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Ports, Grace, "Formal and Informal Undergraduate Ethics Education in Engineering" (2018). *Undergraduate Voices*. 2.
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Literature Review

Formal and Informal Undergraduate Ethics Education in Engineering

Grace Ports, University of Dayton

Introduction

This literature review attempts to answer the question of whether formal education or informal education of ethics within civil engineering is more beneficial. If there is a lack of structured education of ethics in civil engineering, then another area of interest is to discover where engineers are being informally educated. Another area of inquiry is whether it is more beneficial to teach engineers ethics prior to the time when they are required to study the code of ethics for their certification exam, or should engineers wait until moments before the exam to study the code. This article examines the potential benefits of studying the code of ethics in a formal setting as well as the effectiveness of learning ethics informally.

The topic of a structured education in engineering ethics has been a controversial and somewhat confusing area of discussion (Li & Fu, 2012). As the field of engineering develops, interest in ethics education grows. An issue that many undergraduate institutions struggle with is determining the best way to teach ethics and professionalism in the field of engineering. Some even question whether or not ethics should be taught to undergraduates in a formal setting. This confusion stems from the lack of research conducted on finding the best way to teach ethics. Li and Fu (2012) address this confusion stating that "a critical gap still exists in what to teach and how to teach engineering ethics in order to produce the best possible ethical engineers in today's fast-changing environment" (p. 340). Not having a standard for all undergraduate engineering programs causes confusion.

Professors and faculty are unsure of what they are supposed to teach and what methods would be the most effective for teaching. As Li and Fu point out, engineers are required to keep up with a fast-paced, constantly changing environment, which makes it even more important for engineers to be taught ethics and professionalism.

This literature review has been written from my perspective as a first-year undergraduate student who plans to pursue a career in civil engineering in the future. I am interested in learning more about how I can optimize my education of ethical concepts, whether it would be through formal undergraduate courses or through experience-based opportunities. I understand the significance of engaging with ethics and professionalism and hope that this literature review will reveal the best ways of learning ethics for my own studies and for other engineers currently studying for their bachelor degree.

Methods

For this research project, I used information gathered from an interview to guide my review of literature. The interviewee, an experienced discipline insider, was prompted with questions which related civil engineering to the humanities. After being given several possible topics, brief research was done in order to discover which topic filled a gap in current literature. A topic of discussion which the interviewee did not know much about was formal and informal education of ethics within civil engineering, or on a broader scope, engineering in general. Once I found this topic to delve into, I found reliable sources which expanded upon this topic. When documents and articles were found which clarified the status of ethics education in engineering, they were then annotated and separated into different categories of thought to be compared and contrasted to other documents. These documents were separated into categories which focused on the current curriculum of ethics in engineering, the informal education of civil engineering, and ethics relating to civil engineering. By separating the literature into categories, commonalities and differences within the literature became evident. These trends were then analyzed in order to come to a conclusion.

Statement of the Problem

According to several studies, students actually have a desire to learn ethical codes which pertain to their field (Gil-Martiín, Hernández-Montes, Segura-Naya, 2010; Monteiro, 2016). Monteiro (2016) conducted a training session showing that

students consider it "necessary to incorporate ethics education in engineering courses" (para. 83). Some students, however, were hesitant to answer whether they thought ethics education was necessary or not because they did not "consider themselves informed about the subject in question" (para. 84). After Monterio revealed several themes of ethics education in a brief training session, the students agreed that it was indeed important to incorporate ethics into the engineering curriculum. This training also revealed that the students not only thought the curriculum would be necessary for their professional career but felt that the information would apply and improve their ability to respond to situations in their personal lives.

Along with Monteiro's findings, Gil-Martiín, Hernández-Montes, and Segura-Naya (2010) have also discovered undergraduates' thoughts after participating in a course which focused on ethics in engineering, specifically relating to civil engineering. The course, "went beyond professional aspects; with students seeking to include moral and ethical principles in their own ordinary lives as well as in their professional development" (p. 412). The researchers found that although the main focus of the course was the ethical dimensions which construct engineering standards, many of the students found that although they were engaging with law, they were more concerned about learning ethics to be moral citizens. They also found that this course prompted the students to seek more general knowledge about conscience.

Consistent with the students desiring to deepen their knowledge of ethics, Hoke (2012) points out the argument that, "ethics education is itself a means of meeting one's obligations under ASCE's Code of Ethics" (p. 41). The American Society of Civil Engineers' Code of Ethics (2012) states, "Engineers shall continue their professional development throughout their careers, and shall provide opportunities for the professional development of those engineers under their supervision" (Canon. 7). Accordingly, it is required that engineers be able to comprehend Code of Ethics and be able to apply their knowledge and ethics education to complex ethical dilemmas.

Engineering ethics can be taught to undergraduate students in various ways. However, these means of teaching ethics can be separated into two categories, formal education such as classroom-based learning, or informal education, which is an organic experiential means of education. In the following sections, I will address the benefits and shortcomings of these two means of teaching engineering ethics.

Formal Ethics Education

While the studies conducted by Monteiro (2016) and Gil-Martiín, Hernández-Montes, and Segura-Naya (2010) confirm students' desires to learn ethics in engineering, there are uncertainties across the field regarding the best methods and strategies for teaching ethics. There are two general schools of thought dealing with the education of ethics for engineers. One school argues that it is most beneficial for engineers to be taught ethics formally during their undergraduate academic career (Cao, 2015; Colby & Sullivan, 2008). The other school argues that this is not the best time to teach ethics; instead, it is more beneficial to wait until a student is participating in hands-on practices, such as co-ops or other employment, or studying for their master's degree (Bairaktarova & Woodcock, 2015; Berne & Briggs, 2003; Colby & Sullivan, 2008; Newberry, 2004)

As Cao (2015) mentions in the "Comparison of China-US Engineering Educations in Sino-Western Philosophies of Technology," as humans progress into the future, ethical dilemmas will not disappear, but continue to accumulate: "Old engineering ethics issues will become intensified, and new conflicts will continually emerge in the society" (p. 1632-1633) making engineering tasks more difficult for engineers who have not received a formal education in dealing with ethical dilemmas. Cao not only calls for engineering ethics to be implemented into the academic curriculum, but also for there to be "some consensus" (p. 1632) internationally which holds nations accountable for "codes of engineering ethics, accreditation of engineering programs, and the making of international technological and engineering laws" (p. 1632). Cao urges, "engineering ethics education should be given a proper disciplinary status" (p. 1632).

Colby and Sullivan (2008) also highlight the importance of teaching ethics in undergraduate education, suggesting that institutions need to make the ethics education more "intentional" (p. 333). "Ethics Teaching in Undergraduate Engineering Education" recommends that if institutions want to "strengthen their students' ethical development, they should consider tracking students' exposure to these issues, identifying where and how this learning takes place" (p.336). According to Colby and Sullivan (2008), documentation which looks to follow how and when undergraduates learn ethics shows that the curriculum is often unclear and "sometimes even seemed to be inaccurate" (p. 336).

A nonprofit, non-government organization, ABET, or Accreditation Board for Engineering and Technology, has been attempting to clear this confusion in

undergraduate education by creating criteria for programs at colleges or universities to become accredited. According to ABET's website, "ABET accreditation provides assurance that a college or university program meets the quality standards of the profession for which that program prepares graduates." ABET claims that there are several reasons why a program should consider the accreditation process. The first reason they suggest is for the students within the accredited programs. By being in these programs, the students are guaranteed to learn the global standards within their engineering field. By being a college or university that offers ABET-accredited programs, the school is able to boast that it offers a high-quality of education. The ABET also aids employers by guaranteeing that the student of ABET-accredited programs received all the necessary educational requirements (A Valued Credential). Part of the accreditation criteria focuses on student outcomes, including comprehension of ethical concepts. The Criteria for Accrediting Engineering Programs, 2016-2017 states that students should have the "ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability" as well as "an understanding of professional and ethical responsibility" (Criteria for Accrediting Engineering Programs, 2016-2017).

For instance, the University of Illinois is ABET-accredited in aerospace engineering, agricultural and biological engineering, bioengineering, chemical engineering, civil engineering, computer engineering, computer science, electrical engineering, engineering mechanics, general engineering, industrial engineering, materials science and engineering, mechanical engineering, and nuclear, plasma, and radiological engineering. At the University of Illinois, they offer the course "Ethics and Engineering," open to students of all majors. This course teaches both normative ethics as well as ethical applications to the engineering field. The course will aim to lead the students to develop their moral character (ECE/PHIL 316: Ethics and Engineering). This class could ensure that engineering students are learning "professional and ethical responsibility", as the ABET requires (Criteria for Accrediting Engineering Programs, 2016-2017).

As Cao suggests, in order to keep up with new ethical complications, there needs to be an international consensus that holds the nations accountable for the engineering ethics education that they are providing. Cao expressed that engineering ethics is critical and "should be given a proper disciplinary status" (p. 1632). Colby and Sullivan agree, claiming that engineering ethics education needs

to be made more "intentional" (p. 333). ABET sees this need and has been working with engineering programs at 776 colleges or universities in 31 countries. ABET is making engineering ethics a requirement within its accredited programs.

Informal Ethics Education

Although formal ethics education is supposed to provide a substantial foundation of ethical education, an overwhelming number of articles suggest that the formal education of ethics is not necessary (see Bairaktarova & Woodcock, 2015; Berne & Briggs, 2003; Colby & Sullivan, 2008; Newberry, 2004). Their findings argue that the ethics education that engineers acquire outside of the institution are more beneficial and meaningful than within a classroom. The advocates of this view have several different reasons as to why they are against classroom-based undergraduate ethics education. The arguments vary from the lack of maturity of students to the impracticality of trying to fit another course into the already dense required academic classes. These arguments which counter formal education can be separated into three categories: lack of time, lack of maturity, and lack of experience.

Critiquing formal ethics education in undergraduate education, Colby and Sullivan (2008) also point out several shortcomings in undergraduate engineering studies regarding ethics education. They criticize the narrow definition of ethics and professional responsibility and suggest broadening the definition. Colby and Sullivan (2008) raise the point that ethics cannot be fully understood only within the frame of undergraduate education, "Competence in these and other aspects of engineering practice requires many years of on-the-job learning and professional development" (p. 335). While learning ethics during a student's undergraduate years might lay the foundation for their profession, it takes years of practice in order to fully understand the depth and breadth of ethics and professional responsibility. While having a basic understanding of engineering ethics taught in undergraduate classes could be beneficial, a strict curriculum should not be stressed considering complete comprehension requires several years of hands-on experience.

Another issue addressed is that undergraduate students might not necessarily be receiving the hands-on practice which learning ethics requires. Colby and Sullivan (2008) use the example of nursing and medicine to explain their argument:

> In both of these fields, professional responsibility is learned primarily in the context of practice-based education, in the parts of their training that involve supervised care of patients. This approach to teaching professional responsibility and ethics engages students with models of high quality work, supports the development of conscientious habits, makes clear to students the relevance and importance of ethical issues for their work, and deepens their understanding of complex issues within an institutional context. (p. 336)

Applying the same argument to engineering, it would be more beneficial for students to engage with activities such as "design courses, co-op experiences, summer or part-time engineering work, or project-focused extra-curricular activities" (p. 336), which are all considered informal methods of learning. Working in a setting surrounded by those who are experienced makes these types of informal, hands-on experiences more valuable than a formal, classroom education. Being surrounded by others who have several years of experience in the field will most likely make a greater impact than learning ethics from a textbook. Berne and Briggs (2003) exemplify this when they explain the results of taking undergraduate engineering students to visit "intelligent, well-read senior citizens" (p. 93). They suggest that we can look to those older and more experienced than us to shape our understanding of "what is right, what should happen and should not, relative to the way we will use and adapt to, and perhaps depend on, technological developments to come" (p. 94).

Along with lacking experience in the field, Newberry (2004) suggests that young engineering students may also lack the maturity or time to attempt to learn ethics. Rather than aiming to thoroughly teach ethics to undergraduates, professors and faculty are providing the students with preliminary information, which they may later use as a base to build upon later in their careers. Newberry rationalizes that "after all, perhaps college-aged people are not yet primed for serious emotional engagement on these issues, so the task is simply to cultivate the soil in which it can later sprout" (p. 347). While this concept promotes education in ethics, it only proposes that a rudimentary level of education should be provided. This suggests that a basic level of ethics education should be introduced but should not be expected to be fully understood until the engineers have had experiences to further clarify ethical concepts. Newberry (2004) suggests instead that the most

appropriate time for engineers to formally learn ethics is while they are studying to obtain their master's degree. The American Society of Civil Engineers (2017) has responded to this topic by asserting that the four years of undergraduate studies is not sufficient enough for civil engineers. ASCE now recognizes a master's degree as being the first professional degree in the field. This statement by the ASCE shows that they acknowledge the difficult and extensive course load of undergraduate civil engineers.

One of the reasons why an undergraduate degree in engineering is not sufficient enough to be considered a professional degree for civil engineering is because the undergraduate education does not allow enough time for thorough learning of engineering ethics. Undergraduate engineering students already have a full curriculum, solely composed of technical content. If these students are already extremely busy with their other required classes, when will they squeeze ethics into their education? This also raises the concern about the legitimacy of ethics education if it is not considered or treated as equal to the other technical classes (Newberry, 2004).

Writers who are skeptical about the formal undergraduate education of ethics in engineering underline many problems with the lack of hands-on practice, the immaturity of undergraduate students, and already extensive course load. However, there was also a study conducted which shows that even if students do receive an ethics education, they would not show a better comprehension of professional responsibility than a student who has not taken any ethics class. Bairaktarova and Woodcock (2015) conducted a case study with 190 undergraduate students. The students were asked to read two vignettes dealing with ethical and moral decisions and choose the correct answer out of four choices. Only one of the answers was correct. While Bairaktarova and Woodcock (2015) predicted that those students who had taken ethics classes would perform better, they "found no impact of having previously taken an ethics class" (para. 10). Bairaktarova and Woodcock hypothesize, "It is possible that as engineers-in-training become more seasoned, their awareness of the range of volitional control they have across different ethical dilemmas may increase" (para. 24).

One way for an undergraduate student to become more experienced within the field of engineering is through cooperative education. A university that encourages experiential-based learning of engineering ethics is the University of Dayton. The Department of Engineering at the University of Dayton offers cooperative education. This program requires that students complete three work terms with the

same company. The University of Dayton lists the benefits of partaking in the cooperative education program:

> 1. Train in a chosen academic discipline. 2. Define career goals and evaluate career choices. 3. Earn money for educational expenses. 4. Gain maturity, develop self-confidence and learn money management. 5. Acquire work experience. 6. Develop understanding and appreciation of problems and diversities. 7. Ease the transition from graduation to full-time employment. (Cooperative Education: University of Dayton, Ohio).

Throughout the three work terms, students will be treated as employees of that company. It is through this experience that the students will acquire a greater understanding of the information they were taught in class as well as ethical concepts used in the workplace.

Though students state that they desire to learn ethics during their undergraduate academic career, the most efficient method of learning ethics is unclear. While most say that some kind of introduction to ethics is important, most evidence leads to the conclusion that ethics is best taught to engineers who are more mature and can learn from hands-on experiences.

Conclusion

From the information presented in various articles on the topic of ethical studies within engineering, those which attest to the informal education of ethics hold a stronger argument. Though some articles claim that the formal education of ethics is necessary for undergraduates, there are many other articles which challenge this position. While those who counter the argument for formal education would agree that some basic level of formal education of ethics might be helpful, many state that the most crucial time for students to learn ethics is during hands-on experience. Those who are for informal education argue that undergraduates lack three critical aspects of learning ethics. Undergraduates lack the proper amount of time, maturity, and opportunities for experience.

Colby and Sullivan (2008) and Newberry (2004) explain their position that undergraduates lack time to dedicate to the study of ethics. Colby and Sullivan (2008) raise the point that ethics cannot be fully understood during undergraduate

education. While the curriculum may lay a foundation, "competence in these and other aspects of engineering practice requires many years of on-the-job learning and professional development" (p. 335). It is extremely difficult to obtain these years of experience during undergraduate studies, as the students are already focused on their many classes. Newberry (2004) suggests that undergraduate studies are not the ideal time to teach young engineers ethics. Engineers already have a full curriculum, mainly composed of technical content. If an ethics class is squeezed into the already heavy course load, then the student might doubt the legitimacy or importance of the class.

Newberry (2004) also suggests undergraduates might lack the maturity that is required to fully comprehend ethics. He suggests that this is a time when students are not yet prepared to form "emotional engagements on these issues" (p. 347). Instead, the best time for a student to formally learn ethics is while they are studying to obtain their master's, as the American Society of Civil Engineers views a master's degree as being the first professional degree in the field.

Colby and Sullivan (2008) and Berne and Briggs (2003) argue that undergraduates lack the opportunities to gain the experience required to fully comprehend ethics. As Colby and Sullivan (2008) suggest- along with their argument that developing a comprehension curriculum of ethics requires ample time- ethics also requires years of practice and hands-on experiences. They even go as far as comparing the methods of learning engineering ethics to medical ethics. As it is extremely beneficial for medical students to involve themselves in the care of patients, it is equally as important for engineers to engage themselves in activities such as, "design courses, co-op experiences, summer or part-time engineering work, or project-focused extra-curricular activities" (p. 336). Berne and Briggs (2003) add that it would be impactful for engineers to learn ethics from those who have years of experience. They argue that hearing from other human beings' experiences is more influential than words from a textbook.

While this review of literature concludes that informal education of ethics for engineers might be more beneficial, this conclusion leads to several questions. If informal education is the best method of teaching ethics, then how can the information be regulated and taught to all engineers? If engineers are learning ethics through the experiences of those who are older, how can we make certain that the information they are being taught is still relevant to the current ethical dilemmas?

As a first-year undergraduate at University of Dayton's College of Engineering, I have learned that while learning a basic level of ethical concepts in the classroom

is valuable, participating in experience-based learning opportunities is critical. After learning from the two schools of thought, I plan to participate in the University of Dayton's Cooperative Education program in order to gain experiential-based education of engineering ethics.

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