Exploring Perceptions of Social Responsibility in Engineering Students

by
Amy Jahr

A THESIS

submitted to
Oregon State University
University Honors College

in partial fulfillment of
the requirements for the
degree of

Honors Baccalaureate of Science in Bioengineering
(Honors Scholar)

Presented March 3, 2016
Commencement June 2016
AN ABSTRACT OF THE THESIS OF


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Michelle Bothwell

Incoming and graduating engineering students in the School of Chemical, Biological, and Environmental Engineering at Oregon State University were surveyed in order to assess awareness and integration of social responsibilities into their emerging professional persona and how those views are informed by program and faculty interactions. Preliminary analysis of responses indicate that student perceptions of social responsibility may vary with academic progress and discipline. Questions were grouped into scales and analyzed for reliability in SPSS using the Cronbach’s alpha score. A reliable scale for professional responsibility was identified in both incoming and graduating students and a reliable depoliticization scale was identified in graduating students only. Graduating students in bioengineering rejected elements of meritocracy, attributed in part to completing discipline-specific coursework focused on deconstructing power, privilege and oppression in society and within engineering. Graduating students in all disciplines were less likely to identify a professional responsibility as an engineer to design accessible and inexpensive products, perhaps a result of the for-profit corporate job market most engineers will enter. Further quantitative analysis of the data set is recommended to identify correlations between demographic variables and social responsibility perceptions. This should be complimented by recording qualitative focus group data which could provide further insight into how students understand social responsibility.

Key Words: Engineering, Social Responsibility, Meritocracy, Depoliticization

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I understand that my project will become part of the permanent collection of Oregon State University, University Honors College. My signature below authorizes release of my project to any reader upon request.

________________________________________
Amy Jahr, Author
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EXPLORING PERCEPTIONS OF SOCIAL RESPONSIBILITY IN ENGINEERING STUDENTS

INTRODUCTION

Engineering education traditionally focuses on developing students’ technical competencies while ignoring non-technical considerations in engineering decisions. Current engineering coursework and professional cultural attitudes frame social and political concerns as outside of the realm of engineering. Erin Cech proposes that this “culture of disengagement” is supported by the ideological pillars of depoliticization, technical/social duality, and meritocracy in engineering (Cech, 2010). Depoliticization refers to the absence of discussion of social and political concerns that may be polarizing. The technical/social duality reinforces depoliticization by considering social and political concerns as variables too complex to be integrated into engineering decision-making and questioning the objectivity and “purity” of science and engineering itself. Meritocratic ideology supports the belief that hard work, talent, and dedication lead to success within professional engineering, and in general society as well, suggesting that all engineers have equal access and opportunity to achieve this success. Together, these pillars prevent engineers from addressing the social and political influences of engineering decisions.

When engineers consider themselves neutral and objective, they disengage from social and political issues. Without recognizing their own conscious or unconscious biases, engineers’ work reflect the status quo to maintain current distributions of power and privilege in society (Riley, 2008). These biases and values of engineering operate outside of the edge of awareness, making education an important tool to reverse these trends. Socially responsible engineering requires educating students about the social and political ramifications of engineering decisions to achieve “balance […] where engineers can contribute in a positive way towards lessening the world’s most pressing issues without being blinded by a belief in the infallibility of engineering” (Kabo, 2010, p. 2). Donna Riley holds that the position and meaning of engineering in society can change by diversifying engineering values and worldviews
Definitions of socially responsible engineering are broad and can include protecting the environment, global public service projects, designing products accessible to marginalized communities, and considering the social and political ramifications of a product or process. Put simply, socially responsible engineering reduces suffering and injustice (Kabo, 2010).

This study aims to capture understandings of social responsibility among current engineering students at the beginning and end of their engineering education. It is specifically structured based upon the pillars of Cech’s “culture of disengagement” (Cech, 2013). The perceptions of social responsibility of incoming and graduating students in Chemical, Biological, and Environmental Engineering (CBEE) at Oregon State University (OSU) were assessed using a survey administered in an introductory and 4th year course. CBEE supports three disciplinary programs and the curriculums share many technical course requirements, but each have different ethics course requirements. Bioengineering (BIOE) and environmental engineering (ENVE) students take an ethics course focused on ethical decision making as a professional while chemical (CHE) engineering students take a course that splits content between professional engineering ethics and process safety management. BIOE students complete an additional course on the construction of social difference, privilege and oppression and its manifestations in engineering. It is hypothesized that student understandings of social responsibility will vary by discipline, and that these differences can be explained by programmatic and faculty influences. In other words, BIOE students are expected to demonstrate a broader understanding of the responsibilities of engineers to society because they have taken two courses explicitly focused on the professional and societal responsibilities of engineers compared to the one course taken by ENVE students and 5 weeks of course content taken by CHE students. Project results will provide baseline data that will inform future curriculum development.
LITERATURE REVIEW

Social Responsibility: Engaging the Context of Engineering

Engineering, and science in general, has traditionally distanced its role in developing technologies and knowledge from how others have used those products. Scientists and engineers speak out inconsistently on the intersections of their work with social and political realms. This “laissez faire” policy, where whatever will be will be, makes engineers and scientists complicit in how their developed technologies and knowledge are used (Beckwith and Huang, 2005). For example, eugenists misinterpreted geneticist’s work to support and develop social frameworks that devalued the “unfit.” However, those geneticists whose works were misinterpreted did not step forward to publicly correct these misinterpretations because it was not seen as part of their duties as scientists (Beckwith and Huang, 2005). Social responsibility seeks to counter this complacency by empowering engineers and scientists to engage social, political, and cultural issues. While Jon Beckwith and Franklin Huang wrote of the importance of social responsibility in science, their words are equally true for engineers:

“When social harm may result from the misuse and misrepresentation of science, who better to present the criticisms, describe the uncertainties or identify the falsehoods than scientists knowledgeable in the relevant field? […] If a goal of scientific training is to help scientists to be more critical thinkers, then preparing them to be engaged in looking critically at the social implications of their science can only aid in achieving that goal” (Beckwith and Huang, 2005, p. 1-2)

As an emerging concept within engineering, the meaning of social responsibility varies. Angela Bielefeldt and Nathan Canney define social responsibility as “an obligation that an individual (or company) has to act with concern and sensitivity, aware of the impacts of their action on others, particularly the disadvantaged”
(Bielefeldt & Canney, 2014). Linda Vanusupa, Lynn Slivovsky and Katherine Chen define 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” (Vanusupa, Slivovsky and Chen, 2006, p. 2). Social responsibility involves re-thinking and redefining the engineering design process. Current engineering design practices are limited by professional discourse that does not consider community needs, even going so far as to treat the customer as a problem (de Vere, Kapoor, & Melles, 2011). Under this paradigm, design solutions become “imposed upon a public which has little choice but to endure their social, environmental and economic impact” (de Vere, Kapoor, & Melles, 2011, p. 2). Socially responsible engineering would consider whether a design solution increases opportunity, well-being and empowerment in a community, to ensure the culturally sensitive design that does not project the values of the designer (de Vere, Kapoor, & Melles, 2011).

Denial of engineering’s responsibility for the effects of a developed technology begins in education, as seen by the omission of discussing the social, political and cultural ramifications of design (de Vere, Kapoor, & Melles, 2011). If engineering students are to become the next leaders of socially responsible engineering, they need to be prepared by their coursework and mentors. Development of social responsibility requires three components: an ability to act, a willingness to act, and awareness of needs (Vanusupa, Slivovsky and Chen, 2006). Traditional engineering education has emphasized the ability to act, or technical competency, above and at the expense of the other two components needed for social responsibility. Engineering faculty often respond to requests to develop more well-rounded engineers with the claim that something must be cut from the program in order to accomplish this goal, thereby diminishing students’ technical prowess and ability to develop new technologies (Vanusupa, Slivovsky and Chen, 2006). However, altering the way engineering material is presented in class may be sufficient to inspire social responsibility in students (Vanusupa, Slivovsky and Chen, 2006).
Vanusupa and colleagues (3) propose developing social responsibility in the classroom by raising an awareness of community needs through discussion and then connecting the design process to five guiding principles: 1) that everything is connected, 2) the earth is a closed thermodynamic system, 3) make responsible choices early in the design process, 4) the sun is the earth’s energy source, and 5) optimize rather than maximize (Vanusupa, Slivovsky and Chen, 2006). This method demonstrates how design decisions ripple through society, producing ecological thinking that recognizes that “the good of one is often highly dependent on others or on the whole” (Whitbeck, 2011, p. 259). Engineering students are called on to consider these effects above the profit-making potential of a product, tying the engineering design process to issues of sustainability and consumerism. As it stands, the social responsibility attitudes of students may vary considerably based on discipline, gender and engagement in volunteer activities (Canney, 2014).

*Engineering Ethics: Highlighting Individual Action*

Engineering ethics is becoming a more prominent instructional topic within engineering, given engineering’s importance to innovation in society, and the potential for negative outcomes resulting from incompetent or negligent engineering practices. The need for engineering ethics has been recognized by the creation of codes of ethics by professional engineering societies (Davis, 1991). Including ethics in an engineering curriculum, whether as individual courses or integrated into science and technology classes, broadens students’ understanding of the responsibilities of an engineer. The goals of teaching ethics in engineering education, according to Joseph Herkert, are: increasing ethical sensitivity, increasing knowledge of conduct standards, improving ethical judgement, and improving ethical will power (Herkert, 2005). As Caroline Whitbeck puts it, for engineering design and ethical problems, “there is rarely, if ever, a uniquely correct solution” although some solutions are clearly better than others. (Whitbeck, 2011, p.57). Engineers need to learn to navigate this problem space in order to effectively address ethical dilemmas. The Accreditation Board for Engineering and Technology (ABET) requires students in accredited engineering programs in the United States to develop an “understanding of
professional and ethical responsibility” and to “understand the impact of engineering solutions in a global, economic, environmental and societal context” (ABET, 2015, p. 3). These requirements correspond to both micro-etic and macro-etic realms (Herkert, 2005). Micro-etics, as the branch concerned with individual behavior only, can be described as professional ethics, the “special morally permissible standards of conduct” that apply to members of a profession (Harris, 1996, p. 93). Macro-etics describes the “collective social responsibility of the profession and to societal decisions about technology” (Herkert, 2005, p. 374).

Ethics is traditionally taught in engineering curriculums through case studies or prominent and catastrophic news stories to discuss what ethical decisions a particular engineer could face (Bucciarelli, 2007). This gives students the opportunity to explore line-drawing or moral conflict style problems and to practice developing so-called creative middle-way solutions prior to entering the field (Harris, Davis, Pritchard, & Rabins, 1996). This ethical pedagogy is consistent with ABET’s Engineer of 2020 Initiative to drive curriculum change to prepare engineering students for workplace needs, which calls for programs to “explore the use of case studies of engineering successes and failures” (Williams, 2014). However, the reliance on case studies and subsequent discussion of what an individual engineer ought to do is unrealistic and overemphasizes micro-etics at the expense of macro-etics. Case study discussion often fails to note the social environment of the workplace where teams of engineers are responsible for ethical and technical decisions (Bucciarelli, 2007). The case study then teaches individual action where teamwork and communication are needed. Macro-ethical issues such as sustainability and social justice are thought of as too large to consider in these individual cases, despite the influence engineers and engineering decisions have over such issues.

The case study method highlights the responsibilities of engineers, most prominently safety. Codes of ethics are often referenced for their guiding principles in case studies. The National Society of Professional Engineers instructs members to “hold paramount the safety […] of the public” in its Code of Ethics of Engineers, illustrating the visibility of safety concerns in engineering ethics (NSPE, 2016).
Safety concerns are easily included in technical engineering courses, as students are reminded of the importance of solving problems correctly to create safe products in the future (Bucciarelli, 2007). This highlights the responsibility of engineers for technical decisions in product safety, but transforms a call for social responsibility into a call to avoid liability (Herkert, 2005). This is a perversion of engineering’s humanitarian goals with ramifications for the professional identity of engineers.

Professional identities encompass the personas, values, and behaviors of members of a profession such as engineering (Harris, Davis, Pritchard, & Rabins, 1996). The development of a professional persona is a critical step for engineering students, where they decide if they see themselves as an engineer or not. Initiation into engineering as a profession then requires development of a professional engineering persona. In course reflections from engineering students, Michael Loui found that students’ professional identities are primarily informed by acquaintances who are engineers, such as family or friends, rather than engineering course requirements (Loui, 2005). These students learn the characteristics and responsibilities of engineering outside of a formal learning environment, making it difficult to influence their conception of their future engineering self. These students identified the characteristics of professional engineers as: technically competent, ability to communicate interpersonally, strong work ethic, and possessing moral standards. They would consider themselves professional engineers based on tangible markers, such as a degree or license; external approval, such as a job; and/or internal qualities, such as technical competence and work ethic. While these students recognized the importance of understanding the social effects of technical decisions as engineers, few articulated social responsibility, or responsibilities beyond assigned tasks and liability, as a part of their professional persona (Loui, 2005).

Social Justice: An Engineering Blind Spot

Engineering as a profession presents itself to society as humanitarian in nature (Garrison, Amos, Stevens, & Jocuns, 2007). Engineers are capable of producing technologies and solutions that drastically improve quality of life for individuals and
communities. However, this humanitarian influence is largely unrealized, as it is mitigated by elements of engineering culture that distance engineers from social issues (Cech, 2013). Chief among these social concerns is social justice, or simply the equitable distribution of power and resources across social groups (Riley, 2008). A more elaborate definition of social justice is “the struggle to end different kinds of oppression, to create economic equality, to uphold human rights or dignity, and to restore right relationships among all people and the environment” (Riley, 2008, p. 4). Although engineering and social justice problems may overlap, engineering problems are often defined in a way that excludes social justice considerations. Engineering is distanced from social justice by its supposed objectivity, but the influence of power upon engineering can be seen by what research is funded and what research is left unfunded (Riley, 2008). The elements of engineering culture that prevent engineers from addressing social justice considerations when making engineering decisions will be described here.

Donna Riley examines common ideologies exhibited by engineers in problem solving within her text “Engineering and Social Justice” (Riley, 2008). The first is positivist epistemology, the acquisition of knowledge through the scientific method. This mindset purports that all knowledge is rationally justifiable and can be proved scientifically, logically, or mathematically. Adherence to this mindset leads to classifying other ways of knowing as less factual and less reliable, and thus excluded from engineering considerations (Riley, 2008). Reductionism is another prevalent mindset, commonly seen in engineering problem solving. Reductionism is reducing large, ill-defined problems into smaller, well-defined problems. These small problems can then be analyzed, understood, and recombined to understand the larger problem. This technique may work well for mechanical, structural, and chemical systems, but many social, political, and cultural systems cannot be broken down and summed back up in the same manner (Riley, 2008). This contributes to engineering’s difficulty, and at present, dismissal of considering such ill-defined systems. Engineers also express varying degrees of belief in technological determinism, that technology develops isolated from social, political, cultural and economic forces. Instead, technology
influences those forces, leading technology to construct society but ignoring how society may construct technology (Riley, 2008). All of these mindsets contribute to a belief in the objectivity of science and engineering work.

The objectivity of science and engineering constructs technology as neutral: asocial and apolitical (Cech, 2013). Engineers are then not responsible for the consequences of a technology based on how others choose to use it. Riley characterizes this neutrality as a “myth,” supported by the documented conservative and libertarian values and political beliefs of engineers (Riley, 2008, p. 41). These beliefs may also prevent engineers from addressing social justice concerns because they justify inequities as resulting from differences in individual talents and efforts. This meritocratic ideology and its effects on engineering is discussed more in-depth later, but for now it runs counter to ideologies of social justice, which suggest differences in power determine an individual’s opportunities for success. Riley suggests engineers either “naively believe” or “have a vested interest in believing” that engineering work improves quality of life for all (Riley, 2008, p. 60). Access to the technology for all is assumed, although this is dependent upon one’s social, political and economic situation. Without universal access, technology may actually increase inequities rather than reduce them (Riley, 2008).

When engineers relinquish responsibility for the technology they develop, their employers are able to determine the applications of the technology. Engineers primarily work in for-profit organizations in industrial, commercial, and military settings (Riley, 2008). While there are a number of problems outside of these fields that engineers could work on, there are currently few opportunities. In 1984, 20 % of all U.S. engineering jobs were sponsored by the Department of Defense (Riley, 2008, p. 63). As Jens Kabo sees it, the “profit making paradigm is deeply entrenched in current engineering context,” both inside and outside of the classroom (Kabo, 2010, p. 31). These organizations have rigid hierarchies, teaching engineers to follow orders rather than ask questions. When this acceptance of authority is combined with the practice of basing engineering decisions upon precedent, engineers can become
agents of the status quo to perpetuate social inequities that they may be capable of reducing (Riley, 2008).

This blindness to social justice among engineers includes the relations among engineers themselves. Engineering is perceived as a field that gives the working-class a chance to move into the middle class (Riley, 2008). Beginning with engineering as route to the middle class, students from the working class do not have the same privileged backgrounds as middle or upper-middle class students and may be more susceptible to attrition during the weeding out phase of engineering curriculums. This may be seen as more of the natural order than a structural element preventing minorities and other disadvantaged groups from moving into the field (Riley, 2008). As Riley explains, the “structural aspects of racism are not understood by many white engineers, thus identifying racism would be perceived as tantamount to accusing an individual of intentional discrimination” (Riley, 2008, p. 80). Asian Americans have been able to break into engineering and are an overrepresented group. This is explained by an “innate” ability for engineering work among Asians, and proof that additional support for minorities in engineering is not needed (Riley, 2008, p. 84). The failure of other minorities to become and persist as engineers then results from some intrinsic quality which they lack. Minority engineers who do persist then work harder, and perceive that they must work harder, than white engineers to prove their competence (Riley, 2008).

Given that engineers deny or do not acknowledge racism among their ranks, it is unsurprising that sexism goes unnoticed as well. Women respond to hostility in the workplace by masking their gender and renouncing radical social ideologies like feminism (Riley, 2008). Many women engineers deny experiencing sexism within their field personally, and extrapolate from that experience to state that there is no sexism in engineering. Similarly, women in engineering often deny that they are feminists, despite supporting efforts for equality among genders in the workplace (Riley, 2008). The status quo of gender relations in the workplace is reinforced when the marginalized group seems content with their situation.
The tendency of engineering to pursue technologies that are most beneficial to the majority, potentially at the expense of minorities and underserved populations, contributes to the perpetuation of social injustice (Riley, 2008). This can be seen in case studies of engineering-for-development projects, where the focus on technical concerns prevents the social justice goals these projects are designed to address. Dean Nieusma and Donna Riley argue U.S. engineers overlook the social power they hold compared to other participants in engineering-for-development projects, namely the members and native engineers of the project community. These U.S. engineers then fail to consider the social and political community contexts which define the feasibility and sustainability of the project (Nieusma & Riley, 2010). They characterize the relationship that emerges between U.S. engineers and the development community as one in which the U.S. engineers have “saving knowledge” and “know better” in technological and cultural ways (Riley, 2008, p). This dynamic contributes to the design of projects that do not serve the needs of the development community, but allows U.S. engineers and engineering students to feel as if they have engaged in humanitarian outreach. The remedy, according to Nieusma and Riley, is to “de-center” the technical aspects of the project, and instead focus on the “cultural and economic contexts in which most development projects are situated” (Nieusma & Riley, 2010, p 31).

Integration into engineering culture begins when students are in college. These students are often recruited into the field by the promise of helping others through technology and will often cite a desire to help others as a reason for selection engineering as a major (Bielefeldt & Canney, 2014). However, Lari Garrison and colleagues found that the most common reason students chose to study engineering was for the comfortable lifestyle an engineering degree provides, not for humanitarian reasons (Garrison et al, 2007). It is not known whether this trend exists across all engineering disciplines, or is particularly prevalent in a few. These engineering students, and future professionals, who pursue engineering to live comfortably later may not integrate service to humanity into their engineering identity (Kabo, 2010). Furthermore, Erin Cech actually found that engineering students’ interest in public
welfare decreased over the course of their engineering degree. She argues this “slide into disengagement” is a result of the wider engineering culture, and not simply neglect within engineering curriculums (Cech, 2015, p.2). Humanitarian actions are influenced by an individual’s sense of social awareness and social responsibility. Social awareness is an awareness of groups in need and complex social issues, a recognition of one’s ability to help, a feeling of connectedness to others and a sense of a moral obligation to help (Bielefeldt & Canney, 2014). Angela Bielefeldt and Nathan Canney found engineering students’ sense of social responsibility varied significantly with students’ voluntary participation in community service activities, but was also affected by gender and engineering discipline. This opens the question of whether the content emphasis of different engineering curriculums influences a student’s openness to engaging social issues as an engineer.

Cech believes the professional engineering culture of social disengagement can be combatted by incorporating social awareness and social responsibility more prominently and consistently into engineering curriculums to significantly affect student outlook. However, as Kabo points out, there are relatively few ideas about how awareness of social identity, social justice and social responsibility should be taught to engineers. Collaborations with social science experts in engineering courses are rare, and perception of a responsibility to others may not be enough to incite action in an individual (Kabo, 2010). Kabo believes that “development of critical think skills needs to be at the center of any educational effort aimed at addressing awareness of the social impact of engineering” (Kabo, 2010, p.). Kabo suggested that the process of learning social justice is not about “knowing more” but about “knowing something differently”. Riley echoes this call for critical thinking. She argues engineers learn how to think “analytically only in certain ways appropriate to technical analysis,” and not how to question “what is given” or “the validity of our assumptions” (Riley, 2008, p. 41) This approach allows engineers to comprehend the details of a system, but prevents engineers from understanding the context in which their work is situated.
When discussions of difference and power are constructed as tangential to real engineering work, engineers become complicit in perpetuating the status quo through their inventions. Loui believes practicing engineers need an “awareness of societal consequences” in order to understand the effects of technical decisions on the public (Loui, 2005, p. 385). Cech argues that this should be considered a “core professional skill” for all engineers (Cech, 2015, p. 2). Cech has labeled engineering’s lack of involvement in social justice as the “culture of disengagement” (Cech, 2013). This “culture of disengagement” prevents engineering from addressing social justice concerns by defining social and political activism outside of engineering’s responsibilities. Cech has defined three pillars of this “culture of disengagement” - depoliticization, the technical/social duality, and meritocracy (Cech, 2013). The relation of these three ideologies to engineering culture and practice will be discussed in the following sections.

Depoliticization: Defining “Real” Engineering

Engineering work is separated from social or political concerns through the ideology of depoliticization (Cech, 2013). Through depoliticization, social and political concerns not only can but should be excluded from pure engineering practice. The advancement of the public good from engineering solutions becomes secondary to the technical considerations of that work. Engineering is conceptualized as neutral and objective once social and political concerns are removed. However, engineering work is social and political due to the nature of the challenges engineers address. Engineers may conceptualize their work as occurring in a social and political vacuum and not consider how technologies they develop influence larger societal systems. The ideology of depoliticization is an oversimplification, since engineering work exists within a social and political context, and thus can never be truly asocial or apolitical (Cech, 2013).

Depoliticization has consequences in professional engineering culture. On an interpersonal level, depoliticization prevents engineers from discussing socially or politically charged issues. This contributes to marginalized groups feeling unwelcome
in the workplace, as their experiences outside of the dominant paradigm necessarily relate to social or political topics (Cech, 2013). Depoliticization then perpetuates social norms through silence. Depoliticization also narrows the range of possible solutions to challenges to those that can be solved by technical means only. Kevin O’Connor and colleagues highlighted how student approaches to engineering challenges construct complex social problems as able to be solved by simple technological solutions (O’Connor et al., 2015). The issue becomes well-defined, and thus easier to solve, through depoliticization, although other sociocultural solutions exist and may be more desirable. Depoliticization limits the scope of engineering decisions to problematize only technical factors.

Technical/Social Dualism: Devaluing the Social

The technical/social dualism is the ideological division of engineering competences and subfields into mutually exclusive technical or social categories (Cech, 2013). This division results in differential valuation of engineering activities and knowledge in such a way that “technical” aspects are valued above “social” aspects. The purity of an engineering discipline is then directly related to the degree to which social aspects of engineering can be excluded from decision-making, although engineering work necessarily requires both technical and social skills. Furthermore, these distinctions between “technical” and “social” may envelope other cultural constructs such as masculinity and femininity. Technical competencies are often characterized as masculine while social competencies are characterized as feminine.

The value-laden nature of the technical/social duality has implications for professional engineering culture. The formulation of engineering’s Grand Challenges, the fourteen largest tasks facing engineers today, highlights technical aspects above social, political, ethical and cultural (Cech, 2012). Developing economical solar energy and carbon sequestration methods, two of the fourteen Grand Challenges, address the global challenge of climate change from a purely technical framework. This defines social, political and cultural changes as outside the realm of an engineer’s responsibility, despite the necessity of such interventions for solving a
global challenge. In the United States workforce, Erin Cech finds that the technical/social duality contributes at least in part to the gender wage-gap among professional engineers. Women are less represented and underpaid compared to men in more technical engineering subfields. No such gender wage gap was found among social engineering activities such as management (Cech, 2013). Thus, focusing on only technical aspects of engineering can perpetuate social and political issues both within and outside of the profession.

_Meritocracy: Pathway to Success in Engineering_

Meritocracy is popularly recognized as the “American Dream,” or the belief that success results from the combination of individual skill, hard work, and dedication (Cech, 2013). Individuals are perceived as personally responsible for their position in society due to equality of opportunity for personal achievement with fair and equitable reward distribution. The only barriers to success are an individual’s lack of motivation or skill. However, significant inequities exist and persist on the basis of social identities such as race, gender, and socioeconomic and ability statuses, despite discrimination of such identities being formally illegal. A pervasive belief in the fairness of social reward systems legitimizes the social injustices that result from the inequitable distribution of power, privilege, and opportunity in society. Both dominant and subordinate identities then often perceive meritocratic systems as fair, despite the systematic barriers to success they may experience (Cech & Blair-Loy, 2010).

Meritocratic ideology is deeply rooted in engineering culture. Engineering students frequently understand the struggles they experience in school from difficult coursework as bringing a comfortable lifestyle, defined by affluence and flexibility, after graduation (Garrison, Amos, Stevens, & Jocuns, 2007). The difficulty and competitiveness of engineering education becomes a criterion by which engineering students can assess themselves as more meritorious than students in other majors of study. Joseph Herkert describes engineering education as a “Darwinian selection process” where those who cannot keep pace with heavy workloads and poor
instruction drop out of engineering (Herkert, 2005). Such belief in meritocracy may extend into the workplace, causing employees in science and technology to identify individual shortcomings rather than structural barriers to the advancement of marginalized groups in engineering (Cech & Blair-Loy, 2010).

In a broader context, the prevalence of meritocratic ideology in engineering culture prevents engineers from addressing the societal structures which produce inequality, whether engineers contributed to the formation of such structures or not (Cech, 2014). If engineers have no responsibility for social inequality, then they have no responsibility to address social inequalities. This blindness to social difference also hampers engineers’ abilities to design products and processes for a diverse community with varied consumer needs.
MATERIALS AND METHODS

Incoming and soon-to-be graduating engineering students in CBEE at OSU were surveyed to assess development of social consciousness, integration of social responsibility into their emerging professional personas, and programmatic or faculty influences upon such processes. Students were recruited through the 1st year orientation (CBEE 101) and 4th year engineering laboratory (CBEE 414) courses and time was allotted in class for survey completion. The survey was delivered online through Qualtrics software. All students were presented with survey consent documentation prior to engaging with the survey. The survey consent document can be found in Appendix A and survey questions can be found in Appendix B. Demographic questions were presented in a fixed order with write-in responses so students could self-identify. Content questions were presented on a 5-point Likert scale in a randomized order. All students were given 20 minutes to complete the survey if they chose to respond.

Data recorded from the survey was analyzed for trends in perceptions of social responsibility across discipline and social identities. Questions were grouped into scales according to content and analyzed across self-reported student majors and class standing. Differences in responses between majors and classes were qualitatively assessed by plotting average responses for all majors together and individually with error bars representing the standard error of the mean. Reliability analysis of scales was performed in SPSS to determine if question groupings measured a consistent underlying construct. This research was approved by the institutional review board for human subjects research.

The Qualtrics survey platform recorded 207 survey responses from the 225 students enrolled in CBEE 101 and 136 survey responses from the 138 students enrolled in CBEE 414. Tables 1 and 2 describe the self-reported racial/ethnic identities and socioeconomic classes of students, respectively. The majority of respondents indicated their race as white, with Asian as the second-largest racial demographic. The majority of respondents identified as middle class.
Table 1. Self-reported racial/ethnic identities of student respondents to the survey.

| Racial/Ethnic Identity | Frequency (%) |  |
|------------------------|---------------|
|                        | Incoming Students | Graduating Students |
| White                  | 63.8           | 59.6           |
| Asian                  | 15.5           | 9.6            |
| Hispanic               | 2.9            | 2.9            |
| Black                  | 5.3            | 0.0            |
| Other                  | 1.9            | 5.1            |
| Not Reported           | 10.6           | 22.8           |

Table 2. The self-reported socioeconomic class identities of student respondents to the survey.

| Socioeconomic Class   | Frequency (%) |  |
|-----------------------|---------------|
|                       | Incoming Students | Graduating Students |
| Low                   | 8.7            | 2.9            |
| Middle                | 58.4           | 50.0           |
| Upper                 | 15.5           | 14.0           |
| Not Reported          | 17.4           | 33.1           |

Thirty-four percent of incoming student respondents identified as women and 48.3 % of respondents identified as men while the remaining 17.3 % declined to state. Thirty percent of graduating student respondents identified as women and 49.2 % of respondents identified as men while the remaining 20.6 % declined to state. Ninety-three percent of incoming students reported their age. Of those students, all but one were under the age of 24. Eighty-two percent of graduating students were between 21 and 24 years of age with 3.3 % of student respondents reporting being over the age of 24 and the remaining 14.7 % not responding. Three percent of incoming student respondents indicated a disability and 6.3 % indicated a sexual/affectional identity.
other than heterosexual. Four percent of graduating student respondents indicated a disability and 3.6% indicated a sexual/affectional identity other than heterosexual. Table 3 shows the self-reported religious affiliation of student respondents with the majority identifying as Christian or none.

Table 3. The self-reported religious affiliations of year student respondents to the survey.

<table>
<thead>
<tr>
<th>Religious Identity</th>
<th>Incoming Students</th>
<th>Graduating Students</th>
</tr>
</thead>
<tbody>
<tr>
<td>Christian</td>
<td>39.6</td>
<td>27.9</td>
</tr>
<tr>
<td>Muslim</td>
<td>3.4</td>
<td>5.1</td>
</tr>
<tr>
<td>Other</td>
<td>5.3</td>
<td>2.9</td>
</tr>
<tr>
<td>None</td>
<td>39.1</td>
<td>37.5</td>
</tr>
<tr>
<td>Not Reported</td>
<td>14.0</td>
<td>26.5</td>
</tr>
</tbody>
</table>

Eighty-three percent of incoming students reported their first language as English while 9.7% reported learning another language first. Seventy-two percent of graduating students reported their first language as English while 11.7% reported learning another language first. Seventy-two percent of incoming students reported the United States as their national identity, 8.7% of students reported a national identity outside of the United States, and 19.8% did not report a national identity. Sixty-six percent of graduating students reported the United States as their national identity, 8.0% of students reported a national identity outside of the United States, and 25.7% did not report a national identity. No incoming student respondents reported veteran status, although one reported being the dependent of a veteran. No graduating student respondents reported veteran status. Table 4 shows the academic majors of incoming student respondent and Table 5 tabulates the frequency of incoming students who knew friends or relatives who attended college. While this question was intended as a proxy for first-generational student status, it is unknown whether students who did not identify any relatives or acquaintances on the survey
are first-generation students or just declined to respond to the question. The majority of surveyed students are studying chemical engineering.

Table 4. The self-reported academic majors of student respondents to the survey.

<table>
<thead>
<tr>
<th>Academic Major</th>
<th>Frequency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Incoming Students</td>
</tr>
<tr>
<td>Chemical Engineering</td>
<td>45.4</td>
</tr>
<tr>
<td>Bioengineering</td>
<td>27.5</td>
</tr>
<tr>
<td>Environmental</td>
<td>9.2</td>
</tr>
<tr>
<td>Other</td>
<td>7.7</td>
</tr>
<tr>
<td>Not Reported</td>
<td>8.7</td>
</tr>
</tbody>
</table>

Table 5. The results of students self-reporting relatives and acquaintances they knew who have attended some or graduated from college. It should be noted that values are not expected to add up to 100% as students could identify multiple relatives and acquaintances who had attended college.

<table>
<thead>
<tr>
<th>Figures Who Attended College</th>
<th>Frequency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Incoming Students</td>
</tr>
<tr>
<td>Parent or Grandparent</td>
<td>75.4</td>
</tr>
<tr>
<td>Brother or Sister</td>
<td>48.3</td>
</tr>
<tr>
<td>Cousin or Other Relative</td>
<td>74.4</td>
</tr>
<tr>
<td>Close Friends</td>
<td>82.6</td>
</tr>
<tr>
<td>Other Acquaintances</td>
<td>69.1</td>
</tr>
<tr>
<td>None Identified</td>
<td>7.7</td>
</tr>
</tbody>
</table>
RESULTS AND DISCUSSION

Qualitative Analysis of Survey Responses

This section visually presents survey results. Survey questions were grouped according to subject, and average responses to question prompts within those subjects were plotted with error bars representing standard error of the mean. Figure 1 shows student responses to survey prompts relating to depoliticization.

![Figure 1](image)

Figure 1. Average A) incoming and B) graduating student responses to questions of the depoliticization scale.

No clear differences among disciplinary majors or classes can be noted. Students overall indicate general agreement with each statement. This suggests students
perceive themselves as aware of the intersections of engineering with social and political dimensions and consider those intersections worthy of attention within engineering.

Figure 2 illustrates student responses to questions in the technical/social duality scale. These questions target whether social and political considerations taint the “purity” of engineering work.

![Figure 2](image)

**Figure 2.** Average A) incoming and B) graduating student responses to questions in the technical/social duality scale.
Again, no clear differences can be seen between majors in either the incoming or graduating classes. The graduating students are slightly more inclined to consider general education requirements as extraneous to their work as engineers.

Figure 3 shows the responses of students to questions within the meritocracy scale.

![Bar chart](chart.png)

**Figure 3.** Average A) incoming and B) graduating student responses to questions in the meritocracy scale.

BIOEs demonstrate a dramatic shift in thought about whether engineers of color and women engineers have the same opportunities for advancement and recognition as white, male engineers between the incoming and graduating classes. Graduating BIOEs are much more likely to disagree with statements that suggest engineers from marginalized groups receive equal treatment within the field of engineering. This
sentiment is not present among incoming BIOEs or other graduating students, indicating that BIOEs have learned to challenge elements of the meritocratic ideology through BIOE-specific courses. However, graduating BIOE students still agree that they will be assessed by their merits, indicating that they still do subscribe to meritocratic ideologies in some contexts.

Figure 4 displays student responses to question prompts asking them whether they have the following responsibilities as engineers: to understand how social, political and economic power are distributed in society; to protect the environment; to consider if a developed product or process will have a just distribution of risks and benefits; to consider how a developed product or process will be used by others; and to design inexpensive and accessible products, even if they produce little profit.

Figure 4. Average A) incoming and B) graduating student responses to whether they have particular responsibilities as engineers.

Overall, views of the responsibilities of engineers seem to be largely conserved among the disciplines and across years, as given by the overlapping error bars in most cases. The importance of protecting the environment to ENVEs is notable, although
perhaps not surprising. It reasonably follows that individuals studying environmental engineering are more likely to be motivated by a desire to protect the environment than other engineering students. The importance of protecting the environment to incoming ENVEs may suggest students with an interest in protecting the environment self-select into the ENVE major. Students were most neutral towards whether they have a responsibility to design inexpensive and accessible products, and responses to this prompt are notably lower among graduating students than incoming students. This may be reflective of students’ awareness of the relationship between engineering and industry, where profit-making potential is generally valued over societal benefit.

Figure 5 illustrates the responses of students to questions assigned to the social agency scale. No significant differences can be seen between majors or across classes.
Figure 6 displays average student responses to the prompts of whether they perceive their social identities as influencing their interactions with others and whether they consciously alter their behavior to fit into engineering culture. These were not grouped into a scale because they are not believed to be connected to a similar underlying construct, but provide interesting evidence of students’ awareness of social identity and its influence on behavior. Graduating students recognized the influence of their social identities upon their interactions with others to a higher degree than incoming students. This may result from the prevalence of identity-related discussions in courses and communities located around a university campus. However, both classes are not aware of altering their behavior to integrate into the culture of engineering.

Figure 6. Average A) incoming and B) graduating student responses to questions regarding awareness of the influence of social identity upon the interactions of individuals and groups.
Quantitative Analysis of Survey Responses

The scales introduced in the previous qualitative analysis section were analyzed for reliability, that is, how closely related the question responses are as a group. Table 6 reports the Cronbach’s alpha score of the scales for both incoming and graduating students. The Cronbach’s alpha is a reliability measure that indicates whether items in a scale are internally consistent, meaning responses to scale items correlate with each other.

Table 6. The Cronbach’s Alpha scores of survey scales to assess scale reliability. Refer to Appendix B for the survey questions that correspond to the question numbers listed.

<table>
<thead>
<tr>
<th>Scale</th>
<th>Questions In Scale</th>
<th>n</th>
<th>Cronbach’s Alpha Score</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Incoming Students</td>
</tr>
<tr>
<td>Depoliticization</td>
<td>2, 10, 18</td>
<td>3</td>
<td>0.543</td>
</tr>
<tr>
<td>Technical/Social Duality</td>
<td>12, 13, 19, 20, 21, 22</td>
<td>6</td>
<td>0.579</td>
</tr>
<tr>
<td>Meritocracy</td>
<td>7, 8, 11, 23, 24</td>
<td>5</td>
<td>0.547</td>
</tr>
<tr>
<td>Professional Responsibility</td>
<td>2, 3, 4, 6</td>
<td>4</td>
<td>0.664</td>
</tr>
<tr>
<td>Social Agency</td>
<td>14, 15</td>
<td>2</td>
<td>0.184</td>
</tr>
</tbody>
</table>

Most developed scales presented above did not prove to have reliability, as measured by a Cronbach’s alpha score approximately equal to or greater than 0.70. So, responses to a question within the scale were not necessarily closely related to other question responses within the same scale. Obtaining reliability for small scales is difficult. It is therefore unsurprising that the social agency scale shows low reliability because it is only comprised of two questions. The question prompts and average responses in the meritocracy scale are shown below in Table 7.
Table 7. The average responses to questions within the meritocracy scale.

<table>
<thead>
<tr>
<th>Question</th>
<th>Average Response</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Incoming Students</strong></td>
<td><strong>Graduating Students</strong></td>
</tr>
<tr>
<td>7. Engineers of color have the same opportunities for advancement.</td>
<td>3.17</td>
</tr>
<tr>
<td>8. Women engineers have the same opportunities for advancement.</td>
<td>3.10</td>
</tr>
<tr>
<td>11. The recognition and advancement I will receive as an engineer will be based on my performance, which is rooted in hard work, talent, and dedication.</td>
<td>4.07</td>
</tr>
<tr>
<td>23. GPA is a good measure to use for Pro-School decisions because it reflects the effort and ability necessary to be a good engineer.</td>
<td>3.06</td>
</tr>
<tr>
<td>24. Most students who drop out of engineering lack the intellectual capability and perseverance needed for engineering work.</td>
<td>2.61</td>
</tr>
</tbody>
</table>

Students expect themselves to be recognized based on merit, as evidenced by the average response of 4.07 and 3.90 to question 11 for incoming and graduating students, respectively. However, they view the influence of meritocracy in the evaluation of others neutrally based on average responses to questions 7, 8, and 23 that are about 3. But, these students reject meritocratic ideologies when asked about whether they explain why their peers decide to change their major. This scale demonstrates how student responses to questions within a scale may lack consistency.
because students’ thoughts are fragmented by context. Student responses vary based on whether the question asks about their experiences or the experiences of others. Other scales may not have reliability because the scale questions measure different underlying constructs.

The depoliticization scale had reliability for the graduating class only. The range of means for items within the depoliticization scale were similar for both incoming and graduating students. Mean responses to questions varied from 4.03 to 4.12 for incoming students and 3.98 to 4.12 for graduating students. However, the standard deviations for each question was higher among the larger incoming student class than the graduating class, indicating less agreement on these positions. This indicates that graduating students have related opinions on these items, as evidenced by the Cronbach’s alpha of 0.726, while incoming students do not. This difference in opinion may result from student experiences as they move through the curriculum as the incoming students have little experience within which to contextualize these questions.

The professional responsibility scale is reliable for both classes, but only if question 6 (whether engineers have a responsibility to develop accessible and inexpensive products even if they do not generate profit) is excluded from the scale reliability analysis. While including question 6 did not influence the reliability of the scale for incoming students, it caused the reliability of the scale to drop below the threshold for graduating students. This is indicative of students’ growing awareness of the overwhelming employment of engineers in for-profit corporations and the military. As students become more concerned with finding a job after graduation, they begin to question or even reject a responsibility to develop accessible and inexpensive products.

When scales are reliable, a mean response can be computed for an individual student’s responses to all questions within a scale. Table 8 displays the average response to reliable scales when students are grouped by disciplinary major. It can be seen that, across all disciplinary majors, incoming students responded more positively within the professional responsibility scale.
Table 8. The average responses to reliable scales, grouped by academic class and disciplinary major.

<table>
<thead>
<tr>
<th>Scale</th>
<th>Class</th>
<th>Disciplinary Major</th>
<th>Average Response</th>
<th>Standard Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Professional Responsibility</td>
<td>Incoming</td>
<td>BIOE</td>
<td>4.09</td>
<td>0.07</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CHE</td>
<td>4.04</td>
<td>0.06</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ENVE</td>
<td>4.33</td>
<td>0.09</td>
</tr>
<tr>
<td></td>
<td>Graduating</td>
<td>BIOE</td>
<td>3.97</td>
<td>0.09</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CHE</td>
<td>3.93</td>
<td>0.06</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ENVE</td>
<td>4.11</td>
<td>0.08</td>
</tr>
<tr>
<td>Depoliticization</td>
<td>Graduating</td>
<td>BIOE</td>
<td>4.11</td>
<td>0.10</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CHE</td>
<td>4.03</td>
<td>0.07</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ENVE</td>
<td>4.25</td>
<td>0.11</td>
</tr>
</tbody>
</table>

This might suggest that the responsibilities of engineers to other members of society become less salient as engineering students progress through their degree programs.
CONCLUSION AND RECOMMENDATIONS

Incoming and graduating engineering students in CBEE at OSU were surveyed to assess perceptions of social responsibility developed in the engineering profession. Preliminary analysis of the results based on average responses and standard errors suggests student perceptions of social responsibility may vary with discipline and progress through a degree program. Graduating BIOE students who had been exposed to discussions of social identity, power, and privilege were most willing to reject elements of meritocracy while incoming students were more likely than graduating students to define designing accessible and inexpensive products as part of an engineer’s responsibilities. Early quantitative analysis found reliable scales for professional responsibility for both incoming and graduating students and for depoliticization in graduating students only.

The next steps of this project are to continue the quantitative analysis of this data set using factor analysis. Results of this analysis are expected to identify academic discipline, class standing, and demographic variables that correlate with social responsibility perceptions, including tendencies to engage or disengage ideologies of depoliticization, technical/social duality and meritocracy. The particular groupings of questions into scales may be reconsidered in order to improve scale reliability. Responses will be analyzed for differences in perception across demographic and disciplinary groups. Student perceptions of social responsibility and the influence of faculty and curriculum upon those views could be further elucidated using follow-up focus groups based on the findings of the quantitative survey analysis. These would be used to further explore student reasoning and rationale behind survey responses, such as how students distinguish meritocratic ideology as it relates to themselves or target groups.
REFERENCES


APPENDIX A: Survey Consent

Purpose: You are being asked to participate in a research study as part of the NSF-funded RED project. The goal of the RED project is to cultivate an inclusive culture in which students engage in realistic, consequential work. This goal will require changes in how faculty and students interact and approach engineering education. We conceptualize these changes in terms of new curricular and co-curricular experiences for students, faculty development, and key structural changes. The purpose of this research study is to document the change processes.

Activities: The study activity you are consenting to involves participation in an online survey about the social responsibility incurred in the engineering profession. You must be at least 18 years old to participate in this research.

Time: The survey should take about 20 minutes to complete.

Benefit: We do not know if you will benefit from being in this study. However, we do expect the research and related work to benefit the CBEE community by increasing our inclusivity and effectiveness in achieving our goals.

Payment: You will not be paid for being in this research study.

Voluntary: Participation in this study is voluntary. You are free to skip any questions you would prefer not to answer. Your participation or non-participation in this research will not impact your relationship and standing with the School and will not impact your standing in this course.

Study contacts: If you have any questions about this research project, please contact Jim Sweeney at 541-737-2491 or jim.sweeney@oregonstate.edu, or Sue Nolan at 206-221-8502 or sunolen@uw.edu. If you have questions about your rights or welfare as a participant, please contact the Oregon State University Institutional Review Board (IRB) Office, at (541) 737-8008 or by email at IRB@oregonstate.edu.
APPENDIX B: Survey Questions

Demographic Questions:
1. Race _______________________
2. Ethnicity ______________________
3. Disability Status ______________________
4. Sexual/Affectional Identity ______________________
5. Age _______________________
6. Social Class ______________________
7. Veteran _______________________
8. Religion _______________________
9. Gender Identity/Expression _______________________
10. National Identity _______________________
11. Geographic Origin _______________________
12. First Language _______________________
13. Major(s) _______________________
14. Who do you know who has gone to college or is in college now? Check all that apply:
   a. Parent or Grandparent
   b. Brother or Sister
   c. Cousin or other relative
   d. Close friends
   e. Other people I know

The following questions were presented in random order on a 5-point Likert scale:

1. My social identities (such as race, gender, sexual orientation, ability, etc.) influence my interactions with others.
2. As an engineer, I need to understand how social, political and/or economic power are distributed in my culture.
3. As an engineer, I have a responsibility to make engineering decisions that protect the environment.
4. As an engineer, I have a responsibility to ensure the just distribution of risks and benefits of a technology I develop.
5. As an engineer, I have a responsibility to consider how a product or technology will be used.
6. As an engineer, I have a responsibility to design accessible and inexpensive products, even if they have little profit potential.
7. Engineers of color have the same opportunities for advancement as white engineers.
8. Female engineers have the same opportunity for advancement as male engineers.
9. I am careful to act in ways that fit into the culture of engineering even if I have to hide or down-play aspects of myself or my identity.
10. The engineering decisions I will make in my career may have social and/or political implications.
11. The recognition and advancement I will receive as an engineer will be based on my performance, which is rooted in hard work, talent, and dedication.
12. Good engineers consider social factors when making engineering design decisions.
13. It would be not be appropriate for me to consider political factors when making an engineering decision.
14. I would not take a job if I disagreed with the practices of the company or organization.
15. I would be comfortable mentioning a social concern about a developing technology to a senior engineer or supervisor in the workplace.
16. CBEE faculty who I have interacted with have expressed the importance of social responsibility in the development of technology.
17. Coursework I have taken in CBEE has helped me understand the responsibilities of a professional engineer.
18. CBEE faculty should understand how social, political and/or economic power influence the experiences of their students.
19. It is not appropriate to discuss social concerns in engineering classes.
20. It is good to discuss political concerns in engineering classes.
21. Engineering coursework should focus on improving students’ technical competencies not social and ethical responsibilities.
22. Baccalaureate Core courses that deal with humanities and social sciences are extraneous to real engineering work.
23. GPA is a good measure to use for Pro-School decisions because it reflects the effort and ability necessary to be a good engineer.
24. Most students who drop out of engineering lack the intellectual capability and perseverance needed for engineering work.