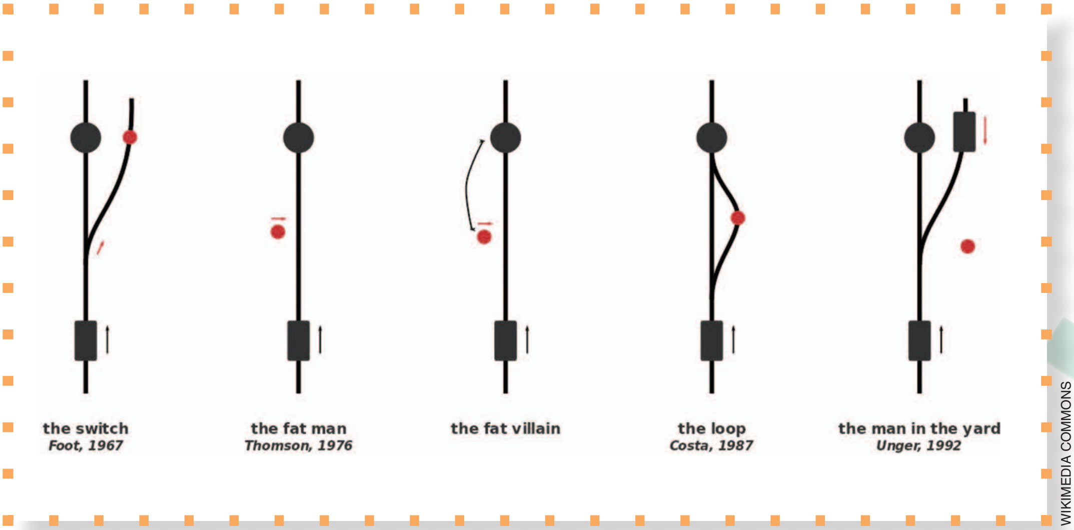
Teaching Engineering Ethics

A Phenomenological Approach

Valorie Troesch



Five variants of the trolley problem.

Two concerns dominate engineering ethics pedagogy. The first is that 21st century technologies present daunting ethical questions that require strong engagement with engineering ethics. The second is that engineering students don't emotionally engage with the study of ethics – in short, they don't care much about it. Instead, today's engineering students are confident that technology itself will operate to resolve most ethical questions.

In a 2012 article, Pine argues that emerging technologies pose unique ethical issues for engineers and that a "new" ethics instruction for the 21st century is essential for engineering students [1]. Newberry finds that, although engineering students can learn and apply the rules of professional ethics and are capable of considering ethics from multiple perspectives, they deem the ethics component of their coursework to be "the least interesting, the least useful, and the most trivial" [2]. Although students can intellectually engage in ethical study, they do not achieve emotional engagement, which Newberry defines as "developing a student's desire, on an affective level, to recognize, to care about, and to resolve ethical issues" [2]. Pine and Newberry agree that effective ethics instruction is critical. I agree with them, but I suggest an approach that does not expect students to "learn and apply ethics." I propose a phenomenology-informed pedagogy that asks students to explore and reflect on the lived experience of being an

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ethical engineer. This instructional approach, which has been pilot tested in the engineering classroom, could offer an alternative for 21st century ethics education that would emotionally engage our engineering students with ethics.

Aristotle and the Nature of Knowledge: Engineering vs. Ethics

Traditional engineering ethics pedagogy embodies a debate concerning the nature of knowledge that goes back to the ancient Greeks. In the Nichomachean Ethics VI, Aristotle sets up a taxonomy of knowledge that includes *epistêmê*, which is theoretical or scientific knowledge such as mathematics and physics, knowledge that is universal and unchanging; *technê*, which is productive or craft knowledge characterized by the application of reason and used by people to design or do things – this includes a range of professions from artists to doctors to engineers; and *phronesis*, which is intelligence or practical wisdom, including ethics, with application to action taken in politics or the affairs of state [3]. Importantly, Aristotle distinguishes *phronesis*, from both *epistêmê* and technê. That is, he distinguishes ethical knowledge from both scientific and engineering knowledge, and he creates a dichotomy – objective, verifiable, and unchanging truth that stands at the top of the knowledge taxonomy, versus knowledge and understanding as reflective, dialectic, and interpretivist – that has persisted through the millennia. This dichotomy has a direct impact on how we teach engineering ethics.

Much of traditional undergraduate engineering ethics education is premised on the assumption that, because scientific and engineering knowledge are different from and privileged over ethics knowledge, the only way to make ethics understandable to engineering students is to teach it same way that engineering courses are taught. This method would be with a linear, objective, positivistic, problem-solving approach that assumes pure reason will yield correct, and often quantitatively determined, answers to ethical questions.

This article contends that we first have to challenge the assumptions underlying this dominant educational paradigm. Bunge, who is both a theoretical physicist and a philosopher of science, argues that technology itself is not ethically neutral. He writes that "technology is involved with ethics and wavers between good and evil" [4]. Second, he argues that we do a disservice to both the profession and to society when we train engineers and other technologists to be no more than "skillful barbarian(s) who must be kept in (their) modest place as the provider(s) of material comfort" and who are expected only "to carry on their task without being distracted by any ethical or aesthetic scruples" which are exclusively in the domain of management [4].

In this article, I review the theories commonly used in engineering ethics instruction and then introduce a phenomenology-based inquiry approach, its theoretical foundations, how it is used in the classroom, and my research on student learning outcomes. The phenomenological methods are intended to supplement and not supplant ethical theory.

Three Traditional Theories of (Engineering) Ethics

The three most taught ethics theories are deontological or rules-based ethics, consequentialist (utilitarian) ethics, and Aristotelian virtue ethics. Kant gave us the paradigm of rules-based ethics, the Categorical Imperative: to act only according to that maxim by which you can at the same time will that it should become a universal law [5]. The rules that govern "right" behavior are derived through reason, they are universal, they are inviolable, and they apply without exception. Benjamin Constant posed the challenge of the "inquiring murderer:" should a person lie to a murderer who asks the location of his intended victim? Kant's stunning reply was that lying about the would-be victim's location would violate the maxim of truth-telling and would be wrong [6].

The National Society of Professional Engineers (NSPE) has given us rules for engineers - the NSPE Code of Ethics. The rules are prescriptive, telling engineers how they "shall" conduct themselves professionally. All my engineering students can recite Canon 1 of the NSPE Code of Ethics: "Engineers, in the fulfillment of their professional duties, shall hold paramount the health, safety, and welfare of the public" [7]. Some students understand this rule as clear-cut, absolute, and inviolable. In their view, nearly every professional engineering ethics decision can be unambiguously decided by reference to this Canon. But Davis [8] argues that professional ethics codes cannot be applied effectively without interpretation.

Act utilitarian ethics or consequentialism requires that we act in ways that will result in "the greatest good for the greatest number" [9], [10]. Consequentialism appears to be a pragmatic theory for ethical decision-making – we weigh the consequences of options and we pick the action that will do the most good or, in some cases, the least harm. Consequentialism is deceptively simple and is, in reality, a very complex and demanding way to live. Consider, for example, Peter Singer's contemporary utilitarian argument that people living in affluent countries have a moral obligation to commit all their income in excess of what they need to provide for their own essentials to the cause of global famine relief [11].

In engineering, "utility" often relies on a variety of decision-models such as risk analysis and cost-benefit analysis to help engineering students quantify factors to calculate the "right" decision. Although multiple factors may go into the calculation, students don't see this process as particularly challenging – it requires that a formula be applied to a set of facts in order to yield the correct answer. It is a familiar part of the design process for which students are trained beginning from year one in Engineering Fundamentals.

Virtue-based ethics receives increasing attention in engineering ethics education literature. Aristotelian virtue ethics holds that the right action is that which a virtuous person would do under the circumstances. Hursthouse writes that virtue as a character trait is "a well-entrenched or settled state of a person – a certain sort of way they are, through and through, all the way down – which involves a disposition of a very complex sort" [12].

Many scholars contend that virtue ethics offers great promise for developing the "emotional engagement" with ethics in engineering students. Harris argues against "preventative ethics" – negative rules and disaster case studies – and for a "virtues ethics" in which students create a "professional virtue portrait of the good engineer" [13]. Stovall relies on Aristotelian *phronesis* and argues for a virtue of "self-awareness." He writes that the "virtuous professional is the successful professional" [14]. Pritchard [15] also argues against an over-emphasis on wrongdoing and disasters, and shifts the focus to questions of character of the "responsible" engineer, recommending that students study examples of exemplary engineering practice [16]. Frey offers an engineering ethics pedagogy grounded in moral psychology wherein students study the competencies needed to be ethical and "practice moral expertise" in the classroom [17]. Virtue ethics is used in professional ethics in addition to engineering, including medicine, law, and business. The Jubilee Centre's website includes many resources on virtue ethics education. [18]

The method nearly universally employed to teach students how to use ethical theory is the case study. Case studies – real or fictitious – are plentiful: the space shuttle Challenger and Columbia disasters, the Hyatt Regency skywalk collapse, the Bhopal chemical spill, and the made-for-the-classroom depictions of multiple ethical dilemmas in films such as *Henry's Daughters* [19]. The case study method offers variety in the classroom, including class or small group discussions, role play, debates, and essay responses.

In 2000, Herkert described the state of engineering ethics education in the U.S.A., including the utilization of case studies and codes of ethics [20]. Bucciarelli, writing in 2008, strongly criticizes this traditional approach because it treats engineering practice as "solitary, instrumental, mono-paradigmatic, materialistic, value-neutral, hard, certain and calculative" rather than as a profession where engineers must be prepared to address "the social, the organizational – even the political – complexities of practice" [21]. Pine's 2012 article described innovations in ethics instruction that are being introduced at a handful of universities but, commendable as these efforts are, the pedagogical approaches are predominantly traditional [1].

With the abundance of literature on alternative engineering ethics pedagogy, why doesn't actual engineering ethics pedagogy change? Herkert concludes that the most notable challenge in undergraduate engineering education is the failure of engineering faculty to accept responsibility for teaching ethics [20]. If we expect engineering ethics pedagogy to change, then we must make those changes meaningful to the people who will implement them in the classroom. Before we can emotionally engage our students in ethics, we must first emotionally engage the faculty who are teaching ethics. Although it is outside the scope of this paper, one possible benefit of having faculty use a phenomenological approach to teaching engineering ethics is that it may also increase their engagement.

Phenomenology as a Pedagogical Method

Most proponents of alternative engineering ethics instruction aim to have students grasp the essence of being an ethical engineer. They expect that this experience will make students care about ethics in a way that traditional ethics instruction does not. For example, virtue ethicists ask students to identify the virtues of a good engineer [13], [15]. Bucciarelli argues that students need to understand the complex world of the engineer beyond the technical aspects of design work [21]. Lynch and Kline contend that engineering students need to experience ethics in the "real world" rather than studying abstract notions of codes and moral theories [22]. Phenomenology – the revealing and description of essences of phenomena – can inform a pedagogical method that helps students discover and experience what it is to be an ethical engineer.

Phenomenology is particularly useful to study professional experience because "it tries to place a researcher in the perspective of the research participants in order to understand their experience and feelings, thus unveiling what it means, from their point of view, to be in the situation within the experience" of that professional person [23]. Phenomenology is a philosophy that studies essences [24], [25]. As a research method, phenomenology seeks to discover and describe the essences of human experience in the real, everyday, lived world. By describing the essences of experiences, we aren't seeking their scientific, theoretical, or causal explanations. Rather, phenomenology describes an experience and interprets it to express a general understanding about its essence – what is that experience about, what is its meaning [26], [27].

Phenomenology as a pedagogical method for engineering ethics education is not untried or unreported.

Porra [28] introduced phenomenological methods to help students understand the values, forces, interests, and mechanisms in society that pose ethical questions for design engineers. Broome described an activity he tried in an ethics workshop to prepare students for the FEE licensing exam. He asked students to take the exam before he delivered his lecture. Then, also before the students received any instruction, Broome asked them to take the exam again but, this time, to imagine themselves as an "aged, highly mature person: a family member or some legendary character; someone who exhibited great wisdom and caring for others." The results were stunning: students generally failed or performed marginally on the first exam but "maximized the examination" when they imagined themselves to be wise and caring [29].

Wike, who adopts a values-based approach to teaching engineering ethics, describes values in phenomenological terms: "If, as I am claiming, the best way to talk about ethics is in terms of values, then ethics is everywhere. Ethics isn't 'outside' a technical practice; it is already there. We just have to make it explicit" [30]. Lynch and Kline closely describe a phenomenological approach to engineering ethics when they suggest that students focus on the everyday mundane ordinariness – the essence – of engineering ethical decision-making [22]. These approaches share a common aim to help students understand – to experience, describe, and empathize with – the real world experience of being an ethical engineer.

I propose a phenomenology-informed curriculum that can be used by engineering and non-engineering faculty to help students study ethical experience. Sadala and Adorno used phenomenology methods to help student nurses understand the world of nursing on an isolation ward. They prescribe phenomenology as the most appropriate way to investigate professional experience because students will acquire "experience in a situation where they relate to an already given world, which is out there, into which they are launched and which they will have necessarily to face" [23]. I propose placing my students in the shoes of the researcher and having them ask the phenomenological question: "What is it to be an ethical engineer?"

Phenomenological research is a rigorous methodology [31]-[33]. My intent is not to train my students in phenomenological research but to apply some of the concepts to an engineering ethics pedagogy. Phenomenology employs the concept of "bracketing" [24] or the putting aside of biases or assumptions associated with the phenomenon in order to understand the essences of an experience. Several principles from phenomenology research guide the design of assignments. [32]. First, the question: "what is it to be an ethical engineer?" does not have a pre-known answer and no theory is put forth for students to test. Instead, inquiry is a subjective experience in which each student explores the phenomenon and discovers his or her own answer to the question. Second, the focus is on real engineers, real-world engineering practice, and the "everydayness" of engineering work and ethical practice. Third, because there are no fixed answers, ambiguity is expected and necessary. Becoming comfortable with ambiguity in a profession that rejects that notion is part of the inquiry process. Finally, this is an inductive rather than deductive process; questioning, reflection, and interpretation are the tools of discovery.

Assignments are not prescriptive or rigid. The phenomenological inquiry approach allows an instructor to try a variety of assignments and to use student performance and feedback to gauge outcomes and make revisions. I begin the course by introducing the three course objectives: 1) to develop a working knowledge of the principles of ethical theory and how these theories connect to personal and professional decision making, 2) to explore and articulate their understanding of what it is to be an ethical engineer, and 3) to demonstrate proficient communication skills.

Course Introduction

Reading

Excerpts from *Bunge, Philosophical Inputs and Outputs of Technology* [4]. Bunge explains that technology is not ethically neutral and that engineers are not morally irresponsible professionals who operate in isolation, merely solving design problems. Rather, engineers always have choices about the good or evil of the technology on which they work, and society benefits when engineers use their expertise to help make these decisions. To be an engineer is necessarily to be concerned with ethics.

Writing

Writing enables phenomenological reflection and understanding of lived experience [27]. My students write a brief introductory autobiography that asks them to reflect on their life (including internship or co-op) experiences, examine their values, and explain how they see themselves as emerging engineers.

Ethics and Values

Reading

Wike, Professional *Engineering Ethical Behavior: A Values-Based Approach* [30]. Wike reinforces the point raised by Bunge that engineers have ethical responsibilities that cannot be passed off to management. And she rejects the idea that engineers can rely on laws and codes of ethics for the answers to ethical problems in engineering practice. She offers instead a values-based approach to moral decision-making for engineering design.

In-Class Activities

I do not assume any theoretical ethics knowledge of my students, so I think they need to have some grounding in ethical theory. My phenomenological methods are intended to supplement and not supplant ethical theory. I provide an overview of the three dominant ethical theories (deontology, consequentialism, virtue) and how they relate to engineering ethics. Then, I pose two ethics problems to the students. The problems posed are well known to ethicists but not necessarily to engineering students: the case of the inquiring murderer (a problem of deontology) and the trolley problem (a problem of consequentialism: there is a runaway trolley and you can operate the switch that will avoid the trolley killing five people on the track, but by switching tracks, the trolley will kill one person on the other track).

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Following this, I ask students to think about how ethical decisions are actually made. If codes and rules and utilitarian calculations of consequences have limited practical usefulness in ethical decision-making, then how do engineers make ethical decisions? Most students recognize that they rely on their "values" to make decisions. What they do not think about, however, is how their values influence nearly every decision they make, usually with ethical consequences.

A set of three activities helps them think about values. First, I ask the students to recall what they ate (or didn't eat) for breakfast and then to think about why they made those choices. What students discover is that even the simple choices they make about breakfast are based on their personal values and often carry ethical implications.

The second activity asks student to work in small teams to consider the Canons of the NSPE Code of Ethics and to identify the values that are behind these rules. If they cannot rely on the NSPE Code of Ethics to definitively answer professional ethical questions, then why does it exist? Where did these rules come from?

The third activity is also a team activity. Each student is asked to reflect on the values that made him or her choose engineering as a profession and the particular field of engineering. These three activities are inclusive ways to have students begin to talk about values, to realize how influential values are in all decision-making, and to understand how ethical consequences follow from values.

Finally, I ask the students to consider a real-world case such as the Space Shuttle Challenger disaster. Students now understand the issues in the case from a values perspective rather than from a rules or consequentialist perspective, resulting in new questions, alternative possibilities, and perhaps otherwise unconsidered ethical options and obligations.

The terms "values" and "virtue ethics" are often used interchangeably. Virtue ethics arises from the Aristotelian notion of the virtuous person and the virtues such a person would possess. Aristotle is unwavering in his conviction that the virtuous person acts virtuously because that is who the person is. The virtuous person, as recognized by Aristotle, is exceedingly rare. Current writers who advocate for a virtues- based approach to engineering ethics usually begin with Aristotle and then offer prescriptive, though rarely identical, lists of the virtues that a virtuous engineer would possess [13]-[15].

A values-based approach to engineering ethics emphasizes human values, things that are important to and that motivate people [30], [34]. In this respect, values-based ethics resembles virtue ethics. But values cross all theoretical boundaries in ethics. As the in-class activities on values demonstrate, both deontological and consequentialist ethics are premised on complex sets of values, although the theories themselves seek to give universal guidance on right behavior without the need to explicitly acknowledge or identify the values underlying them. As part of a phenomenological inquiry into what it is to be an ethical engineer, students discover and reflect on the values they think are important, rather than have these values delivered to them as pre- packaged content.

Engineer Interview

Reading

Downey, Lucena and Mitcham, *Engineering Ethics and Identity: Emerging Initiatives in Comparative Perspective* [35]. The authors interview engineers from France, Japan, and Germany and compare their cultural views on what it is to be an ethical engineer. My students represent a diversity of cultures. The ability to work in a global workplace is now a requisite skill, and this reading offers a glimpse into how engineers in different cultures vary in their understanding of what it is to be an ethical engineer. The article opens a discussion of the cultural differences represented by the students themselves.

Interview and Writing

Interviewing is the principle method of phenomenological research [36]. Talking with a person to discover the essence of the experience being investigated is the best way to understand that experience. My students interview practicing engineers. Students develop interview questions focused on what is it to be an ethical engineer. Students report that this is the assignment they most dread but also the one that, after they've done it, is the most meaningful to them. Talking to an engineer about being an ethical engineer is, from all I gather, a beneficial one for both the student and the engineer.

Technology and Being an Ethical Engineer

Readings

Readings on ethical questions posed by technology are abundant, and I vary the reading assignments each term. Some that I have used include: Shraeder-Frechette, *Technology and Ethics* [37]; Manion, *Ethics, Engineering, and Sustainable Development* [38]; and Heidegger, *The Question Concerning Technology* [39]. Readings should offer wide-ranging views on ethics, technology, and the role of engineers in the development of technology. Heidegger is a classic if not an easy read. But his central message is that the best way to come to terms with technology is to engage in continuous questioning so as not to become "enframed" by it. This reading is intended to have students begin to develop the habit of questioning, not only technology, but their roles as citizen engineers.

Individual Student Meetings

I meet individually with each student twice during the semester to review their research plans and progress and to address concerns and questions. Students report that these meetings are helpful to keep them on track and to give them feedback. I also get feedback about the effectiveness of coursework.

Final Research Essay

The capstone assignment is a research essay that asks the students to use their work from the semester to address the question: what is it to be an ethical engineer? The question requires an interpretivist [26] approach. They must describe how they interpret and understand the essences of what it is to be an ethical engineer. Students are expected to refer to readings, interviews, and other sources.

Quantitative and Qualitative Research

This project began as a hypothesis in my Engineering Ethics in Design course, a 1-credit undergraduate 3000-level elective offered at Michigan Technological University. I wondered if a phenomenological inquiry by the students into the essence of what it is to be an ethical engineer could yield more satisfactory learning outcomes and greater student engagement with the study of engineering ethics. In the fall semester of 2011, I offered the revised Engineering Ethics course. To assess the effectiveness of the revised course, I selected the Defining Issues Test-2 (DIT-2) as a pre-test during the first week of the semester and a post-test at the end of the semester.

The DIT-2 is a test of ethical reasoning developed by researchers in the Center for the Study of Ethical Development. It is a multiple choice test that consists of a set of five (non-engineering) scenarios presenting various ethical dilemmas without obviously right answers. The DIT-2 has a large national database. The DIT-2 gives two principal scores, the P score and the N2 score, which quantitatively measure the participants' ethical or moral reasoning skills [40], [41]. The DIT (predecessor to DIT-2) and DIT-2 have their critics [42]-[44], and alternatives are being tried. Borenstein *et al.* developed the Engineering and Science Issues Test (ESIT) that uses job-related ethical dilemmas from science and engineering, rather than the non-engineering- specific dilemmas of the DIT-2, to measure moral judgment [45], and researchers continue to develop alternatives tests to the DIT-2 that will accurately measure ethical sensitivity. Nevertheless, the DIT-2 continues to be used by researchers to measure the ethical reasoning skills of engineering students [46] and the effectiveness of engineering ethics instruction [47], [48]. Therefore, my study uses the DIT-2.

Table 1 shows the pre-and post-test results (P and N2 scores) for students in ENT 3958 for each of the three semesters in which the course was piloted. Those scores are compared to results of the SEED project and the DIT-2 national norms for college-aged students. (SEED - the Survey of Engineering Ethical Development – was a multi-year research study funded by NSF and headed by PIs from Lawrence Technological University, California Polytechnic State University, and the University of Michigan. This research conducted a nationwide assessment of the ethical development of over 4000 undergraduate engineering students from 18 institutions, including Michigan Tech. The DIT-2 was used to measure ethical reasoning skills. The study measured students' ethical development across all undergraduate years without regard for whether students had studied ethics. SEED offers a broad snapshot of the current ethical development of U.S. undergraduate engineering students. 238 undergraduate engineering students from Michigan Tech participated in the study.) Mean N2 and P scores of students in ENT3958 showed statistically significant improvement in each of the three years. For example, in 2011, N2 scores increased by 23.40%; in 2013, N2 scores improved by 26.62%; in 2014, N2 scores improved by 38.38%.

There are limitations of the pilot study. First, the number of students in ENT3958 is small. Second, there was no control group of students who studied ethics using a traditional engineering ethics curriculum and no control group of students who took no ethics course at

TABLE 1. Dit-2 Scores compared mtu, nsf seed, National Norms.

DIT-2 Score	ENT 3958						NSF SEED Project		DIT-2 National Norms for College-Aged Students
	2011		2013		2014				
	Pre-test (n=20)	Post-test (n=16)	Pre-test (n=20)	Post-test (n=17)	Pre-test (n=13)	Post-test (n=13)	MTU (n=238)	17 Other institutions (n=~3700)	
P Score	30.1	35.75	26.10	31.29	30.77	43.33	29.9	32.9	P scores range from 32.2 to 37.8, increasing with age during college.
N2 Score	28.59	35.28	26.82	33.96	34.08	47.16	29.7	32.4	N2 scores range from 31.1 to 36.9, increasing with age during college.

all. However, because of the small number of students who enroll in this elective course (offered only once per year), it hasn't been practical to establish a control group. This remains an option to be explored.

Despite these limitations, what might these results tell us? First, results are consistent from year to year. Second, they are statistically significant rather than explainable by chance. Third, these results confirm that our engineering students are capable of ethical reasoning that is on par with and in excess of their peers across all other majors and institutions. Fourth, this pedagogical approach in a 1-credit ethics course could arguably make a difference in achieving student learning outcomes and engagement with the study of ethics.

Finally, I will comment on the 2014 course where students demonstrated much stronger improvement. It's possible that course modifications had an effect. Students were given more autonomy in their research and a broader selection of readings. I also introduced the individual meetings during that semester. At a minimum, all these results strongly suggest that further research is warranted.

My intent was to design an ethics pedagogy that would also improve my students' emotional engagement with ethics. Although improved ethical reasoning scores are important, these scores do not measure engagement. For that, I chose an interpretivist research method. I hypothesize that a qualitative analysis of the final research essays written by students in ENT3958 (all three semesters of the pilot course) could reveal themes that signify emotional engagement with the study of ethics. I am using NVIVO software for data coding and a three-stage phenomenological research method (collection of descriptions of lived experiences, reduction of data into essential themes, and interpretation of themes) (Orbe) to determine if the thematic content of the essays is consistent with expressions of emotional engagement.

This qualitative work is ongoing and final results are not yet available for publication as the thematic data must still be put to an interdisciplinary panel for interpretation and review. However, a few preliminary observations are possible. Students express their understanding of being an ethical engineer primarily in the context of values. They rely on the interviews with practicing engineers and use the readings to more or less confirm what they discussed in the interviews. They do not discuss being an ethical engineer as someone who relies on rules or decision models. They all say that their understanding of ethics and being an ethical engineer is more complex and demanding that they had originally believed and that they are now more concerned about making ethical decisions when they are working as engineers.

Engineering Students Can Improve Ethical Reasoning Skills

Results from this phenomenology-informed pilot ethics course indicate that undergraduate engineering students can improve their ethical reasoning skills and their emotional engagement with the study of ethics. Preliminary research also suggests that interpretive phenomenology can serve as a qualitative research method to measure the engagement of engineering students in the study of ethics by examining themes discussed by students in written essays that express their understandings of what it is to be an ethical engineer. Such research could cross-validate quantitative data obtained through DIT-2 tests or measure engagement in ways that the DIT-2 cannot. Future work includes completion of the interpretive phase of the qualitative research and development and testing of a phenomenology-informed ethics module for first year Engineering Fundamentals instruction.

Author Information

Valorie Troesch, J.D., is an Adjunct Faculty at Pavlis Honors College, and is a Ph.D. Candidate in the Department of Humanities, Michigan Technological University, Houghton, MI, U.S.A. Email: vtroesch@mtu.edu.

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