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Connecting Engineering Ethics with a Shared Curriculum

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Abstract

An ethics across the curriculum approach is often developed as either engineering faculty and students participating in an interdisciplinary effort or engineering departments implementing ethics education across multiple engineering classes. Most of the literature studying ethics across the curriculum focuses on institutions which do either the former or the latter, but not both simultaneously. However, assessment of student learning outcomes showed that if both approaches are used simultaneously and are purposefully connected with each other, the capacity of students to identify ethical systems and practical foundations for making judgments is improved, and students are better able to apply an ethical system to value judgments.

As part of an intermediate engineering design class, students were assigned an essay in which they connected engineering codes with a chosen system of ethics. The instructor assessment of the first iteration of this assignment noted that some students had difficulties describing the basic tenets of an ethical system beyond a single characteristic statement and often conflated their own personal lived ethic with a formal system of ethics. A revision to this assignment included requiring students to read briefings of several formal ethical systems. These briefings were excerpts from the assigned course pack from an ethics and policy class in the Core sequence, a set of worldview and ethics classes required for all students in the university and collectively taught by faculty from departments across the university, including engineering. This improved the students' understanding of ethical systems and also reinforced concepts from Core. Outcomes were measured by ABET assessment tools developed by the department. The fraction of students that struggled to describe the basic tenets of an ethical system was reduced by a factor of three, and the fraction of students that could clearly support judgments with ethical tenets increased from 40% to 64%.

In addition to the pedagogical modification, several things enhanced the student learning experience that have implications for how educators and institutions can effectively deliver ethics education. First, having an assessment plan that covers both microethics and macroethics encourages forming the connections between them. Second, a mindset of interconnectivity among classes is crucial. Third, participation from engineering department faculty in the general education components enables them to make these cross-curricular connections. Lastly, faculty mentoring and training help achieve this shared goal. Future directions could include making these intentional connections common throughout other classes in the engineering curriculum, including both studio design classes and engineering analysis classes.

Introduction

Teaching engineering ethics is important for a number of reasons, including the tremendous impact of technology on society, the reputation of the engineering profession, and the character development of students [1] - [6]. Additionally, higher education institutions have the practical requirement to include ethics education to maintain ABET accreditation for engineering programs [7]. Ideally, students are equipped to consider ethical dilemmas from the microethics of individual ethics decisions to the macroethics of policy implications on an organization and society as a whole, and students should understand how microethics and macroethics are connected [4], [8], [9]. Graduates should not only be equipped to behave ethically as professional engineers in their individual practice as an engineer but also be equipped to understand broader ethical complexities that could arise as a corporate manager or executive, a research director, or any other local, national, or global position of leadership.

An ethics across the curriculum (EAC) approach within an engineering program has been identified as an effective way to deliver engineering ethics education [1], [10]. Its integrated nature helps students understand that ethics is essential to professional engineering practice and not detached from technical engineering activities [11], [12]. Moreover, the relevance of ethics to students is reinforced when they see their engineering faculty instructors engaged with the content [3], [13] - [15].

The engineering ethics curriculum at Whitworth University employs an EAC approach within the engineering department coupled with a group of classes within the general education requirements that focus on ethics and beliefs. This paper will first describe the structure and components of this hybrid model. It will then describe a modification to an existing engineering ethics assignment that attempts to connect the ethics content from the general education requirements with this engineering ethics assignment. This modification helped the students achieve the desired learning outcomes for this assignment. A closing discussion will consider the elements of this approach that were essential to this outcome that could potentially translate to other programs.

Background

Mitcham and Englehardt describe two different classes of EAC models: singular and multi-level. [2]. Singular EAC models exist within a particular discipline such that multiple required classes for a particular engineering degree contain components of engineering ethics education embedded within those specifically engineering courses. Multi-level EAC models incorporate courses that are designed to span multiple disciplines which might be incorporated in general education requirements.

Because singular EAC models are embedded in engineering courses, they tend to focus primarily on applications of engineering codes of ethics. For undergraduate students, a typical goal is to make ethics a component of a required course taken each of the four years of the program [16] -

[18]. Singular EAC models are often more focused on considering microethics that affect the personal decisions of a practicing engineer.

Multi-level, or robust, EAC models tend to be more common at liberal arts colleges such as Whitworth [2]. These tend to focus primarily on morality, philosophical ethical theories, and the application of personal values [2], [19]. Compared to the singular EAC models, multi-level EAC models are often better equipped to help students think about macroethics and the social impact of policies. However, there can be some challenges for this approach to incorporate meaningful discussion and application of professional codes of ethics [19]. Sometimes a team-teaching approach working across the engineering and philosophy disciplines can be used to create a class that incorporates both philosophical theories and the professional responsibilities of an engineer [20].

The different strengths of the two models are valuable to student development in engineering ethics, and so we are left with the question:

> "How can a curriculum use an EAC approach to develop both branches of engineering ethics education and effectively connect the two sides with each other?"

Some institutions implement both approaches and have allowed programs for individual engineering disciplines to use their own preferred model [21]. Although most programs have historically employed one model or the other, this should not be a binary choice [3], [8]. Snieder and Zhu argue that ethics education must connect a professional approach to ethics with a philosophical approach to ethics to achieve the most effective educational impact [4]. Students can receive the benefits of both approaches, but a mechanism to intentionally connect those approaches is required.

The engineering ethics curriculum and the connection between the two parts of the hybrid approach described in the following sections aim to deliver the full benefit to the students. The ideal outcome is for students to be able to evaluate their specific situations based on a deeper self-consistent system for defining the good, applying that knowledge to a particular problem, and arriving at a decision of what is the ethical thing to do.

A Hybrid Curriculum

The hybrid ethics curriculum is part of a general engineering degree in Whitworth's Engineering and Physics Department and includes an EAC approach for philosophical ethics and an EAC approach for applied professional ethics. The former is housed in the general education component of the curriculum, and the latter belongs to the Engineering & Physics Department. Engineering faculty regularly participate as part of the faculty teaching team that is responsible for classes in the general education component of the EAC approach, including one engineering faculty member that has been the lead instructor for 14 years of the university's ethics and policy course required for all students regardless of major. The engineering program's ABET student learning outcomes include measures for ethics development, and the assessment protocol is designed to collect data from both sides of this hybrid structure. A summary of the curriculum can be found at the end of this section in Table 1.

Whitworth's general education requirements were updated in 2019 and named the "Shared Curriculum", a designation to distinguish it from the previously existing general education model. The Shared Curriculum's name also notes the effort to have shared general outcomes among all courses supporting it and the idea that the curriculum is meant to be shared among the departments and faculty of the university. The requirements are divided into four inquiry groups of this distributive model: belief, culture, expression, and science. Each inquiry group consists of three to five courses. Some of these courses can also count toward a student's major. For example, calculus and physics required for the engineering degree satisfy the math and natural science requirements, respectively, in the science inquiry group. Although most of the philosophical ethics content from the Shared Curriculum is found in the belief inquiry group, other Shared Curriculum classes are also expected to contribute to some of these objectives, albeit more tangentially. For example, all courses receiving the natural science designation, including General Physics I, which is required for all engineering students, must explore the relationship between scientific inquiry and faith/worldview commitments. To satisfy this criterion, instructors frequently include content about ethics, epistemology, or the social impacts of technology.

The belief inquiry group consists of five courses: a biblical literature course; a faith, reason, and contemporary issues (FRCI) course; and three courses in the Core sequence. The three specific courses in the Core sequence (Core 150, Core 250, and Core 350) are required for all undergraduate students, but a number of different course offerings from which students must select at least one can satisfy the other two requirements in this inquiry group. The Core sequence is designed to help students not only understand how to behave ethically but also understand why such actions should matter as a desirable outcome. This is accomplished by providing the students with the tools required to identify and articulate their deeply held commitments (Core 150), validate them based on centuries of intellectual history (Core 250), and then use them to define and seek just outcomes for institutional and social problems (Core 350). On the matter of teaching ethics, Core 350 treats ethics as teleological, first to proactively define the good to achieve, and then to make specific decisions toward that end. It defines ethics as grounded in rigorous systems of thought, built on well-defined views of human nature with clearly articulated claims about human constitution and capabilities.

Core 350 introduces students to various philosophical systems for defining morality [22] and focuses on the five ethical theories described below [23]. These theories can agree on the ethics of an action (e.g., do not steal) but can have vastly different reasons for that prescription:

1. Consequentialist Ethics focuses on the outcomes of decisions; the most prominent example of this theory is utilitarian ethics, which specifies the end to be achieved as maximizing the overall good for the entire set of constituents. Because of its focus on

empirical measurability, it is the de facto theory of ethical consideration in natural and applied sciences [24].

2. Deontological Ethics focuses on the actions themselves regardless of their outcomes; prominent examples of this theory include Kantian and Neo-Kantian ethics which seek to maximize individual rights and prevent the treatment of individuals as means to an end.
3. Natural Ethical Law is a system analogous to the concept of scientific laws; just as the material world functions consistently and predictably in well-defined patterns called "laws", there are moral "rules", such as the Tao, which govern how things ought to function ethically.
4. Supra-Rational Ethics is based on willingly trusting the knowledge and intent of an Authority, and, therefore, complying with a revealed code of decision-making; though a prominent example of this theory is Divine Command Ethics or Theological Voluntarism, it is noteworthy that any ethical theory in which the complexities and uncertainties of decision-making are deferred to a higher authority (such as a professional society's code of ethics) functions in the same way.
5. Virtue Ethics focuses on the agent and how a decision influences the character formation and flourishing of the actor; because of its emphasis on the individual and not on the institution or society, this is not widely used in making policies or codes of ethics but is, nevertheless, enormously influential in motivating individuals in their formation.

An EAC approach is also implemented in multiple engineering courses. Although two courses from the design sequence are specifically designated to require ethics instruction according to the program's curriculum plan, instructors also include ethics content in additional courses. These courses include two engineering analysis courses and a class that considers work and vocation which students are required to take after completing a technical internship. Two of the design courses were selected to require ethics instruction: Principles of Engineering Design, a lower division class, and Engineering Design Project II, an upper division class that is the second half of the yearlong senior capstone project. Engineering codes of ethics are introduced in Principles of Engineering Design, and the connection between these codes and the general education content from Core is discussed in detail in the subsequent sections. In Materials Science and Engineering, an upper division elective, students are given assignments to consider the past and future impacts of materials development on society and to consider how the production of materials and applications of materials might promote or violate various ethical standards. In Statics, a lower division requirement for all students in the program, students will consider the collapse of the skywalks in the Hyatt Regency in Kansas City, MO in a module similar to the one described by Bottomley [12]. In Internship Reflection, students are equipped to seek discernment of vocational plans based on their internship experience, the readings and discussions throughout the semester, and alignment with their personal values, beliefs, and goals. The aforementioned virtue ethical theory helps students connect what they want to do with who they want to become.

Shared Curriculum		Engineering Major	
Core 150	Required for all students	Statics	Required
Core 250	Required for all students	Principles of Engineering Design	Required
Core 350	Required for all students	Materials Science & Engineering	Elective
Biblical Literature	Select from options	Internship Reflection	Required
FRCI	Select from options	Engineering Design Project II	Required
General Physics I	Required for engineering		

Table 1. Hybrid EAC roadmap summarizing courses with ethics and worldview-related content supporting the two branches.

Connecting the Two Parts

The first ethics lesson in Principles of Engineering is an introduction to engineering codes of ethics. It starts by distributing the codes for the National Society of Professional Engineers [25], the American Society of Civil Engineers [26], and the American Society of Mechanical Engineers [27], including their fundamental canons. Students have time in class to analyze and discuss with each other the key similarities and differences among the codes and to identify things that might be expected or surprising from these codes. A written assignment follows this lesson in which students are to select from a set of ethical theories and justify how the tenets from their chosen ethical theory support the three fundamental principles of the code of ethics from the American Society of Mechanical Engineers code of ethics. In the development of the essay, students are to describe the key tenets of the ethical theory they have selected, identify key terms, and define those terms. One of the learning objectives for this assignment is to help students dig deeper into the connection between professional engineering codes and philosophical ethical theories.

This assignment was part of the ABET assessment for the ethics student learning outcome. After the first time this assignment was deployed, the instructor noted that more instruction was needed to separate the concepts of a personal lived ethic versus a formal ethical theory and that the students' descriptions of the ethical theories were not sufficiently detailed. When considering this course in the context of the entire curriculum, this makes sense; the information about ethical theories is taught in Core 350, but most students had not yet taken that course. This likely left most students resorting to internet searches about utilitarianism, virtue ethics, or deontological ethics without the necessary guidance to make the connections between the ethical theories and the engineering codes that the assignment intended. Although some students were able to manage on their own, several struggled to describe the basic tenets of a formal ethical theory and instead essentially connected the engineering codes to their own personal feelings of morality.

To address the shortcomings noted in the original assignment, a revised version was given that included an excerpt from the Core 350 reading packet that gave briefings on the five ethical theories described in the previous section. These briefings are five to six pages for each ethical theory and start by concisely stating a general position or focus and then describing the important central ideas of each theory. These briefings also include relevant connections to epistemology and the implications of how one might relate to culture and society. These briefings note the strengths and weaknesses of each approach and connect them with contemporary figures whose work aligns with each theory. These summaries are written by a philosophy faculty member who is a part of the Core 350 teaching team and enable the students to connect with the content from the Shared Curriculum. Regardless of whether the students have completed Core 350 prior to this design class, connecting the relevant content from Core 350 should improve student outcomes relative to the expected student default behavior with the original assignment of taking the first link(s) from a generic internet search of an ethical theory. This priming may also benefit students in subsequent FRCI courses or Core 350 if they have not yet reached those courses.

Results

An assessment rubric for evaluating the student learning outcomes was previously developed by the department as part of the launching of the engineering degree for ABET accreditation. Two performance indicators re assessed for this assignment, and the corresponding rating descriptions are shown in Table 2.

Performance Indicators	**Aggregate Rating**			
	Weak	**Developing**	**Acceptable**	**Exemplary**
4a. Identifies ethical systems and practical foundations for making judgments.	States ethical systems or practical foundations in simple black and white terms with no competing goods.	Identifies only practical foundations as applicable to making judgments.	Identifies a single, though applicable, ethical system with a practical foundation to make a judgment.	Identifies multiple ethical perspectives (e.g. professional codes, philosophical systems, or Biblical perspectives) to analyze a situation from various means.
4b. Uses reasoning and rationale to apply an ethical tenet to judgments.	States personal opinions as supportive rationale for ethical judgments.	Judgment is supported with disconnected reasoning.	Judgment is supported with reasonable reasoning.	Judgment is clearly supported with ethical tenets including potentially conflicting ones.

Table 2. Performance Indicators and Rating Descriptions

Fifteen student papers were considered for the first version of the assignment, and fourteen student papers were considered for the second version of the assignment. For both iterations and both performance indicators, student ratings ranged from “Developing” to “Exemplary” and no ratings of “Weak” were assigned. For performance indicator 4a, the mode of the distribution shifted from “Acceptable” to “Exemplary”, and the number of students in the “Developing” category was reduced from three to one. A general shift to stronger ratings was also seen for performance indicator 4b. A comparison of the student rating distributions for performance indicator 4b is shown in Figure 1. The revision enabled the students to identify, describe, and apply tenets of ethical theories and effectively connect them with the given canons of professional engineering codes.

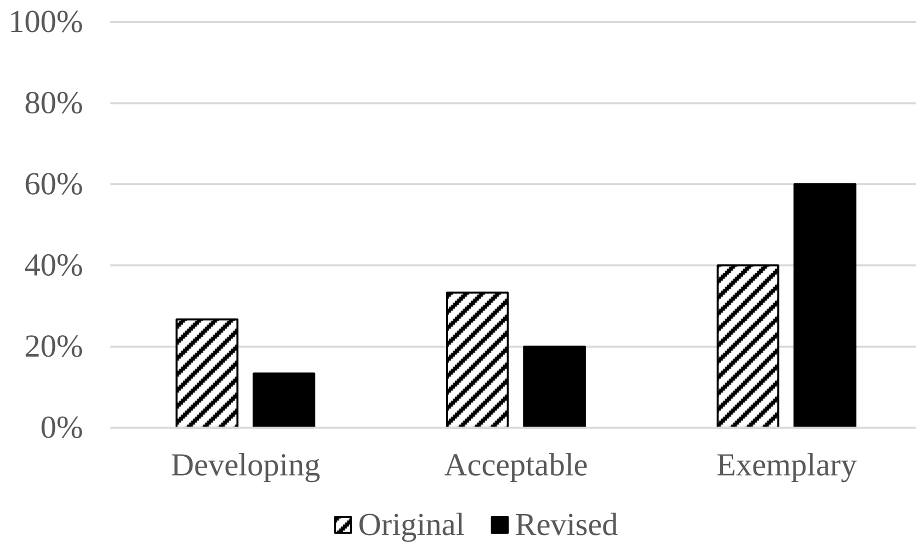

Figure 1. Student rating distributions for the performance indicator for applying ethical tenets to judgments.

Discussion

Having observed the improved results of the curricular modification, future directions could include making these intentional connections in other engineering courses that already contain ethics content. Also, ethics modules can be included in more classes in the engineering curriculum, including both studio design classes and engineering analysis classes. Additionally, there is likely more existing work in the department in individual classes that is not shared with the rest of the members. This happens in department meetings for classes that are tagged for formal ABET assessments, but sharing other activities from across the engineering curriculum would likely enhance and encourage other efforts.

Some general observations from this curriculum development experience may be able to translate to programs at other institutions. First, having an assessment plan that has rubrics that cover both sides of the ethics spectrum helps guide the development of the hybrid approach and incentivizes forming the connections between them. The department’s interdisciplinary mindset that values work alongside the arts and humanities lent itself to creating this kind of standard. Second, a mindset of interconnectivity among classes is crucial. Faculty often work diligently to convince students that their course content should be retained and remembered after the conclusion of the course, and many will also refer to content from prerequisite courses. However, faculty should hold this mindset across the entire curriculum, including the general education, not just along the course sequence in which their courses reside. Third, the shared nature of the general education curriculum and participation from engineering department faculty were critical components in developing this kind of cross-curricular connection. Most faculty in the department have participated as instructors in the Core program, and all regularly teach courses that contribute to the general education requirements. Many of these courses are primarily for students pursuing majors outside of the department. This kind of participation is essential and is one of the catalysts for developing the connection between the general education ethics component and the professional engineering ethics component. The instructor responsible for the assignment revision featured in this paper was aware of the briefings describing the ethical theories after being part of the Core 350 teaching team. Previous papers have noted that one of the barriers to this sort of instruction is the reluctance of engineering faculty to participate and the lack of training for this activity [5], and some institutions have described approaches to address this [17]. Lastly, to build on that observation, faculty mentoring and training help achieve this shared goal. In this case, senior faculty members who were willing to share course content enabled others to use that material in different ways to achieve the desired outcomes. Even the assessment procedures were first modeled by a senior faculty member in the department when the engineering program was initiated. Just as important, however, is the recognition that this is a two-way street. Other faculty need to be interested and willing to invest the effort to develop these skills. Institutions can and should consider ways to encourage and create time for this practice.

Conclusion

This work demonstrates how connections between philosophical ethical theories can be made with practical engineering ethics codes. It is valuable for students to learn both of these and to be able to connect them with each other. The engineering ethics curriculum can be designed with this student learning outcome in mind from the larger EAC concept down to the smaller details in individual assignments as demonstrated in this case with the introduction to engineering codes of ethics within an intermediate-level design class.

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for writing the briefings describing the various ethical theories that were shared with the engineering students and has been a leader in the Core 350 teaching team.

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