exploration through the medium of film. Films were chosen by the group based on faculty recommendations that supported course themes, and timed to support class discussion as much as possible. These included *Soylent Green*, a 1970s science fiction cult classic that depicts the effects of climate change (as well as gender and class oppression) in New York City in 2022; particularly on point is the engineering of food and the alienation of people from their food sources, echoing readings on fast food production. *The Insider* presented the high costs and benefits of real-world whistle-blowing in the tobacco industry, and the professional ethics questions faced by the 60 Minutes staff seeking to cover the story. Outside of class, students attended a screening of *The Water Front*, a documentary about water privatization in Michigan, and attended a workshop with filmmaker Liz Miller. Clearly any number of films could be relevant to the topic and augment student learning.

**Action essay.** Students were challenged to get involved in an ethical issue raised by a community to which they belonged. A topic proposal and a reflection describing what actions they took and their significance were the associated deliverables. Student topics are shown in Table 2. Each student found a topic that resonated personally and enabled them to connect an outside interest with ethical principles and methods of analysis they learned in the class. This item met course objectives related to critical thinking and acting reflectively in the world.

<table>
<thead>
<tr>
<th>Should the college’s design clinic accept projects from defense contractors who place restrictions on the participation of international students?</th>
<th>Interviews with and recommendations to Design Clinic and Program Directors; personal decision about participating in project when fellow team member was excluded</th>
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<tbody>
<tr>
<td>How should the town community get involved in addressing climate change?</td>
<td>Worked with campus climate action group, got involved in planning strategies and events</td>
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<tr>
<td>How can the college Bicycle Kitchen help to increase the use of bicycles on campus?</td>
<td>Worked with bicycle kitchen on campaign to offer free bikes on campus (disallowed by public safety)</td>
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<tr>
<td>How should a Design Clinic team approach ethical concerns related to their project restoring a local stream and ecosystem damaged in part by previous actions of engineers?</td>
<td>Consulted with student team and participated in brainstorming about ethics concerns.</td>
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<tr>
<td>Should the U.S. invest dollars in space when poverty, hunger, and homelessness continue to exist?</td>
<td>Letter to congressperson about funding priorities</td>
</tr>
<tr>
<td>How does the issue of net neutrality affect the Latino community, and what should be our response?</td>
<td>Letter in a Spanish language publication addressing the issue and urging action</td>
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**Term paper.** The term paper represented an opportunity to pull multiple course objectives together around conducting research, explaining complexities of relationships in science, technology and ethics, thinking critically, and communicating effectively, all while engaging students in a topic of personal interest. Table 3 presents topics chosen by students for their term papers; they are significantly different from topics that might emerge in a more conventional engineering ethics course focused on individual professional ethics. Social context is clearly at the heart of each of these topics, with a broader approach to analysis.

<table>
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<tr>
<th>Table 3: Student term paper topics</th>
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<tr>
<td>Analysis of Sweden’s decision not to develop nuclear weapons</td>
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<tr>
<td>Comparing engineers’ professional and society’s collective responsibilities in the Tacoma Narrows and Minneapolis 1-35 bridge collapses.</td>
</tr>
<tr>
<td>Analysis of South African AIDS policy and its ethical implications in the context of colonialism</td>
</tr>
<tr>
<td>The ethics of immigration restrictions for engineers: U.S. and United Kingdom</td>
</tr>
<tr>
<td>Corporate responsibility of U.S. firms in developing countries: the case of Doe Run in La Oroya, Peru</td>
</tr>
<tr>
<td>Ethics of how to integrate cultural considerations into science and engineering: the case of well-building in Kenya</td>
</tr>
<tr>
<td>Analysis of China’s industrialization and widening economic inequality: the role of technology in education and health care disparities</td>
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**Assessment**

Because learning and assessment are highly linked\(^6\), the self-directed learning reflections of students provide a primary vehicle for assessment. This is inherently a qualitative approach to assessment, and one that involves subjective judgment and interpretation of student narratives. Such an assessment follows logically from the content and pedagogy employed here; when one intentionally teaches content that challenges positivist assumptions, with pedagogies that do the same, one also ought to leverage assessment approaches that are consistent with the theories and approaches represented by the content and the pedagogy. A conventional approach such as objective testing would introduce power dynamics and a kind of alienation or non-relationality that directly undermine the intent and practice of liberative pedagogies. When learning and assessment are combined as they are with liberative pedagogies, teachers and students make the test together; when tests cease to be an ordeal, engineering culture is transformed\(^6\).

It may be noted that because self-directed learning reflections are graded work, one could question the influence of the grade on student content, as well as the discussion of power dynamics in testing above. One can readily see that it is impossible to level all power dynamics without transforming the institutional structures in which education occurs; still, the practice of liberative pedagogies entails sharing power whenever possible, including in assessment. In order to mitigate the effect of grades assigned to the work, students are told clearly that honesty is rewarded in evaluating reflections, and grading is generous, focused on completion and thoughtfulness.

Further, additional assessment tools employed included formative minute-paper assessments, informal oral surveys regarding the readings and classroom dynamics, written summative course surveys, and other student coursework. Results from student course work were compared with written evaluations administered by the faculty member and by the college; both are made available to the instructor only after grades are turned in. Results were consistent across all forms of assessment, though it should be noted that with such a small sample size, it is difficult to draw many conclusions.
The self-directed learning reflections are reported here because they provide the greatest depth of information regarding the meaning of the course for students. The qualitative data they provide are most appropriate to the context of this course and the small sample size. Each course objective is dealt with individually, followed by some overall observations.

**Think critically.** Students describe strong engagement with the thinking critically throughout the course, and individual progress in the practice.

“Every assignment has required me to think critically; yet the assignment that has made me struggle the most at thinking about both sides of the story is the term paper.”

“Being exposed to these vast ethical approaches and ways of thinking, I was then able to formulate my own arguments and thereby thinking critically of these issues. Listening to the perspectives of my classmates on various issues through the debates I was able to evaluate issues in a more informed and less rigid way.”

**Lead discussions.** Students were challenged by this objective, and their comments reveal their struggles and resulting growth:

“I think there were some weeks that I was more or less successful with this objective. As the semester went on, I did learn how to better lead discussions in a way that was more effective. The leading of class discussions helped me find out which ways were successful and which were not.”

“Many… readings were difficult to read and absorb due to the way in which they were written and this made me have to sit, read very carefully, then come up with ways to lead a discussion that would help bring out the main topics in the reading. This skill I believe is one that not many engineers have.”

**Conduct research.** Students articulated specific challenges and lessons learned in conducting research for a term paper, including identifying literature, evaluating sources, and narrowing a topic:

“I use the Internet tremendously for research purposes, but I have never really sat to think of how biased the Internet could be… Now I find myself actively seeking the source of any research that I may solicit from the Internet.”

“Initially, I found it difficult to do research on my topic because I felt as if there was just so much out there and I did not know how to narrow the material down so that it can be specific to just my topic. Through the library resources class that we had, I have become more effective at research… I have been able to define the problem more clearly.”
Communication. Students consistently found that the course gave them ample opportunity to improve their communication skills, citing oral presentations, action essays, and the term paper as key evidence of improvement in writing and argumentation.

“The term paper and associated oral presentation have allowed me to communicate the findings of my paper. While my action essay was less based on research, it was a means of communicating to other people about an issue of science, technology, and ethics that I felt needed to be dealt with on campus.”

Co-production of engineering and society. Students reported a sense that their understanding of the complex interactions among science, technology and ethics improved.

“I think that I have gained a much better understanding about how science, technology and ethics inform social context and how these contexts inform the way that science, technology, and ethics are addressed. I have been able to learn about these interactions through the readings and the class discussions. In addition, I have been able to focus on these interactions in my term paper…..I think that after this class, I am much more able to explain … these interactions.”

Act reflectively. Students provided a great deal of evidence of learning to act reflectively, not only in relation to the action essay assignment, but in ways that demonstrated an internalization of course themes and questions overall. The impact on individual civic engagement is notable; I quote more extensively here to illustrate the range of action:

“while researching net neutrality I came across the argument that net neutrality legislation will decrease the access of low-income Latinos to the Internet…. I wanted to find more information [about the sources of these statements but]…I could not find concrete information. Not finding this information made me wonder how many Latinos from my community are aware about net neutrality, probably very little. As a result, I decided to write to the editor of my community’s newspaper.”

“[the action essay] made me actively try to help in coming up with ways to solve an issue and also made me realize that I am capable of helping even if it is a minor contribution compared to other persons.”

Some students expressed a desire for more work in this area, either as part of the course, or a redoubling of individual effort:

“We were never really given a case study to see how we would react ourselves on the spot in a similar situation. This I think would be a good test of what we had learned in the class.”

Assess and direct one’s own learning. The fact that the students assessed and directed their own learning is evident throughout this section of the paper. One student described changes she made in approaching an international topic for her term paper, after an experience in another course
where she found it difficult to gain access to the affected community. She used her social network instead to locate individuals in the community, with whom she was able to communicate. Other students cited the importance of choice in the course as a support to their self-directed learning:

“I think that the open-ended aspects of both the term paper and the action essay have allowed me to direct my learning and focus on issues that I find interesting and important.”

“From the beginning, I took this class as a challenge, an opportunity, and a means to accomplish some of my personal goals [including] taking more responsibility for my own learning and success, and connecting my education to the person I want to be… The reading discussions, action essay, and term paper have helped me in the process of accomplishing my goals by giving me choices.”

**Overall**

In their general reflections about what they learned, two themes emerged. The first relates to connections made to other coursework. This worked in both directions, with students discussing material from other courses that they brought into the ethics course, as well as material from the ethics course being applied in other courses, including and especially other courses in the engineering major.

“I think that personally this course has just made me become more critical of any sciences and how they may impact lives and the environment. Professionally, I think that this course will influence the choices that I will make in the future. Ethics should play an important role in my decisions especially those that I make as an engineer.”

The second theme relates to personal transformation. Students wrote about the ways in which the class produced changes that they internalized. They made connections to who they are and who they want to become personally and professionally:

“Throughout the semester, I have asked myself how I would have approached the ethical question at hand and could I live with the consequences of action and inaction. I do not yet have concrete answers, but the questions are making me think about what values I hold dear and whether a specific field would challenge or encourage those values.”

“Prior to taking this class, I had an understanding of engineering content and we had done a few ethics case studies but I had never thought about the broader implications of the technologies that could be created with the material that we learned in our courses…... Professionally, this course has made me realize… that I need to create a broader look at how I am going to go about [my work].”

“Many areas of my field are all defense funded, which by itself has so many ethical issues surrounding it already. It made me really analyze to what extent I
would want to get involved in defense in the future, and what projects I may want to consider not working on since they may affect my personal goals."

“What I have learned is that I am the one who is in control of my future.”

Discussion

What stands out in these excerpts is an overall sense that students report critical thinking, personal transformation and reflective action as outcomes. To what extent can one, or ought one make claims about student action and personal transformation? I have argued here that both of these matter tremendously in learning ethics, and liberative pedagogies hold these as outcomes. The available assessment data are drawn from student work and self-reports, which have some limitations due to their subjectivity, along with the unavailability of useful quantitative data due to the small sample size. Still, these student comments reveal a depth of reflection and sense of commitment I have not seen in my other courses with engineering ethics content. While this certainly may be attributable to both the content and the pedagogy, one cannot rule out simple chance as a factor.

What other evidence might suggest a role for content and pedagogy in the observed outcomes? Beyond the quotes provided here, as the course instructor I have examined the entirety of what students have written throughout the semester, and consider, for example, what questions students ask, or what insights they offer about themselves, or about the relationships between power and knowledge throughout the course; such analysis provides an overall sense of student transformation. Instructors develop a sense of the students based on their relationships with them, through which students reveal parts of who they are and who they are becoming, and through which faculty can gain a sense not only of students’ intentions to think differently or act differently, but also a sense of why, which holds the key to critical thinking, reflective action, and personal transformation. I have certainly incorporated these methods in interpreting the students’ narratives. Will these students behave more ethically than if they hadn’t had the class? That truly is up to the students. Are they more able to behave ethically than if they hadn’t had the class? I believe they are.

This may not be terribly satisfying for those who bring a scientific model to engineering education investigation. What then remains? The students’ narratives – that is, what they have to say about themselves, their learning, their actions, and their transformation, and the relationships with others in the class that bear witness to these narratives. We should not underestimate the power of these narratives. After all, Derrida would say that’s all we ever have to go on.

One important issue that emerges from student comments about their achievement of learning objectives, and my own reflection on the course, is the readiness of engineering students to take a course like this, and the challenges encountered by students and faculty when material and assignments are at too high a level. The course is certainly interdisciplinary enough to challenge any undergraduate; it is unlikely a student would possess the scientific and technical background, knowledge of philosophy and ethics, and an understanding of critical theories about gender, race, and class. In that sense, every student would be challenged. However, engineers (and in this
offering all students were engineers) face specific gaps in experience related to reading critically, participating in (let alone leading) discussions of reading, and writing a 20 page research paper.

It is essential that support be provided for these challenges; a member of the library staff conducted a well-taught class on research tailored to their term paper topics, and remained available for individual consultation throughout the semester. The term paper was divided into several smaller deliverables: a topic proposal and annotated bibliography, and outline with revised bibliography, a complete draft (optional), a final oral presentation at which working feedback was given, and a final written draft. Providing support for reading and leading discussion is somewhat more elusive. Some students in the class reported conducting additional research to understand the readings and topics, and this came through in their discussion facilitation. Casual Internet queries may be sufficient for many topics to provide definitions for jargon and additional context for case studies. It was helpful to remind students of the task of understanding what the author is saying and what is at stake in their work before rendering judgments of whether they liked the reading.

Additionally engineering students face challenges regarding positivist world views and a notion that “technology is neutral.” While several readings at the beginning of the course were intended to build a framework for analysis that included a paradigm shift regarding their understanding of technology in society, the shift didn’t “stick” with many students. It was necessary to refer back to the reading and often correct misunderstandings. The message that “technology is neutral, it’s what society does with it that matters” was re-examined at several points during the semester. This is difficult work, important and necessary. Having non-engineers in the class would change the dynamic significantly, and likely help with the world-view transition. It could provide positive models for discussion and a wealth of disciplinary information different students might bring to the questions of this course. At the same time, the “two cultures” divide persists in many institutions, including our own, and extra work is needed to reassure apprehensive students crossing into other disciplines, acknowledging the difficulty and risks involved.

Many course elements presented here, including the action essay and self-directed learning reflection, should scale up to larger classes without much difficulty. Student-led discussion, however, is more difficult, especially with mid-size classes of 20-30, too small to create discussion sections, but large enough that students aren’t readily comfortable with discussion. One strategy that may be effective is having a panel of student discussants for a reading. A team of 4 students or so leads discussion, facilitated with questions from the instructor that they answer as authorities. (Questions can be posed in advance to make this exercise less intimidating, and to generate student preparation notes which can be handed in.) After some period of discussion, the floor is opened for questions and discussion from the rest of the class. Other formats using small groups may be similarly effective; Augusto Boal’s drama techniques can be utilized to act out and experiment with course material. This can be especially powerful and transformative when power dynamics are first illustrated and then resisted through theatre.

Conclusion

In answering the call of colleagues to teach macroethics to engineers, an upper-level seminar-style course was designed and taught with seven students. Innovation in content drew from many
different disciplines including engineering, philosophy, science and technology studies, feminist and postcolonial science studies, and engineering education. Innovation in pedagogy sought to meet several challenges students face in confronting the new worldviews represented on the course reading list, and demonstrate a new set of power relationships that support ethical thought and action. In keeping with the content and pedagogy, learning and assessment were intertwined, and students’ self-directed learning reflections became a central focus for understanding the meaning of the course in terms of meeting learning objectives and accomplishing the stated outcomes of critical thinking, reflective action, and personal transformation. Student self-assessment narratives reveal challenges faced, objectives met, and significant progress in critical thinking, reflective action, and personal transformation.

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