CULTIVATING DISPOSITIONS TOWARDS SOCIAL RESPONSIBILITY: STUDENTS' PERCEPTIONS OF THE SOCIAL RESPONSIBILITIES OF ENGINEERS

by

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ABSTRACT

Engineering social responsibility is the responsibility of engineers to evaluate the broader impacts of their work on public welfare. Despite the central role of social responsibility to the engineering profession, social responsibility does not seem to be adequately emphasized in engineering curriculum. This study seeks to understand how engineering students understand the social responsibilities of engineers. Data were collected at a large, public institution through a survey and interviews with ten students and three professors. The results from this study indicate that students understand the responsibilities of engineers to benefit and prevent harm to society. When asked about influences on their views of social responsibility, students identified personal and extracurricular experiences, not engineering courses. This finding suggests students may form their dispositions towards social responsibility outside of their engineering curriculum. To cultivate students' dispositions towards social responsibility, engineering programs are encouraged to incorporate instruction about the social dimensions of engineering.

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INTRODUCTION

Engineering failures are human failures

During my first year of college, I attended a lecture about mechanical failure in materials. The lecturer introduced the topic by displaying pictures of engineering catastrophes, including the sinking of the Titanic and the Chernobyl nuclear disaster. The lecturer then asked the class what these catastrophes had in common. The class unanimously responded that these disasters were examples of material failure. The lecturer corrected, "No, these are examples of *human* failure." This remark had a profound impact on me: it confronted me with the responsibility that I would have as an engineer. This lecture was the first time I became aware that I would be entering a profession that could cause unintentional harm and devastation. Through this realization, I developed a sense of professional responsibility to serve people who would be affected by my work as an engineer. My interest in engineering social responsibility further developed as I read articles about social responsibility in engineering education. I chose to build on this area of research for my thesis because I believe it is important for students to graduate with an appreciation for the engineering profession's commitment to public welfare.

Social responsibility in engineering

Engineering social responsibility can be understood as the professional obligation of engineers to consider the broader impacts of their work on society. Social responsibility has been recognized as an important part of the engineering profession.

The first fundamental canon of the code of ethics of the National Society of Professional Engineers (NSPE, 2007) reads as follows: "Engineers, in the fulfillment of their professional duties, shall hold paramount the safety, health, and welfare of the public" (NSPE, 2007). The NSPE code of ethics places engineers' responsibility to the public at the forefront of the profession. Engineers' consideration of the public is important because engineering solutions that do not consider cultural or social contexts have tended to fail (Canney & Bielefeldt, 2015a).

The engineering profession has promoted the role of engineers in improving public welfare to the public. The National Academy of Engineering published a report called "Changing the Conversation" that outlined ways to improve public perceptions of engineering (NAE, 2008). This report articulated a new position statement that emphasized engineering as a creative profession that improves human welfare. The report calls for spreading messages that emphasize engineering for social good: these messages could attract and retain engineering students from underrepresented populations.

Social responsibility has been recognized as an important outcome of undergraduate engineering education. In the EC2000 accreditation criteria, ABET (formerly the Accreditation Board for Engineering and Technology) defined eleven student outcomes for graduates of engineering programs. Though these outcomes do not explicitly mention social responsibility, three outcomes are closely related to social responsibility:

> (c) an 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
> (f) an understanding of professional and ethic responsibility
> (h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environment, and societal context
>
> (ABET accreditation criteria)

The implicit mention of social responsibility in these criteria indicates the importance of social responsibility in engineering programs; however, ABET does not have strict guidelines on specific content to teach students. Despite the mentions of social responsibility in accreditation outcomes, there is evidence that engineering programs are not adequately cultivating students' dispositions towards social responsibility within the engineering profession (Cech, 2014; Zandvoort, Borsen, Deneke, & Bird, 2013). This evidence is concerning because the attitudes that students develop towards social responsibility during their education influence their professional work as practicing engineers. If engineering programs do not develop students' dispositions towards social responsibility, students may not gain the appreciation for social responsibility necessary for them to consider the outcomes of their work on public welfare (Cech, 2014).

LITERATURE REVIEW

Defining social responsibility

The term "social responsibility" is a broad construct that researchers have interpreted in a variety of ways. The purpose of this section is to compare different conceptions of the social responsibilities of engineers.

Vanasupa, Slivovski, and Chen (2006) defined social responsibility as "the responsibility of engineers to carefully evaluate the full range of broader impacts of their designs on the health, safety and welfare of the public and the environment." This definition bestows upon engineers the responsibility to examine sociotechnical aspects of their designs. This definition appeared throughout several studies (Canney & Bielefeldt, 2015a; Lathem, Neumann, & Hayden, 2011; Zandvoort, 2008).

In their interpretation of social responsibility, Vanasupa et al. (2006) proposed three components of socially responsible action: the ability to act, a willingness to act, and an awareness of needs. The ability to act arises from an engineer's technical knowledge and skills. A socially responsible engineer must be willing to act and be aware of the issues and stakeholders involved. These three components were adapted by Canney and Bielefeldt (2015a), who identified the following as indicators of social responsibility in engineering students: the development of technical and professional skills (the ability to act), the recognition that engineering solutions can solve societal problems (an awareness of needs), and the feelings of obligation to serve others with their engineering skills (a willingness to act). Social responsibility can come from an engineer's recognition of their ability to serve others with their professional skills (Canney & Bielefeldt, 2015a). The expertise and specialized competencies of the engineering profession uniquely position engineers to reflect on the broader impacts of their work (Johnson, 1989; Cech, 2014).

The following sections discuss themes and issues that are raised in tandem with social responsibility in the literature: public welfare, sustainability, and ethics.

Social responsibility and public welfare. Social responsibility can be broadly understood as the responsibilities of engineers to serve public welfare and safety (Cech, 2014; Heikkero, 2008; Johnson, 1989; Zandvoort, 2008). Engineers' responsibilities towards the public are distinct from their responsibilities towards the people that engineers design for. This distinction is important because technological objects and systems arguably cannot be designed to serve all populations (Cech, 2014). In other words, socially responsible engineers consider the needs and well-being of people that are affected by the engineering project, even if they are not the intended users of the product or technology. Similarly, Canney and Bielefeldt (2015a) emphasized social responsibility as an obligation to serve disadvantaged or marginalized populations, whose needs may not be visible to engineers. This focus on serving people from disadvantaged populations positions engineers as agents of social change who can reduce social disparities. This connection of engineering social responsibility to issues of social justice was explicit in other articles as well (Conlon, 2008; Pritchard & Baillie, 2006; Zandvoort et al., 2013).

Social responsibility and sustainability. Several articles included issues of sustainability and the environment in their conceptions of social responsibility. These articles address the responsibility of engineers to consider the environmental impacts of the technologies they design (Conlon, 2008; Pritchard & Baillie, 2006; Vanasupa et al., 2006; Zandvoort et al., 2013). These articles position social responsibility as a commitment to creating a sustainable world (Conlon, 2008; Pritchard & Baillie, 2006; Vanasupa et al., 2006), because improvements to human welfare have sometimes caused irreparable harm to the environment (Vanasupa et al., 2006).

Social responsibility and ethics. Studies in engineering ethics and in science and technology studies discuss the relationship between social responsibility and ethics (Bucciarelli, 2008; Conlon, 2008; Swierstra & Jelsma, 2006; van der Poel & Verbeek, 2006; Zandvoort et al., 2013). The study of van der Poel and Verbeek (2006) bridged the literature in the fields of engineering ethics and science and technology studies with a discussion of ethical issues in engineering education.

Zandvoort et al. (2013) connected social responsibility and ethics by implicitly defining social responsibility as an action that satisfies certain ethical principles: do not harm others, prove that risks are within acceptable limits, obtain informed consent of affected people, compensate for any harm to those who did not give informed consent, and guarantee freedom of speech.

Johnson (1989) asserted that social responsibility falls on both individual engineers and on the engineering profession collectively. Some studies drew distinctions between the individual responsibility of engineers and the collective responsibility of the engineering profession to act with social responsibility (Bucciarelli, 2008; Canney & Bielefeldt, 2015a). Bucciarelli (2008) called for a greater emphasis on the collective responsibility of engineers to understand their roles in society and mediate the effects of their work on public welfare. Bucciarelli (2008) claimed that a focus on the microethical issues facing an individual engineer was too narrow and advocated for greater attention to the macroethical issues facing the engineering profession.

Discussions about ethics and social responsibility raise the question of how much influence engineers have over decisions in the design process. Understanding this level of influence can inform how much responsibility engineers bear for the consequences of their designs (van der Poel & Verbeek, 2006). Van der Poel and Verbeek (2006) outlined four factors that influence the agency of engineers to act in socially responsible ways:

1. The regulations, norms, and codes that engineers must adhere to in their designs
2. The division of roles and labor between those involved in the design process
3. The hierarchal structure of the organization and the autonomy engineers have within the organization
4. The ability to foresee social consequences of the engineering design

These four factors affect the strength of any causal relationship between an engineer's actions and the consequences of those actions. This causality determines whether an engineer can be held accountable for the consequences of the technologies they design. Swierstra and Jelsma (2006) illustrated the difficulties of navigating these factors within the work of modern engineers. Swierstra and Jelsma (2006) asserted that in most cases, it would be impossible to ascribe the consequences of a technology to the actions of individual engineers. Despite the challenges of establishing causality, Cech (2014) maintained that these difficulties do not absolve engineers from considering the interests of public welfare during the design process. To mitigate these challenges, Conlon (2008) proposed that engineers can become active in public policy to reframe laws and regulations not as constraints, but as opportunities to facilitate socially responsible action.

One specific ethical framework that has been applied to engineering is ethic of care. Care can be understood as a "value-guided practice, not a system of values" (Pantadizou & Nair, 1999). The ethic of care framework focuses on the relationships between those who are cared for and those doing the caring. Pantadizou and Nair (1999) argued that this framework is particularly suitable for engineering, noting that both engineering and care respond to a need and are oriented towards acting to address that need. A focus on care could encourage engineers to consider affected parties during the design process and foster more socially responsible practices.

These definitions of social responsibility encompass the themes of public welfare, sustainability, and ethics. These definitions emphasize the commitment of engineers to serve the interests of the public, environment, and their profession, respectively. The broad purview of conceptions of social responsibility within the literature informs this study's investigation of students' perceptions of social responsibility: how do engineering students understand social responsibility when there are several interpretations among researchers in the field?

Understanding and assessing students' views on social responsibility

The studies described in the preceding section discuss researchers' and scholars' understanding of social responsibility within the engineering profession. How do engineering students understand social responsibility? Students' understanding of social responsibility can provide insights into how effective engineering programs are in cultivating students' dispositions towards social responsibility. This section describes frameworks and assessment instruments that have been developed to investigate students' views about social responsibility.

Professional and Social Responsibility Development Model (PSRDM). Canney and Bielefeldt (2015a) developed a framework for studying the development of dispositions towards social responsibility in engineering students, called the Professional and Social Responsibility Development Model (PSRDM). The PSRDM describes the development of personal and professional social responsibility through several dimensions, shown in Figure 1.

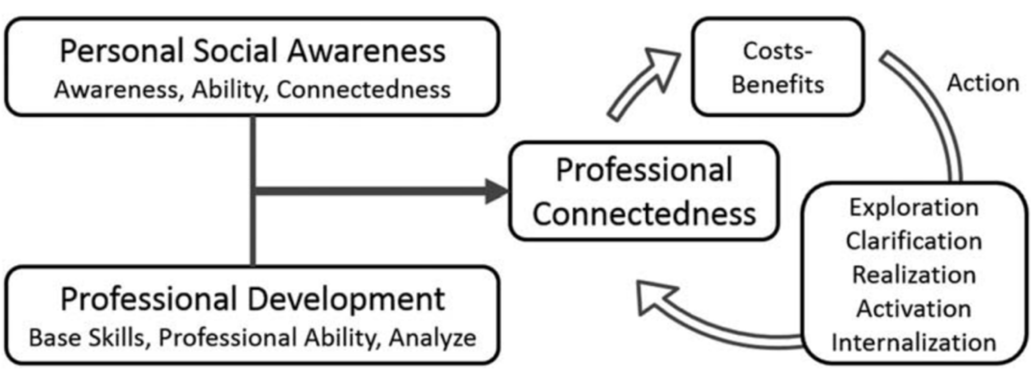

Figure 1: Professional and Social Responsibility Development Model

(adapted from Canney and Bielefeldt (2016)

The Personal Social Awareness realm concerns the development of social responsibility within students' personal lives, separate from their professional identities as engineers. Within this realm is the awareness of those who are in need (awareness), the recognition that one can help those are in need (ability), and the obligation to help others (connectedness). The Professional Development realm comprises the development of students' professional abilities and recognition that their professional abilities can be used to serve others. Within this realm, there are three dimensions. Base Skills refers to the technical and professional skills needed to act with social responsibility. The Professional Ability dimension refers to an understanding that engineers can help others. The Analyze dimension refers to the ability to evaluate the social dimensions of professional work. The Professional Connectedness realm focuses on students' feelings of obligations to use their professional skills and abilities to help others. Within this realm, the Costs-Benefits dimension characterizes the costs and benefits of socially responsible action and how they influence an engineer's decision to act.

Assessing students' understanding of social responsibility. Social responsibility can be difficult to assess as an educational outcome. Shuman et al. (2005) considered social responsibility an awareness skill and asserted that it could be assessed, like other professional skills outlined by ABET. Though students' awareness of social responsibility can be assessed, it is difficult to gauge whether this awareness will translate into socially responsible action in the workplace.

Assessment instruments have been developed to measure engineering students' perceptions of the social responsibility. Lathem et al. (2011) argued that assessing student attitudes is important because these attitudes influence how students may direct their skills and knowledge as practicing engineers. Lathem et al. (2011) claimed that student attitudes could be assessed as outcomes to measure the effectiveness of programs and interventions in influencing students' attitudes and dispositions. Lathem et al. (2011) developed the Student Attitudes Survey to assess the influence of curricular changes on civil and environmental engineering students' attitudes towards the roles and responsibilities of engineers in society.

Canney and Bielefeldt (2016) operationalized the PSRDM with the Engineering Professional Responsibility Assessment to measure students' views of social responsibility. The EPRA consists of Likert items that are related to the dimensions of the PSRDM. The EPRA also asks about students' desirable job attributes, volunteer history, and demographic information. Canney and Bielefeldt (2016) hoped the tool could measure the effectiveness of interventions to increase students' dispositions towards social responsibility. Evidence of the usability, validity, and reliability of the EPRA was collected from thousand students at five different institutions in the United States. Canney and Bielefeldt (2016) used structural equation modeling to show correlations between the dimensions of each realm and establish the validity and reliability of the EPRA instrument. One measure of convergent evidence of validity was the correlation between Likert items and career attributes: students who felt it was important to help others in a career tended to have higher social responsibility than students who viewed helping others as less important in a career (Canney & Bielefeldt, 2016). Ordinal alpha values suggested good internal reliability across items within each dimension (Canney & Bielfeldt, 2016). The EPRA has been used in research studies to assess students' views on social responsibility (Canney & Bielefeldt, 2015b; Canney & Bielefeldt, 2016).

Teaching social responsibility to engineering students

The preceding sections have discussed researchers' and students' perceptions of social responsibility. The purpose of this section is to discuss how the social responsibilities of engineers can be conveyed to engineering students. Teaching social responsibility involves broadening the scope of engineering problem solving to students and challenging them to consider the broader contexts of engineering problems.

The absence of social responsibility in engineering programs. Though the engineering profession values social responsibility, studies have shown that engineering education may not be adequately cultivating students' dispositions towards social responsibility (Cech, 2014; Shuman et al., 2005; Zandvoort et al., 2013). Zandvoort et al. (2013) concluded that in many engineering programs, students are not exposed to instruction in ethics or social responsibility. When ethical issues are raised in courses, the instruction tends to focus on microethical decisions that individual engineers face, rather than the collective responsibilities of the profession to act ethically towards the public (Zandvoort et al., 2013). Bucciarelli (2008) argued that this focus on microethics falls short of teaching social responsibility to students.

To explain the absence of social responsibility in engineering programs, Zandvoort et al. (2013) discussed barriers to teach social responsibility within engineering curriculum. Zandvoort et al. (2013) cited the science and engineering communities' resistance to recognizing the social dimensions of their work. Another barrier to teaching social responsibility relates to the difficult nature of teaching and assessing it. Faculty may feel unprepared to teach social responsibility themselves, preferring to relegate it to their colleagues in humanities and social science departments.

Instructional methods for teaching social responsibility. Researchers who advocate for greater emphasis on social responsibility in engineering courses are aware of the challenges and barriers to teaching social responsibility. To address concerns that engineering curriculum is too packed, many researchers advocate for innovative methods for teaching social responsibility, rather than trying to add content to courses.

Nair (1997) proposed classroom techniques that can develop students' understanding of social responsibility by integrating reflection and ethics into engineering decision making. To introduce a dimension of decision making into engineering courses, Nair (1997) suggested including social and historical aspects while teaching, using concept maps to situate course topics within broader contexts, and assigning problems that give students opportunities to practice ethical decision making. Pantazidou and Nair (1999) suggested giving students examples of relevant ethical principles applied to engineering problems.

Vanasupa et al. (2006) presented global challenges as inspiration for students and identified five principles that they would promote through the curriculum. Some of the principles address the systems nature of engineering and emphasize the closed-system nature of earth by introducing entire product life cycles into the design process. These principles can be revisited at several points in the curriculum to reinforce students' awareness of the roles of engineers in society.

Shuman et al. (2005) suggested service learning projects in engineering as a promising way to incorporate real-world engineering problems into curriculum. These projects can provide students with an opportunity to develop and use professional skills and knowledge to serve a community.

These studies suggest some methods of incorporating social responsibility into engineering curriculum without sacrificing technical content. Integrating social responsibility into existing instruction presents social responsibility as an integral part of the engineering profession. This integration is important because social concerns are frequently viewed outside the purview of engineering problem solving (Cech, 2014).

Research Questions

This study builds on previous studies to further understand and articulate the ways that engineering students understand the responsibilities of engineers towards society. This study also discusses influences on students' views of social responsibility, which has not been addressed in previous studies. Understanding students' perceptions of social responsibility and where they develop these views can inform methods to teach social responsibility.

This study addresses the following research questions: What are engineering students' perceptions of social responsibility in engineering? What are implications for teaching social responsibility in undergraduate engineering programs?

METHODS

Data were collected at a large, public research university in the Midwest. Surveys and interviews were conducted with students on their understanding of the social responsibilities of engineers. Interviews were conducted with faculty members to understand how social responsibility manifested within engineering curriculum at their institution. The Institutional Review Board approved this research study on October 5, 2016 (IRB #17229).

Data Collection

Survey. To broadly understand engineering students' perceptions of social responsibility, a survey was administered to engineering students consisting of one open-ended question and 41 items on a Likert scale. The Likert scale items were taken from the Engineering Professional Responsibility Assessment (EPRA) (Canney & Bielefeldt, 2016). The EPRA instrument was chosen because it contained items that aligned closely with the research questions. In particular, the items from the Professional Development and Connectedness realms were relevant to assessing students' views on the social responsibilities of engineers.

The survey followed the structure of the EPRA. The first set of questions on the survey asked students to rate the importance of various skills for a professional engineer. The second set of questions asked students about important qualities in their future job. These two sets of questions were scaled from 1 = Very Unimportant to 7 = Very Important. The third set of questions asked students to rate the extent to which they agreed with statements about the social and professional responsibilities of engineers. This set of questions was scaled from 1 = Strongly Disagree to 7 = Strongly Agree. The appendix contains the survey questions.

Some items from the EPRA were omitted in the survey. All items related to the Personal Social Awareness realm were omitted to keep the survey at a reasonable length. These omitted items from the Personal Social Awareness realm focused on students' interests in volunteering, which were outside the scope of this study. The survey also omitted five items from the ERPA in the Professional Connectedness dimension and one item from the Costs-Benefits dimension. These omitted items did not specifically mention engineers. The fourteen items included from the Professional Connectedness dimension were likely sufficient to measure the construct.

The Student Attitudes Survey was considered for this study, but it was too specific to civil and environmental engineering.

The survey was administered through an online form. Recruitment emails were sent to academic advisors in all departments in the College of Engineering to forward to undergraduate students in their department. Data from eight engineering departments were collected: 5,640 students received invitations to complete the survey. In total, 81 responses were recorded. The low response rate may be in part due to the lack of incentives available for completing the survey.

Demographic data were collected at the end of the survey. A summary of the demographics of the survey participants is shown in Table 1.

Table 1: Demographic information of survey participants

Demographic characteristic		**Number of participants**
Gender	Women	36 (45%)
	Men	44 (55%)
	Did not respond	1
Year	First-year	28 (35%)
	Sophomore	18 (22%)
	Junior	14 (17%)
	Senior	18 (22%)
	Fifth-year senior	3 (4%)
Race/ethnicity	Non-Hispanic White	44 (54%)
	Asian	24 (30%)
	Hispanic	6 (7%)
	African-American	1 (1%)
	Multiracial	3 (4%)
	Other	2 (2%)
	Did not respond	1

Student interviews. Individual interviews were conducted to collect qualitative data from students about their perceptions of social responsibility. The interview format was semi-structured; most of the interview questions were pre-determined, and participants were prompted with follow-up questions when appropriate. The interview protocol can be found in the appendix. The interview protocol was developed from a survey of the literature on engineering students' views on social responsibility. The protocol was finalized after the survey data had been collected. The responses to the open-ended survey question ("What words or phrases come to mind when you think of social responsibility in engineering?") revealed that some students had misconstrued the definition of social responsibility. Some responses were irrelevant to the definition of social responsibility employed in this study: for example, several students mentioned academic integrity, working in teams, and helping classmates with homework. The interview protocol was piloted tested with a senior engineering student. Based on the feedback during the pilot test, the questions were reworded to include language that would be more accessible to students. For example, instead of asking students for examples of socially responsible actions that engineers might take, the question was rephrased as, "What are ways that engineers can benefit society?" The term "social responsibility" was used sparingly during the interview because the survey results suggested that students were interpreting the term differently than expected. Instead, questions were rephrased to hint at social responsibility in broader terms to stimulate thinking about the social contexts of engineering.

Interview participants were recruited from those who had completed the survey. At the end of the survey, students were invited to participate in an optional interview to share their perceptions of social responsibility in engineering. Fourteen students expressed interest and provided their email addresses. Ten students followed up and signed up for an interview time. The duration of the interviews ranged from thirty to forty-five minutes. All ten interviews took place between in a span of two weeks in a conference room in the engineering library. No compensation was provided to participants. Participants chose their own pseudonyms. Table 2 summarizes the backgrounds of the ten interviewed students.

Table 2: Demographic information of student interview participants

Student	**Year**	**Major (Engineering)**	**Work experience in engineering**
Ariana	Sophomore	Materials	None
Dave	Senior	Materials	Internship at healthcare company
Hugo	Freshman	Materials	None
Kim	Freshman	Industrial	Two internships at manufacturing company
Kyle	Sophomore	Materials	None
Natasha	Junior (transferred)	Electrical	Internship at national laboratory
Sam	Freshman	Aerospace	None
Sara	Senior	Materials	Two internships at healthcare companies
Sean	Senior	Materials	Internship at semiconductor company
Sophia	Senior	Materials	Internship at semiconductor company

I have interacted with five of the ten students outside of the context of this study. I am acquainted with these students because we are in the same major: materials science and engineering.

Faculty interviews. Interviews were conducted with engineering professors to understand their views on how social responsibility manifests in undergraduate engineering education. Professors were recruited by emails sent to department heads to forward to faculty in their departments. Three professors volunteered for interviews. They were from the following departments: Civil and Environmental Engineering, Agricultural and Biological Engineering, and Aerospace Engineering. The duration of the interviews ranged from thirty to forty minutes.

The interview format was semi-structured. The interview protocol can be found in the appendix. The interview protocol was pilot tested with a different professor. At the start of the interviews, the professors were given the definition of social responsibility used throughout this study: the responsibility of engineers to "carefully evaluate the full range of broader impacts of their designs on the health, safety and welfare of the public and the environment" (Vanasupa et al., 2006). An explicit definition was shared with professors to understand how this interpretation of social responsibility manifests in their engineering programs. In contrast, students were not provided with an explicit definition of social responsibility because this study aims to understand students' interpretations of social responsibility.

Data Analysis

Survey. To measure students' views within each dimension of the PSRDM, items that measured the same dimension of the PSRDM were grouped together (see appendix for items corresponding to each dimension). The Likert items within each dimension were averaged to determine the average score for each dimension of the PSRDM. Cronbach's alpha and ordinal alpha (Gadermann, Guhn, & Zumbo, 2012) were calculated to measure the internal reliability of the items within each dimension.

Gender. Statistical tests were performed to determine if there were significant differences between the responses of women and men in the sample. The student responses for items in each dimension were summed, so the total student score within each dimension could be treated as a continuous variable. The scores for women and men within each dimension were tested for normality with the Shapiro-Wilks test. At a significance level of 0.05, the p-values from the Shapiro-Wilks test indicated that the data from women and men were normally distributed for the Analyze, Professional Connectedness, and Costs-Benefits dimensions, while the data for the Professional Ability dimension were not normally distributed. Since the data for the Professional Ability dimension were not normally distributed, the non-parametric Mann-Whitney test was used to test for statistical differences between women and men in these dimensions. For the Analyze, Professional Connectedness, and Costs-Benefits dimensions, an F-test was conducted to establish equal variances between the data for women and men. A two-tailed, independent samples t-test was then used to test for statistical differences between women and men within these two dimensions. Cohen's d was calculated for all four dimensions to measure the effect sizes.

Student interviews. Interviews were transcribed verbatim for analysis. An initial coding scheme was adapted from the PSRDM. Codes were developed from the dimensions of the PSRDM in the professional ability and professional connectedness realms. A table of these codes and their definitions can be found in the appendix.

Inductive codes emerged from the data through thematic analysis (Merriam, 2009). The initial coding scheme captured students' perceptions of the ways engineering could benefit society. Thematic analysis was used to analyze how students defined social responsibility and the role of engineers in society. From this analysis, codes emerged to describe students' views on the consequences of engineering and the people affected by engineering. Codes were also developed to describe influences on students' views of social responsibility.

Faculty interviews. Interviews with professors were transcribed verbatim for analysis. They were analyzed as sources of secondary data. The interviews were analyzed for evidence related to the themes from the student interviews. Professors' recommendations for how to incorporate instruction in social responsibility into engineering courses were noted.

Researcher positionality. In this study, I am careful to separate my role as a researcher from that of a student. Aspects of my experiences were reflected in the interviews with students, but I have been careful to discuss results that represent the broad range of experiences of students in the sample, not just results that sound familiar to me from my own experience. When formulating claims, I deliberately sought disconfirming evidence in the interview data.

RESULTS

Quantitative analysis of PSRDM dimensions

Students' views of social responsibility were measured with respect to four dimensions of the PSRDM. The results are reported in Table 3.

Table 3: Summary of students' views within each PSRDM dimension

	PSRDM Dimension (number of items in dimension)	**Mean**	**SD**	**Cronbach's alpha**	**Ordinal alpha**
Professional Development realm	**Professional Ability** (4)	6.4	0.25	0.54	0.73
	Analyze (5)	5.6	0.39	0.57	0.68
Professional Connectedness realm	**Professional Connectedness** (14)	5.1	0.52	0.90	0.89
	Costs-Benefits (3)	4.8	0.24	0.56	0.49

Students' scores in the Professional Development realm were consistently higher than their scores in the Professional Connectedness realm. This result indicates students recognize the ability of engineers to benefit society, but they have less conviction in the belief that engineers are obligated to use their skills to benefit society. The low Cronbach's alpha values for the Analyze, Professional

Ability, and Costs-Benefits dimensions suggest poor correlation between items in these dimensions; however, these low values may be attributed in part to the small number of items in each of these dimensions. The Professional Connectedness dimension included fourteen items; the high Cronbach's alpha value suggests excellent correlation between items within this dimension.

Differences between women and men. Gender differences were analyzed within each dimension. The differences between means for each dimension are shown in Figure 2. The results indicate that for each of the four dimensions measured in the survey, women had a higher score than men. These differences were tested for statistical significance; the results are shown in Table 4.

Figure 2. Gender differences in PSRDM dimensions

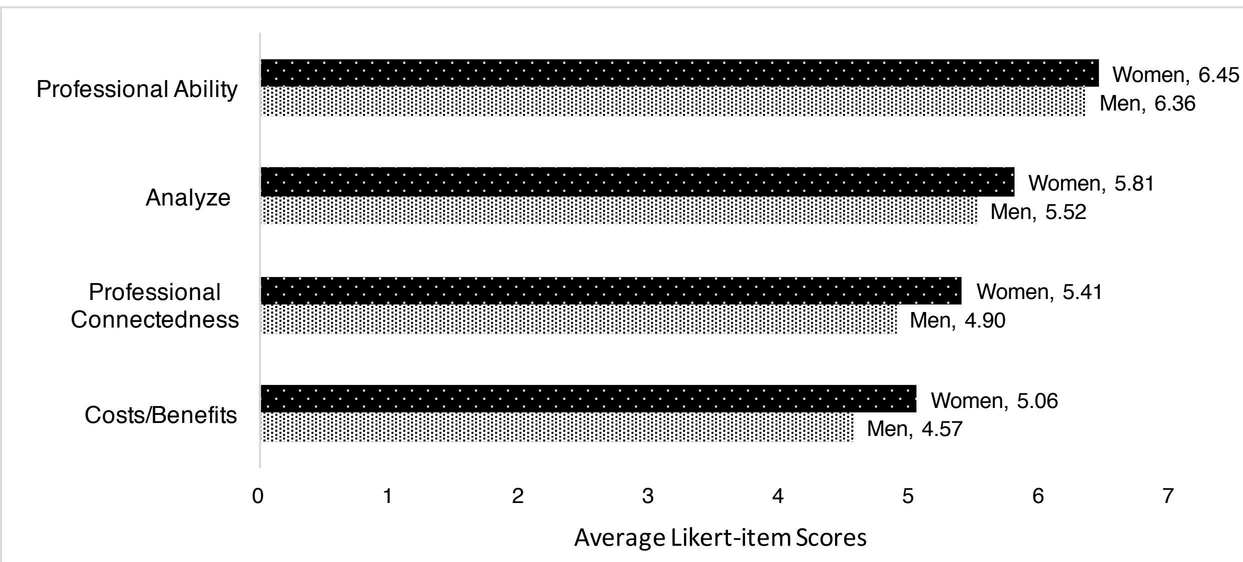

Table 4: Statistical tests for differences between women and men

	Women (n=36)		**Men (n=44)**		**p-values**		
	Mean	***SD***	***Mean***	***SD***	***t-test***	***Mann-Whitney***	***Cohen's d***
Professional Ability	6.45	0.22	6.36	0.27	-	0.61	0.38
Analyze	5.81	0.31	5.52	0.47	0.074	-	0.72
Professional Connectedness	5.41	0.56	4.90	0.58	0.017	-	0.97
Costs-Benefits	5.06	0.35	4.57	0.22	0.054	-	1.7

At a significance level of 0.05, there is a statistical difference between women and men in the Professional Connectedness dimension with a large effect size. This result suggests that on average, women in the sample had stronger feelings than men about the obligation of engineers to benefit society. The difference was smallest for the Professional Ability dimension, suggesting that men and women had similar beliefs about the ability of engineers to benefit society.

Students' interpretations of social responsibility

During the interviews, students presented various interpretations of social responsibility within the engineering profession. Students distinguished between the responsibility of engineers to benefit society with their work and the responsibility to prevent harm to society. Some students conveyed social responsibility as an obligation, either to contribute positively to society or to prevent harm to society. Students' perceptions of the social responsibilities of engineers were categorized under the following four statements:

1. Engineers can benefit society.
2. Engineers should benefit society.
3. Engineers can harm society.
4. Engineers should prevent harm to society.

The relationships between these categories are summarized in Table 5.

Table 5: Students' views of the responsibilities of engineers to do good and prevent harm

	Responsibility of engineers to:	
	Do good	**Prevent harm**
Awareness	Engineers can benefit society	Engineers can harm society
Obligation	Engineers should benefit society	Engineers should prevent harm to society

Engineers can benefit society. Students recognized that engineers have the capabilities to serve and help others, exemplified in this statement by Dave: "We have the skill set to do something good for other people." While Dave spoke generally about the abilities of engineers, Sophia and Kyle mentioned specific skills. Sophia mentioned engineers' approach to solving problems: "I think engineers can give a unique problem solving perspective to a lot of social problems." Kyle described how the creativity of engineers can help develop solutions that improve people's lives: "Engineers are incredibly creative people. One of the things that we can do is connect people with the reality they're living in now to one that they want to be living in." These statements demonstrate students' recognition that engineers influence peoples' lives and can make an impact on social problems. Dave shared an example of how engineers can benefit society from his internship experience in healthcare:

> I knew that my contributions were going to be used for the greater good – it may not be for everyone, but for that subset of people that have certain health issues, I knew that someone is being benefitted by the research I'm doing. (Dave)

Dave felt that his work at his internship would have a meaningful impact on people with a certain health condition. He acknowledged that his work would not necessarily benefit society at large; nonetheless, he felt that his contributions benefitted society because they benefitted a certain subpopulation of society.

Engineers should benefit society. Some students expressed the stronger belief that engineers have a professional obligation to make positive contributions to society with their work. These students stated that the role of engineers is to design technologies and products to improve the lives of others. For example, Dave believed that the role of engineers was to make progress on the twelve Grand Challenges identified by the National Academy of Engineering. These Grand Challenges outline the key areas on which engineers should focus their efforts to improve the well-being of humans around the world. Dave's assertion that engineers should focus on these challenges demonstrates his belief that engineers should use their skills to address global social challenges.

Sam felt that engineers should focus on engineering projects that can benefit people: "Engineers do have a lot of power because they can change the world around them. So I think they should focus on things that would help people." Sam acknowledged that not all engineering work inherently benefits society, made clear by the distinction he makes that engineers should focus on projects that would help people. This quotation implies that Sam believes engineers can choose work that benefits others, which to him is the socially responsible path.

Engineers can harm society. Students recognized that engineers can harm society through the consequences of their designs. Students identified several ways that engineers can harm society, including damage to the environment and dangerous processes in manufacturing.

According to Kim, engineers harm society when they neglect to consider the impacts of their work on the environment: "I'd say nowadays, the environmental thing, not being mindful of that, is the most mainstream way for engineers to harm others." In this quotation, Kim considered harm to the environment as harm to public welfare. Students shared examples of environmental harm resulting from technological advances, including environmental devastation in China arising from mining materials for batteries, the extinction of species in the Great Barrier Reef due to pollution, and the landfill waste resulting from the non-recyclable design of K-cups for Keurig coffee machines. In these examples, students did not discuss whether engineers should be held accountable for their role in developing these technologies, since engineers may not necessarily be the primary party responsible for the adverse environmental effects. In other words, students raised these examples to illustrate how product design can create unintentional environmental consequences, but they did not detail the extent to which engineers should be held responsible for the consequences of these designs.

Kim described harmful effects that manufacturing processes can have on the health of workers. Kim observed from her internship experiences that engineers can neglect the welfare of workers in their work:

> When we're designing products or something, we don't think about how it's going to be manufactured or the dangers inherent in manufacturing or the precautions we have to take, or be mindful of. Because we usually think about the end product. (Kim)

Kim's quotation showed the harmful effects that engineers can have not only on the broader public, but also on people within the company involved in the processing of the technology.

Sam spoke about the rise of technologies involving artificial intelligence and the potential for these machines to displace jobs: "AI [artificial intelligence] could, in the future, cause great harm. It could cause a lot of jobs to be lost." Sam indicated the potential for artificial intelligence to displace jobs. He argued that the displacement of jobs is a harmful effect to society due to the economic implications and the social consequences of unemployment and job instability.

Engineers should prevent harm to society. Students emphasized that engineers have a responsibility to protect against the harmful consequences of the technologies and products they develop. Ariana described this responsibility:

> Every move you make as an engineer can damage things to a very high level. Anyone who's an engineer has a big role to play in determining what's safe and whether this kind of innovation is worth putting out there. (Ariana)

Ariana emphasized the far-reaching implications of engineers' decisions and the responsibility of engineers to evaluate whether these implications carry negative consequences.

Several students recognized the importance of considering the interests of people affected by an engineering project and mitigating possible harms of the project on society. Sara acknowledged that these consequences can be difficult to foresee:

> I think sometimes we create things and we don't realize the effects. And it's hard to, but I think we should be more careful and mindful of that. I think sometimes we get caught up in innovating that we forget that we should also start thinking about what the potential consequences of those innovations are. (Sara)

Sara implied that social implications are often left as an afterthought in the design process. She argued that potential social consequences should be considered from the start of the design process. Natasha also expressed the difficulties in foreseeing the consequences of technological developments, but she maintained that engineers have a responsibility to try:

> I don't think it's possible for any one human or any group of humans to predict the consequences of some engineering project. Or some object, or program, or some technological thing. But you owe it to yourself and to your society, and to humanity and the Earth and maybe eventually the galaxy, to try. And if you fail, well okay, good faith effort was made. (Natasha)

Natasha asserted that the difficulties of predicting consequences do not excuse engineers from neglecting to consider the social implications of their work. Like other students who discussed engineers' responsibilities to prevent harm, Natasha did not suggest concrete ways that engineers could mitigate the social consequences of the technologies they develop. Natasha acknowledged the importance of having good intentions, given the difficulties associated with foreseeing and mitigating social consequences of engineering projects.

Whom does engineering benefit or harm? Within these four broad categories of students' conceptions of social responsibility, there are distinctions within students' statements about which populations are affected by engineering work. Students tended to speak generally about who would benefit from the work of engineers. Students recognized that not all technology benefits society, but some students believed that it is possible to design for everyone. Sam advocated for work that would benefit humanity: "I think [engineers] should be focused on making improvements in the world that is to the benefit of mankind." In this quotation, Sam spoke generally about engineering work that would benefit mankind. He proclaimed the responsibility of engineers to design for humans. Sean advocated a similar position when he claimed that engineers should "make sure that in coming up with these solutions, they are accessible to everyone." Sean attributed to engineers the responsibility of ensuring their designs benefit as many people as possible. Kim also spoke to the ability of engineers to design innovations that improve the lives of everyone: "I think [the role of engineers in society] is to take what you know and create something that makes the lives of everyone easier." These students explicitly stated the responsibility of engineers to serve "everyone," promoting the idea that engineers can design technologies that benefit everyone.

Some students were more specific about who should benefit from engineering work: these students described the responsibility of engineers to serve their clients and those they are designing for. Kyle exemplified this idea when he said, "I think our role is to ultimately serve the people who we're designing for." When prompted to define social responsibility later in the interview, Kyle said:

> I think social responsibility is making sure that you are considering everyone that the problem will affect, or just making sure that you are being considerate of all the outcomes in terms of who you're affecting. (Kyle)

In the first quotation, Kyle addressed engineers' obligation to serve the end users of their technology. In the second quotation, Kyle spoke of social responsibility as the commitment to considering everyone affected by the technology. His quotation implies that people who are affected by a particular technology may not be those for whom the technology was designed. This distinction illustrates how designing solely for technological end users is not sufficient for upholding public welfare interests. To be socially responsible, engineers must also explicitly consider the effects of their designs on the broader public.

The tradeoffs of socially responsible action. Though students recognized engineers' abilities and obligation to serve and protect society, they acknowledged that taking socially responsible action can be difficult.

Individual interests of engineers can compete with public good. Students recognized that the interests of the public can conflict with an engineer's individual interests. Dave exemplified this idea when he said, "Some people may just want to speed through things, and to meet that deadline, or just to make someone else happy at the company. And it's not really thinking about the general public." Dave, like many of the students interviewed, recognized the tensions that affect the decision to act with social responsibility. He explained that rushing to meet deadlines or to please a boss could hinder the engineers' consideration of the public. Sam spoke about the dilemma of choosing between personal ethics and career advancement through the company:

> On a personal standpoint, it benefits you more to focus on the company. Because I assume that would help you get higher up into that company and help you make more money. At the same time, if it's hurting the people around you… It's a difficult question, like where do you balance that? (Sam)

In this quotation, Sam implied that choosing to act in socially responsible ways can come at a personal cost to engineers. He emphasized the difficulty of managing these conflicting feelings. Like Sam, Sara acknowledged the personal conflict that can arise when confronted with an ethical dilemma at work:

> I think that you have to weigh the pros and cons of being business savvy and also just a decent human being… It's a business world out there, you know? They'll just weigh the plus minus system at the end on their invoices. And that's just how it is. I think that there should be incentive to be better than that, within companies but also just individuals doing engineering work. (Sara)

In this quotation, Sara suggested that companies should foster work cultures where individuals do not pressured to choose between their personal ethics and success at their job.

Profit over people. Students described how corporations' efforts to maximize profits can be detrimental to the public. These examples demonstrate the difficulties of making decisions that benefit both business and public welfare simultaneously. Students tended to see business interests in direct competition to public interests. For example, Ariana described the environmental toll that the desire to make cheaper products can have: "We could make cheaper things, but in turn, that might harm the environment because we use more cheaper energies and that thing." Ariana recognized the tension between maximizing profits and upholding a commitment to sustainability. Kim addressed how efforts to maximize profits could also harm people within the company:

> If you're focusing only on the production and selling things and you don't pay attention to the waste you're creating, or you're not being efficient, or you're not really caring about your workers when you're managing the process. (Kim)

In this quotation, Kim explained how focusing on profits can come at the expense of people working at the company.

Students acknowledged the difficulties of resolving the competing interests of business and the public. Sam professed that companies would need incentives to consider public welfare in their business decisions:

> There are no incentives for companies if no one forces them to. Because their main goals focus on themselves and not necessarily the society they're in. Unless it directly impacts them, which a lot of times it doesn't. They can just keep it going. (Sam)

Sam believed that given the choice between profits or the public, businesses would always choose profits.

Mitigating the tradeoffs of socially responsible action. Students described ways that engineers could approach decision making to uphold their professional responsibility to society. Some students provided examples of the individual responsibility of an engineer to protect against harmful consequences, as opposed to the collective responsibility of the engineering profession. Sara and Ariana spoke to an individual agency to act ethically, even when these actions conflict with bureaucratic interests:

> I think if your manager asks you to do something and you honestly don't think that you could live with that decision, you have every right to say no. And I think you should say no. There's a level of ethics that should always play into your decision making, even as a young employee. (Sara)

> Even if you're not the boss or something, if you see something wrong with a project that could either hurt people or hurt the environment or hurt something in a really dramatic way, or even in not so dramatic ways, because like some problems, especially in engineering, can cause really big problems later. Just bring up any problem you see and make sure something gets done about it, if it's an issue. (Ariana)

Sara and Ariana expressed that engineers have the agency to act with social responsibility, despite the actions of their employers. Sara's assertion that engineers should refuse to comply with decisions or tasks that go against their ethics demonstrates her belief that engineers' commitment to their profession should be prioritized over loyalty to their employers.

Kim acknowledged that societal pressures can hinder socially responsible actions:

> If you're manufacturing something and you're creating some waste chemical that's not good, you could set up a law to say, hey, there's a restriction now, you can't do this, but like who would do that actually as an engineer. Because you'd probably be losing money that way. (Kim)

In this quotation, Kim suggested that engineers could influence policy to promote social responsibility, but there would be little business incentive for them to do so.

Though many students were aware of the tradeoffs of taking socially responsibility action, fewer students proposed ways to mitigate these tradeoffs. Some students proposed that consulting with professionals outside of engineering could help mitigate the harmful consequences of engineering decisions, recognizing that engineers were not the only stakeholders involved in engineering work. These professionals could provide insights into possible consequences of the project on areas outside of the engineers' expertise. Some students suggested that this collaboration with other professionals would also allow engineers to design solutions that were accessible to a broader audience.

Some students felt that engineers have a responsibility to work with the government and policymakers to regulate the potential consequences of technologies. For example, Sam felt that engineers should work with policymakers to regulate artificially intelligent technologies to mitigate economic repercussions of automated jobs:

> I do think [engineers] need to work with policymakers to figure out, where do you draw the line between how much automation is beneficial? Because the main argument for AI [artificial intelligence] with companies is that you cut down on labor costs. It's going to have profits. But if you're hurting society at the same time, there has to be kind of a balance between the economic side and all these people who won't have jobs. (Sam)

This quotation illustrates Sam's belief that advancing artificial intelligence could jeopardize job security for some people. Sam suggested that engineers participate in discussions with policymakers to establish limits of artificial intelligence's pervasiveness in society. Like other students who proposed a collaboration with government officials, Sam tended to view engineers in industry as disconnected from public policy and government. This perception implies that students associate professional engineers with industry and may be less familiar with government engineers who develop regulations and technical standards.

Influences on students' views of social responsibility

The preceding sections have discussed students' perceptions of social responsibility. This section describes influences on students' views of social responsibility.

Courses. Many students indicated that their engineering courses did not emphasize social responsibility. Kyle addressed the lack of attention to social responsibility in his courses:

> It is very possible to go through your engineering curriculum here and not get any of that social awareness… You could go four years and never have to examine the social responsibilities of engineers. (Kyle)

In this quotation, Kyle indicated that he did not feel his engineering courses explicitly discussed social responsibility. Dave also felt his engineering courses did not address the social impacts of engineering:

> There are a few biology classes I've taken with good applications and some of the biomaterials classes I've taken are kind of related to what I want to do, like serving society. But I feel like sometimes, in some classes, it's hard to figure out why we're doing some things… Like how is this benefitting me which would benefit someone else. (Dave)

Dave sensed a disconnect between what he learned in classes and what he felt he could apply to making a difference in people's lives.

Students mentioned receiving some ethics instruction in their engineering courses, but they did not cite it as a particularly influential experience for them. Ariana said, "So far, I feel like classes wise, not really. I don't see it that much. There's only the one ethics class, and we're kind of done with it." Natasha echoed Ariana's sentiment, "I wouldn't say that the actual instruction – because I know there are ethics in engineering courses here, but they're like non-technical, so I don't have time for that." Ariana and Natasha both acknowledged that they had been exposed to engineering ethics instruction, but that the instruction had been cursory and did not significantly affect their understanding of the social responsibilities of engineers.

Some students identified courses that were influential to their understanding of social responsibility, but these courses were often outside of the required curriculum for their majors. These courses included electives about sustainable engineering, social justice issues in education, and the Grand Challenges identified by the National Academy of Engineering.

Campus community. Outside of courses, students expressed that their engineering programs influenced their views on social responsibility through exposure to engineering projects with social impacts. Students mentioned meeting influential people on campus, including researchers and their peers. Sara said:

> I think in a lot of ways, it's not really the curriculum itself. It's more the people that I interact with… You meet people, especially people in industry or people in graduate programs who are doing really important things, and you realize that there's a sense of responsibility that you should have. (Sara)

Similarly, Sam said that his understanding of social responsibility was influenced by "being exposed to things that upperclassmen have been doing, and professors have been doing, and the actual impact they make. And the societal benefits that they have."

Sean indicated that professors were the most influential in helping him understand the roles and responsibilities of engineers in today's world: "Definitely professors with real world experience. Or at least a lot of experience, having seen many different examples of engineering failures that affected society." This quotation suggests that Sean found his professors' experiences valuable to learning about the social contexts of engineering work. Professors can draw on their experience in research and industry to positively influence students' views on the role of engineers in society and the social responsibility that accompanies that role.

Parents. Students identified people from their personal lives that influenced their understanding of the role of engineers in society. Some students cited their parents as influences on their views of social responsibility. This influence was particularly salient in students who had parents who worked as engineers. For example, Sara described the influence of her parents, who are both engineers: "I think a lot of what I view an engineer as comes from my parents. I think that I've tied a lot of ethics into engineering as a result of the way that my parents think and what they believe." Sara indicated that her parents' experiences as engineers have shaped her views on engineers and their responsibilities towards society. Students' mentions of parental influences suggest that students extend their conceptions and attitudes towards social responsibility in their personal lives into their professional lives.

Faculty views on social responsibility in engineering education

The interviewed professors had strong beliefs about the importance of teaching social responsibility to engineering students. They agreed that social responsibility is an integral part of the engineering profession's obligation to serve the public. The interviewed professors felt that engineering faculty had an important role in educating their students on the importance of social responsibility. One professor said, "It's a social responsibility to teach social responsibility." Another professor said, "We need people who are engineers, who have the engineering mindset, who understand engineers. To actually address some of these issues."

The professors had different perceptions about the extent to which social responsibility was prioritized within their department's respective curricula. The civil engineering professor believed instruction in social responsibility was deeply embedded within his department's curriculum. The aerospace professor felt that social responsibility did not manifest within his discipline as saliently as it does it civil engineering or bioengineering. He cited its absence from his department's curriculum: "It's not part of our curriculum, I would say. There is very little discussion of social responsibility to the best of my knowledge in hardly any of our classes. In our senior design classes, a little bit." The biological engineering professor felt that while he tries to incorporate social responsibility into his courses, some of his colleagues do not appreciate the importance of teaching social responsibility.

Integrating social responsibility into curriculum. The interviewed professors agreed that undergraduate education was an instructive place to teach students about social responsibility. When asked when social responsibility should be taught to students, two professors suggested that a first-year orientation course for engineering students would be an instructive place to introduce social responsibility because students would be impressionable during their first semester of college. The interviewed professors also mentioned the importance of reinforcing messages of social responsibility in subsequent courses throughout the curriculum.

To integrate social responsibility into existing courses, the interviewed professors suggested projects and classroom activities, such as problem-based learning and case studies. One professor mentioned that instructors could emphasize aspects of projects beyond the technical content. One professor advocated for the creation of new courses with a specific focus on social responsibility. These courses would focus on the legal, social, and financial aspects of technologies and replace course requirements in social sciences and humanities for engineering students. This professor felt that engineering faculty should take the lead in developing these courses.

One professor articulated why he felt that social responsibility was not emphasized more in engineering curriculum. He postulated that engineering professors may not feel comfortable teaching social responsibility and tend to avoid teaching unfamiliar topics. He mentioned that some of his colleagues remarked that students could take courses in ethics or philosophy to learn about social responsibility. In contrast to his colleagues' views, he liked the idea of embedding social responsibility in his department's curriculum. Though the interviewed professors understood the difficulties and limitations of teaching social responsibility, they did not feel that these difficulties absolved professors from teaching social responsibility to engineering students.

DISCUSSION

Research Question: What are engineering students' perceptions of the social responsibilities of engineers?

Students believed social responsibility is an important part of the engineering profession. Students expressed varied perceptions of the social responsibilities of engineers. They described the responsibilities of engineers to benefit and prevent harm to society. Some students were explicit in articulating how they defined society. The themes that emerged from students' definitions of social responsibility were consistent with themes of social responsibility present in the literature. Students mentioned social responsibility in conjunction with issues of sustainability (Conlon, 2008; Pritchard & Baillie, 2006; Vanasupa et al., 2006; Zandvoort et al., 2013), social justice (Conlon, 2008; Pritchard Baillie, 2006; Zandvoort et al., 2013), and ethics (Bucciarelli, 2008; Conlon, 2008; Swierstra & Jelsma, 2006; van der Poel & Verbeek, 2006; Zandvoort et al., 2013).

Comparison with PSRDM. The interviewed students' perceptions of social responsibility were consistent with the dimensions identified by Canney and Bielefeldt (2015a) in the Professional and Social Responsibility Development Model (PSRDM). Students' statements about how engineers can benefit society aligned with the Professional Ability dimension, which Canney and Bielefeldt (2016) defined as "a recognition that engineers or the engineering profession has the ability to help others and/or solve social issues." Students' beliefs that engineers should improve society aligned with the Professional Connectedness dimension, which Canney and Bielefeldt (2016) defined as "addresses issues of responsibility or obligation that an engineer or the engineering profession may have to help solve social problems or help others through their professional capacity." This definition expresses the obligation of engineers to use their knowledge and skills to benefit society.

Students' statements also aligned with the Costs-Benefits dimension. Students understood some of the tradeoffs associated with socially responsible action. In particular, students discussed situations where engineers' personal interests or the business interests of their employers may compete with the interests of public welfare.

The PSRDM omits one important aspect of social responsibility. Students' statements indicated they recognized that social responsibility includes not only making positive contributions to society, but also preventing harm. Although the prevention of harm is salient to students, the PSRDM omits considerations of causing harm.

The results from the survey indicate that while students understand engineers can benefit society, they have less conviction that engineers should use their skills to serve society. This finding is consistent with previous studies that found students' scores in the Professional Development realm are higher than in the Professional Connectedness realm (Canney & Bielefeldt, 2016). The differences between women and men in the sample are consistent with the results obtained by Canney and Bielefeldt (2015b). They had a much larger sample size (N=1,698), although they limited their sample to first-year, senior, and graduate students in civil, environmental, and mechanical engineering at five different institutions. Canney and Bielefeldt (2015b) found the largest differences between women and men were in the Professional Connectedness and Costs-Benefits dimensions, with a difference of 0.5 points on the seven-point scale. Similar differences were found in the sample of this study: the difference between women and men was 0.51 and 0.49 in the Professional Connectedness and Costs-Benefits dimensions, respectively. These similarities in the results suggest the student population studied at this institution may be comparable to student populations in previous studies, which implies that these results could be generalizable to populations outside of this institution.

Responsibility for consequences. Though students could identify consequences of technologies, they had difficulty articulating how the specific actions of engineers can result in long term consequences. Students could point to examples of harmful consequences of technology, such as landfill waste arising from non-recyclable designs, but they did not elaborate on the role of engineers in creating those harmful consequences. Students did not mention whether they felt these harmful effects resulted specifically from the negligence or actions of engineers. In other words, students could describe the outcomes of engineering failures, but they did not discuss the specific actions of engineers that led to those failures. To attribute responsibility for these failures to engineers, a causal relationship must be established between engineers' actions and the consequences of those actions (Swierstra & Jelsma, 2006).

Research Question: What are implications for teaching social responsibility in undergraduate engineering programs?

Students' perceptions of social responsibility, identified in the preceding section, have important implications for engineering education. The variation in students' responses indicate that their views on social responsibility are influenced from a variety of experiences outside of their engineering courses. Students cited extracurricular activities, elective courses, and internship experiences as influences on their understanding of the roles and responsibilities of engineers in society. Students most frequently cited their parents as influences on their views of social responsibility. This finding suggests that some students' views of social responsibility are largely shaped by the time they begin their engineering education and may not connect with the development of their engineering identities.

Students do not feel they are receiving messages of social responsibility in their engineering courses. When describing examples of influences on their attitudes towards social responsibility, students often mentioned past experiences or current events, not examples from their engineering courses. This omission suggests that students do not perceive that engineering courses have significantly influenced their views of social responsibility. Students' views seem to be more heavily influenced by their upbringing and the activities they have chosen to pursue in college than their engineering courses. The apparent lack of formalized instruction in engineering courses on social responsibility corroborates the variations in students' perceptions of social responsibility. This finding implies that efforts to teach social responsibility in engineering courses could improve students' understanding of social responsibilities specific to engineers. Cultivating this understanding is important because the attitudes and dispositions that students develop in college will accompany them into their professional work.

The interviews with professors confirmed students' views that their engineering courses did not include instruction in social responsibility. Two of the interviewed professors explicitly mentioned that they felt their department did not adequately teach social responsibility to their students. The interviewed professors suggested that their colleagues may feel unprepared to teach social responsibility. These speculations are consistent with the findings of Zandvoort et al. (2013) about why social responsibility is seldom taught in engineering courses.

The results from this study indicate that social responsibility is important in the education of future engineers, yet is not taught adequately. The question remains whether engineering education is the right place to foster students' attitudes towards social responsibility or if it is reasonable to expect that they will develop these attitudes once they begin to work as practicing engineers. Findings from previous research suggest that graduates who work at engineering jobs do not experience revived interest in public welfare concerns after college (Cech, 2014). In addition, graduates who pick up social responsibility in industry will likely learn about it within the specific capacity of their jobs. On the other hand, when students learn about social responsibility as undergraduates, the instruction can be holistic rather than targeted to a particular job or industry. In addition, teaching social responsibility in undergraduate education can strengthen the knowledge that engineering graduates draw upon in their profession.

Some scholars feel social responsibility should be taught to engineering students within their curriculum (Cech, 2014; Rulifson & Bielefeldt, 2015; Zandvoort et al., 2013), because classroom instruction can improve students' understanding of the social responsibilities of engineers (Rulifson & Bielefeldt, 2015). Scholars have indicated the importance of having science and engineering professors involved in teaching social responsibility to students. These professors can collaborate with their colleagues in social sciences and humanities to help students recognize the value of including perspectives outside of engineering to address the social dimensions of engineering work (Zandvoort et al., 2013). Moreover, having engineering professors teach social responsibility can positively communicate the significance of social responsibility to the profession.

Limitations of this study

Methods. This research study aims to discuss the breadth of ways in which students understand social responsibility and how it manifests within their experiences in their engineering programs. The students who participated in this study were all from the same institution. The demographic backgrounds of the sample population are not representative of engineering students at their institution: women are over-represented in the sample relative to student population. Women comprise of 45% of the survey sample but only 20% of the undergraduate engineering student population.

There were no pre-determined selection criteria for choosing student interview participants. All students who volunteered for an interview were included in the sample. This study did not sample to exhaustion, which would entail interviewing additional participants until no new themes emerged from the data. The sample was chosen out of convenience. Students who would volunteer their time for an interview may have had a strong interest in social responsibility.

There are limitations in the faculty sample as well. Only three professors were interviewed. Their views cannot be assumed to represent the views of faculty within their departments or all engineering faculty at large. In addition, professors who agreed to volunteer time to interview about social responsibility are likely to have more positive views of social responsibility than their colleagues.

Analysis. There were not enough survey responses to conduct further statistical analyses than the results presented, such as regression. Gender was the only demographic category that had enough data to test for statistically significant differences. There were not sufficient numbers to analyze the data by major, year, or race/ethnicity.

The interviews were coded by only one coder, so no inter-coder reliability could be established. Due to the limitation of having a single coder, secondary data from professors were collected. This data corroborated themes from the student data.

Results. Since the study sample was limited to one institution, the results may not be generalizable to broader populations of engineering students.

I made some inferences in interpreting the results of this study. In the results section, I discussed how students did not seem to be aware of causal relationships involved in the consequences of technology; however, I did not explicitly ask them to define this chain of responsibility in the interview. I also discussed how students tended to speak about engineers who worked in industry, though I did not specifically ask them if they were aware of the role of government engineers in policymaking and regulations.

CONCLUSIONS

Social responsibility is at the forefront of the engineering profession. As engineers are called upon to address societal challenges, engineers should be equipped to consider the social contexts of their work.

The results of this study indicate that students are aware of ways that engineers can benefit and harm society. This study captures the ways in which students understand the responsibility of engineers to prevent harm to society, an aspect of social responsibility that was not included in the Professional Social Responsibility Development Model. In addition to an awareness of the benefits and harm engineers can have, some students indicated the obligation of engineers to use their skills to contribute positively to society and consider potential consequences of their work.

The results of this study discuss influences on students' views of the social responsibilities of engineers. When asked what informed their views, students identified extracurricular activities, internships, and parental influences. Students did not feel their engineering courses emphasized the roles and responsibilities of engineers in society. The results of this study suggest that students seem to develop their dispositions towards social responsibility outside of their formal education. Students' views on social responsibility within the engineering profession seem to be influenced by their personal views and backgrounds outside of engineering contexts. Previous studies have not addressed where students may receive messages about social responsibility outside of the classroom.

Engineering education helps students develop the skills they will need as practicing engineers, including their commitment to public welfare. As part of engineering education, teaching social responsibility does not necessarily require cramming additional content into the curriculum: the social dimensions of engineering can be presented within the contexts of existing course content. For example, a lecture about mechanical fracture in materials could present the use of steel rivets on the Titanic to illustrate the importance of considering the environment of the intended application when selecting materials (McCarty & Foecke, 2008). In addition, faculty can draw upon their experiences in research and industry to positively influence students' views on the role of engineers in society and the social responsibility that accompanies that role.

Future directions for research

Further research is needed to understand how to promote educational efforts to teach social responsibility in engineering courses. Interviews with engineering faculty can be useful in gaining a broader understanding of the challenges of teaching social responsibility. An understanding of these challenges can inform strategies to overcome barriers to teaching social responsibility.

This research may also have implications for student retention in engineering programs. Previous studies have found that students' feelings about the importance of social responsibility decline throughout their time in college (Canney & Bielefeldt, 2015b; Cech, 2014). One possible explanation for this finding is that some students who begin college with a high interest in social responsibility decide to leave engineering. These students may have views of social responsibility that have been influenced by their parents and past experiences. If students perceive that their views of social responsibility are not supported within engineering, they may choose to leave the field. It would be concerning if students with ambitions towards social good were discouraged from persisting in their engineering programs. The engineering profession would suffer from the loss of diversity of students who aspire to use engineering to solve social problems. To understand whether engineering education supports students with strong dispositions for social responsibility, further research can study whether attrition rates are higher among students who have stronger beliefs about social responsibility.

Concluding remarks

My introduction to the social responsibilities of engineers occurred by chance. The lecture that gave me an awareness of the impact of engineering on society was one that I attended on a whim, encouraged by the promise of pizza at the event. I hope that engineering education can be more intentional about creating learning opportunities for students to prepare engineers to uphold their responsibilities towards public welfare. Since education communicates to students the values of the engineering profession, teaching social responsibility to students can reinforce engineers' commitment to society. Engineering educators can empower students to create a world that is more sustainable and socially just than the world we live in today.

APPENDIX

Recruitment message to students

You are invited to participate in an online survey to gather research data for the undergraduate thesis project of Athena Lin, a senior in the College of Engineering. The purpose of this project is to investigate current instruction of social responsibility in undergraduate engineering curriculum at Illinois. Your insights are important for understanding how students perceive social responsibility within their engineering education.

We expect the survey to take about 20 minutes to complete. To take this survey, click on the following link: (survey link here). This survey will be active until October 31, 2016.

After you take the survey, you may volunteer for an OPTIONAL individual interview. The interview session will be audio recorded and will last thirty minutes. To volunteer for an interview, if you are at least 18 years of age, please indicate your interest by following the link at the end of the survey and providing the requested information. Athena will contact you to schedule a time for the interview.

Your participation in this research will remain confidential. No personally identifying information will be disclosed. If you have any questions about the project, please contact Athena at aln@illinois.edu. If you are concerned about your rights as a research participant, please contact the University of Illinois Institutional Review Board at (217) 333-2670 or irb@illinois.edu.

Recruitment message to faculty

Good morning/afternoon,

I am a senior in the College of Engineering. I am working on an undergraduate thesis project under the supervision of Professors Jenny Amos, Michael Loui, and Angus Rockett. The purpose of this project is to investigate current instruction about social responsibility in undergraduate engineering programs at Illinois. Since I gathering expert opinions about how social responsibility should be taught in undergraduate engineering programs, I am writing to invite you to participate in an interview that should not take longer than thirty minutes.

If you are willing to share your expertise with me, please follow this link to provide your contact information. I will contact you within the next two weeks to schedule an interview time at your convenience.

Your participation in this research will remain confidential. No personally identifying information will be disclosed. If you have any questions about the project, please contact me at aln@illinois.edu or Professor Jenny Amos at jamos@illinois.edu. If you are concerned about your rights as a research participant, please contact the University of Illinois Institutional Review Board at (217) 333-2670 or irb@illinois.edu.

Thank you very much for your time and consideration,
Athena Lin
aln@illinois.edu

Informed consent for participation in survey

The research study aims to answer two questions:

1. What are engineering students' perceptions of social responsibility in engineering?
2. What do engineering faculty believe teaching social responsibility should look like?

On this screen, you are invited to indicate whether you want to participate in the research project by allowing your anonymous responses to be used for research purposes. Participation in this survey is completely voluntary: your participation choice will not affect your grade in a course, status as a student, or future relationship with the University.

The research investigators are Professors Jenny Amos and Michael Loui and undergraduate student Athena Lin, University of Illinois Urbana-Champaign.

Eligibility for Participation

Research participants must be at least 18 years old and enrolled as undergraduates in the College of Engineering at Illinois.

Will my study-related information be kept confidential?

Yes, but not always. In general, we will not tell anyone any information about you. When this research is discussed or published, no one will know that you were in the study. However, laws and university rules might require us to disclose information about you. For example, if required by laws or University Policy, study information may be seen or copied by the following people or groups:

- The university committee and office that reviews and approves research studies, the Institutional Review Board (IRB) and Office for Protection of Research Subjects; University and state auditors, and Departments of the university responsible for oversight of research.

The following steps will be taken to ensure this confidentiality:

1. Your responses to the survey are **not** associated with your net-ID or email address. Records of students who have completed the survey are entirely separate from their responses.
2. When reporting the results of surveys, care will be taken to ensure that no individual's responses can be identified.
3. A follow-up interview request is included in the last part of the survey. The interview is **OPTIONAL**, based on your willingness to either participate it or not.

You are allowed to print a copy of this consent form if necessary.

Contact Information

Questions about this research should be directed to Professor Jenny Amos (phone 217-333-4212, e-mail jamos@illinois.edu). Questions about your rights as a research participant should be directed to the campus Institutional Review Board (phone 217-333-2670, e-mail irb@illinois.edu); you may call collect.

Participant Consent

I have read and understood this consent form. I volunteer to participate in this research study. I agree that by completing the survey, it implies my consent to participate in the survey, and allow my data to be used for research purpose.

Informed consent form for interviews with students

Purpose and Procedures

This research study is being conducted by Professors Jenny Amos and Michael Loui and undergraduate student Athena Lin. The purpose of this research study is to investigate current practices in instruction about social responsibility in undergraduate engineering curriculum at Illinois.

You are invited to participate in an interview for about 30 to 45 minutes. The interview will be audio recorded and transcribed.

Eligibility for Participation

Research participants must be at least 18 years old and enrolled as undergraduates in the College of Engineering at Illinois.

Voluntariness

Participation in this research is voluntary. You are volunteering to allow an audio recording and transcription of your interview to be used for research purposes. You may refuse to participate or may discontinue participation at any time. During the interview, you may skip questions that you prefer not to answer. Participation will not affect your grade in a course, status as a student, or future relationship with the University.

Benefits and Risks

Risks are expected to be minimal, no more than in everyday life. The College of Engineering will benefit from accurate information about what influences students' perceptions and attitudes towards social responsibility. Participants may benefit from reflecting on their experiences.

Will my study-related information be kept confidential?

Yes, but not always. In general, we will not tell anyone any information about you. When this research is discussed or published, no one will know that you were in the study. However, laws and university rules might require us to disclose information about you. For example, if required by laws or University Policy, study information which identifies you and the consent form signed by you may be seen or copied by the following people or groups:

• The university committee and office that reviews and approves research studies, the Institutional Review Board (IRB) and Office for Protection of Research Subjects;

• University and state auditors, and Departments of the university responsible for oversight of research.

The data to be used in this research are limited to the interview text with associated demographic information. When the interview is transcribed, your name will be replaced by an identifying code. All collected data will be kept confidential and will be discarded one year later the final journal publication of this research. Copies of audio transcripts will be secured on the laptop of one member of the research team for a minimum of three years. Audio recordings will not be disseminated, but instead will be erased after transcription. No names will be revealed in any publications.

Whom to Contact with Questions

Questions about this research should be directed to Professor Jenny Amos (phone (217) 333-4212, e-mail jamos@illinois.edu). Questions about your rights as a research participant should be directed to the campus University of Illinois Institutional Review Board (phone 217-333-2670, e-mail irb@illinois.edu).

I certify that I have read this form, I have received a copy of this form, I am 18 years of age or older, and I volunteer to participate in this research study.

Please print official name: ____

Signature: ____________________________________ Date: ______________

Informed consent form for interviews with faculty

Purpose and Procedures

This research study is being conducted by Professors Jenny Amos and Michael Loui and undergraduate student Athena Lin. The purpose of this research study is to investigate current practices in instruction about social responsibility in undergraduate engineering curriculum at Illinois.

You are invited to participate in an interview for about 30 minutes. The interview will be audio recorded and transcribed.

Eligibility for Participation

Research participants must be at least 18 years old and employed as faculty in the College of Engineering at Illinois.

Voluntariness

Participation in this research is voluntary. You are volunteering to allow an audio recording and transcription of your interview to be used for research purposes. You may refuse to participate or may discontinue participation at any time. During the interview, you may skip questions that you prefer not to answer. Participation will not affect your grade in a course, status as a student, or future relationship with the University.

Benefits and Risks

Risks are expected to be minimal, no more than in everyday life. The College of Engineering will benefit from accurate information about what faculty attitudes towards teaching social responsibility. Participants may benefit from reflecting on their experiences.

Will my study-related information be kept confidential?

Yes, but not always. In general, we will not tell anyone any information about you. When this research is discussed or published, no one will know that you were in the study. However, laws and university rules might require us to disclose information about you. For example, if required by laws or University Policy, study information which identifies you and the consent form signed by you may be seen or copied by the following people or groups:

• The university committee and office that reviews and approves research studies, the Institutional Review Board (IRB) and Office for Protection of Research Subjects;

• University and state auditors, and Departments of the university responsible for oversight of research.

The data to be used in this research are limited to the interview text with associated demographic information. When the interview is transcribed, your name will be replaced by an identifying code. All collected data will be kept confidential and will be discarded one year later the final journal publication of this research. Copies of audio transcripts will be secured on the laptop of one member of the research team for a minimum of three years. Audio recordings will not be disseminated, but instead will be erased after transcription. No names will be revealed in any publications.

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I certify that I have read this form, I have received a copy of this form, I am 18 years of age or older, and I volunteer to participate in this research study.

Please print official name: ____

Signature: ______________________________ Date: _______________

Survey administered to students

1. I agree to submit my survey data for research purposes.
2. What words or phrases come to mind when you think of social responsibility in engineering?

Please rate how important the following skills are for a professional engineering using the following scale: (1=Very Unimportant, 2=Unimportant, 3=Slightly Unimportant, 4=Neutral, 5=Slightly Important, 6=Important, 7=Very Important)

3. Fundamental Skills (i.e. Math & Science)
4. Technical Skills (i.e. Conducting Experiments, Data Analysis, Design, Engineering Tools, & Problem Solving)
5. Business Skills (i.e. Business Knowledge, Management Skills & Professionalism)
6. Professional Skills (i.e. Communication, Contemporary Issues, Creativity, Leadership, Life-Long Learning, & Teamwork)
7. Cultural Awareness/Understanding (i.e. of your culture, and those of others)
8. Ethics (i.e. ensuring all of your work follows professional codes of conduct)
9. Societal Context (i.e. how your work connects to society and vice versa)
10. Volunteerism (for professional and personal reasons)

How important are each of the following qualities to you when thinking of your future job? (1=Very Unimportant, 2=Unimportant, 3=Slightly Unimportant, 4=Neutral, 5=Slightly Important, 6=Important, 7=Very Important)

11. Salary
12. Helping people
13. Working on industrial/commercial projects

14. Working on community development projects
15. Living domestically
16. Living internationally in a developed country
17. Living internationally in a developing country
18. Own your own business (be self-employed)

Rate the level to which you agree/disagree with the following statements: (1=Strongly Disagree, 2=Disagree, 3=Slightly Disagree, 4=Neutral, 5=Slightly Agree, 6=Agree, 7=Very Agree)
Note: The PSRDM dimension that each item corresponds to is noted in parentheses. Items with an asterisk (*) were reverse scored.
19. Engineers have contributed greatly to fixing problems in the world (Professional Ability)
20*. I would not change my engineering design because it conflicted with community feedback (Analyze)
21. Volunteer experience(s) have changed the way I think about spending money (Professional Connectedness)
22. It is important to me personally to have a career that involves helping people (Professional Connectedness)
23*. Engineering skills are not useful in making the community a better place (Professional Ability)
24. It is important for engineers to consider the potential broader impacts of technical solutions to problems (Analyze)
25*. Service should not be an expected part of the engineering profession (Professional Connectedness)
26. I would be willing to have a career that earns less money if I were serving society (Costs-Benefits)
27. I will use engineering to help others (Professional Connectedness)
28*. I view engineering and community service work as unconnected (Professional Connectedness)
29. I feel called to serve others through engineering (Professional Connectedness)
30*. The needs of society have no effect on my choice to pursue engineering as a career (Professional Connectedness)
31. It is important to incorporate societal constraints into engineering decisions (Analyze)
32*. Technology does not play an important role in solving society's problems (Professional Ability)
33. My engineering skills are strengthened through participation in engineering service opportunities (Costs-Benefits)
34. I feel called by the needs of society to pursue a career in engineering (Professional Connectedness)
35. Engineering firms should take on some pro bono work (work done without compensation (pay) for the public good) (Professional Connectedness)
36*. I doubt that volunteer work will ever have much affect on my career (Professional Connectedness)
37. I think it is important to use my engineering degree to serve others (Professional Connectedness)
38. Engineers can have a positive impact on society (Professional Ability)
39. Knowing that my engineering career is helping others would not increase my personal satisfaction

40. It is important to use my engineering abilities to provide a useful service to the community (Professional Connectedness)
41. I believe that I will be involved in social justice issues for the rest of my life (Professional Connectedness)
42*. I do not think it is important to use engineering to serve the greater community (Professional Connectedness)

Demographic Information
44. Gender
45. Major or intended major
46. Year in school (by years in college, not credit hours)
46. Race or ethnicity
47. Previous engineering work experience

Protocol for student interviews

1. Demographic information (major, year, campus involvement, work experience)
2. What do you believe is the role of engineers in society?
    a. Under this role, what are some responsibilities that engineers have towards society?
3. What are ways that engineers can benefit society?
4. What are ways that engineers can harm society?
5. How would you define social responsibility?
    a. How would you define social responsibility as it relates to the engineering profession?
6. What people or experiences have influenced your thinking about social responsibility? (courses, internships, extracurricular activities)
7. How has the engineering program at Illinois helped your understanding of the role and responsibility of engineers in today's world?
8. How has your understanding of what engineers do changed from before you started studying engineering to now?
9. How do you think your understanding of the social responsibilities of engineers will impact your work in your future career?

Protocol for faculty interviews

1. What will engineering students need to know about social responsibility to help create a sustainable future?
2. Who should teach social responsibility to engineering students?
3. What are some reasons social responsibility should be taught in engineering curricula?
4. What are some reasons social responsibility should *not* be taught in engineering curricula?
5. What are ways to integrate social responsibility into classroom instruction?
6. What has influenced your views on social responsibility in engineering?

Coding scheme adapted from PSRDM
definitions from Canney and Bielefeldt (2016)

Code	Definition
Base skills	With an expectation that all engineers value the technical skills, this dimension focuses on views of professional skills (e.g., communication, lifelong learning, teamwork, management, ethics, or professional responsibility) and the role that they play for a professional engineer.
Professional ability	A recognition that engineers or the engineering profession has the ability to help others and/or solve social issues.
Analyze	A recognition of the importance of including social aspects in the engineering process, including community feedback, and a broad sense of stakeholders.
Professional connectedness	Addresses issues of responsibility or obligation that an engineer or the engineering profession may have to help solve social problems or help others through their professional capacity.
Costs-Benefits	Discussion of the costs and benefits associated with engaging in socially responsible behavior, such as service.

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