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Professional Social Responsibility in Engineering

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Abstract

This chapter presents a range of viewpoints on the social responsibilities of the engineering profession. These social responsibilities of the engineering profession are in many ways synonymous with macroethics. Analysis of the engineering codes of ethics and educational requirements are used to support these arguments, and are compared with the perceptions of engineering students and working engineers. The social responsibilities of engineers include human safety and environmental protection in engineering designs. But it may extend further to include pro bono work and considerations of social justice issues. Research has found that perceptions of the professional social responsibilities of engineers vary across different countries/cultures, engineering disciplines (e.g., mechanical versus environmental engineers) and by gender. The impact of engineering education and broader college experiences on evolving notions of professional social responsibility will be described, in particular community engagement. Concerns about decreasing commitment to socially responsible engineering among college students, a so-called "culture of disengagement" will be presented, as well of the interaction of students' social goals for engineering and leaving engineering studies.

Keywords: professional social responsibility, individual social responsibility, ethics, environment, gender, higher education, pro bono, safety, social justice

1. Introduction

Social responsibilities are a part of all professions. The profession of engineering is no different. However, there are a diversity of opinions within the engineering profession about what specifically these social responsibilities entail, differing among sub-disciplines within engineering and across different countries and cultures. The process by which an individual

develops their feelings toward their professional social responsibilities as engineers, and how these values change over time, have been examined. This chapter will highlight the array of opinions and recent research into these areas.

2. Social responsibilities of the engineering profession

The engineering profession has a variety of ethical responsibilities to society and the environment. This field of inquiry has recently been termed macroethics [1]. But these professional social responsibilities may be in tension with the business side of engineering [2]. The majority of engineers work for businesses, whose primary motivation is often profit and corporate stockholders, rather than societal impacts. Luckily, this has begun to change based on movement toward corporate social responsibility (CSR) and realizations that companies can thrive economically while considering social and environmental impacts (the triple bottom line). CSR means that companies commit to principles of accountability to community stakeholders, customers, suppliers, employees, and investors. CSR often embraces ideas of sustainability, including human rights and environmental issues, as well as a chain of responsibility and duty of care. Engineering-focused companies often make their commitments to CSR publicly available (e.g., Bechtel [3]).

The characterization of engineering as a profession is also somewhat in tension. Individual licensing of engineers promotes the notion of profession, but industrial exemptions in the licensing laws somewhat erode this independence from employers [4]. Zhu and Jesiek [5] also question whether engineering is a profession in China, based on the lack of an explicit ethical code. It becomes clear when exploring the engineering profession that it should not be viewed as homogeneous, but rather consider that there are distinct cultures in this regard among different sub-disciplines and among countries.

This section presents a few sub-topics related to social responsibility in engineering: human safety, environmental protection and sustainability, pro bono work, social justice, and diversity. The extent to which these elements are included in professional codes of ethics, bodies of knowledge, and requirements for educating engineers are considered to reflect commonly held beliefs related to the social responsibilities of the engineering profession. Further, what a professor chooses to teach engineering students in regards to professional social responsibility has been interpreted as endorsement of the relevance of the topic to the engineering profession. For some topics there is general agreement across engineering sub-disciplines and individuals, while other social responsibilities are being actively debated.

2.1. Human safety

Public trust in engineering requires that the profession considers its impacts on human safety. There is widespread consensus in the codes of ethics of engineering professional societies worldwide that engineering has a primary duty to protect public safety, health, and welfare [6]. Engineering-related failures or problems that result in injuries or death are often

front-page news (e.g., levee failures in New Orleans, interstate bridge collapse in Minnesota, ignition switches in cars) [7, 8]. It is of concern that the accumulated impact of frequent news-worthy incidents may over time erode public trust in engineering.

Although generally "bundled," health, safety, and welfare each have particular nuances. Vesilind [9] notes that there may be instances when these three elements differ, both in fact and among the perceptions of various groups within the public. Further, the public should not be viewed as a monolith, but rather engineers need to be aware of "diverse publics" with different needs and goals [10, 11].

Health is generally characterized as being able to function physically without pain, and may also include mental soundness. Promoting health is a direct goal of biomedical engineering. Environmental and civil engineers are tasked with providing clean drinking water and preventing the spread of toxic chemicals via air, water, and soil. Chemical engineering is involved in manufacturing medicines, as well as pesticides and other chemicals that may have toxic effects. Thinking specifically about health-related issues is perhaps less prevalent in other engineering disciplines. One challenge is the uncertainty that surrounds what is in fact protective of human health, given incomplete toxicological information and difficulties evaluating chronic effects (e.g., cancer). Different countries have different paradigms regulating the development, distribution, and use of new chemicals with regards to the information that is required on human health effects, with some taking a more precautionary approach [12]. Further, US drinking water regulations take into account both human health and treatment costs. Overall, engineers may disagree on what conditions sufficiently protect human health.

Safety is associated being protected from physical injuries or death, again considering risks. Thus, civil engineering infrastructure that will be safe in the face of hurricanes or earthquakes, construction engineering to protect on-site workers, mechanical engineering of cars to protect occupants during crashes, etc. Other engineering disciplines are also critically important to safety but as sub-systems may garner less attention (such as software engineering for computer controls or electrical engineering). However, public safety broadly applies to all engineering disciplines. The International Education Association knowledge profile for a Washington Accord Program includes "comprehension of… the professional responsibility of an engineer to public safety" [13]. Disciplinary differences within engineering in the extent that students are taught about safety in their courses were found in a study of engineering educators; among ~1400 survey respondents (96% from institutions in the US), 44% taught engineering/computing students about safety in their courses. However, this varied from 76% in chemical engineering to 26% in computing [14]. Safety is included explicitly as a cognitive "cross-functional" outcome within the Chemical Engineering Body of Knowledge [15].

Welfare relates to overall well-being, potentially inclusive of happiness, health, material wealth, and feelings of security. Thus, welfare is more subjective than health or safety, and is correspondingly harder to measure. While protection of human or public welfare is a common statement in US codes of engineering ethics [16, 17], this term is not included in some international ethics codes [18–20]. The Australia code uses the term "wellbeing" in place of

welfare [18]. The Royal Academy of Engineering's (RAE) Statement of Ethical Principles [20] includes "public good," separate from the "health and safety" paramountcy clause. The Chemical Engineering Body of Knowledge [15] lists "concern for public welfare" among its affective domain outcomes. It is clear that engineers may have different notions of welfare than individuals within the public. Vesilind [9] gives the examples of engineers reducing speed limits on highways to 55 miles per hour to provide increased safety, but having the majority of the public believe their overall welfare was better served by higher limits that enabled them to reach their destinations more efficiently.

There has been a recent debate about how engineers can best serve this most basic mandate to protect human health and safety. One environmental scientist/engineer, Sedlak, accused others of "crossing the line" from dispassionate researcher to being activists [7]. Sedlak (trained as an environmental scientist, but a professor of civil and environmental engineering for over 20 years) called into question Prof. Marc Edwards (MS/PhD civil engineering) and his involvement in the Flint, Michigan, lead crisis, and Daniel Carder (BS/MS mechanical engineering) who helped expose the Volkswagen emission problem. Edwards and Carder likely perceived it as their social responsibility as engineers to uphold the preeminent requirement to protect human health and safety [21, 22], and acted in compliance with the engineering codes of ethics to expose ethical wrong-doing (e.g., ASCE Canon 1d [17]). In response to Sedlak's editorial, a number of individuals shared differing views on the professional responsibilities of environmental engineering and science as related to the public [23–28]. There are perhaps differences in the social responsibilities of engineers and scientists, and the extent to which individuals identify with these disciplines ([24] written by a licensed professional engineer, [36] a Board Certified Environmental Engineer, [25, 27] members of the National Academy of Engineers, [23, 25, 28] degrees in chemistry). An individual's personal identity with respect to their profession may be significant in how they perceive their social responsibilities.

2.2. Environment and sustainability

Engineering codes of ethics include environmental protection among professional social responsibilities (**Table 1**), with the exception of some specialized sub-disciplines (biomedical and aerospace engineering). "Comprehension of the impacts of engineering activity: … environmental" is one of the knowledge outcomes of a Washington Accord Program [13]. Environmental considerations in the engineering design process have also been explicitly required for accredited engineering degrees under ABET (Criterion 3, Outcome 2 [36]). Despite widespread inclusion in codes of ethics and professional education requirements, environmental protection issues do not appear to be an equally prevalent focus of different disciplines within engineering. In a study of engineering educators, an average of 32% of the ~1400 survey respondents taught engineering/computing students about environmental issues, ranging from a high of 76% in environmental engineering to a low of 6% in computing [14]. Among 180 engineering educators in the study by Romkey [37], the average implementation of "I encourage students to consider the potential environmental impact of technology" was 2.49 (where 2 = sometimes and 3 = often on a 1–4 scale). Internationally, commitments to environmental protection are generally considered to be somewhat stronger in the EU versus the US.

Discipline(s)	Country/countries	Environmental protection	Sustainability or sustainable development
Engineering [16]	USA	Yes	Yes
Engineering [20]	UK	Yes	(Succeeding generations, natural resources, public good)
Engineering [18]	Australia	Yes	Yes
Engineering [29]	The Netherlands	Yes	(Long term effect on society and/or environment)
Engineering [19]	New Zealand	Yes	Yes
Engineering [30]	India	Yes	No
Aerospace [31]	USA	No	No
Biomedical [32]	Global	No	No
Chemical [33]	USA	Yes	No
Civil [17]	USA	Yes	Yes
Electrical [34]	Global	Yes	Yes
Mechanical [35]	USA	Yes	Yes

Table 1. Inclusion of environmental protection and sustainability responsibilities in the code of ethics from different disciplines and countries.

Engineers' social responsibility for environmental protection may originate from different ethical frameworks [38]. From an anthropocentric framework, one may simply understand that preservation of the environment is ultimately self-preservation for human life. Alternatively, from a biocentric perspective one may recognize the intrinsic right to life of all organisms on the planet. The environment and ecology may be viewed to have distinct value, beyond that of maintaining human existence.

A more limited sub-group of countries and engineering disciplines include sustainability and/or sustainable development within their code of ethics (**Table 1**). Australia's code shows a commitment to sustainability in the first sentence of the preamble statement, "use of knowledge and skills for the benefit of the community to create engineering solutions for a sustainable future," and "promote sustainability" is one of the four key statements of ethical practice [18]. In fact, the mandate to protect the "health, safety and wellbeing of the community" is placed under the heading of promoting sustainability. Sustainability knowledge or abilities are included as stand-alone outcomes within the bodies of knowledge for US chemical, civil, environmental, and professional engineers [15, 39–41]. Sustainable design and development as a social responsibility of engineers has been endorsed by many scholars around the globe [42–45].

One issue may be the lack of consensus on the meaning of the term sustainability or sustainable development. In general, sustainability includes considerations of both current conditions and future generations, crossing environmental, societal, and economic elements. Sustainability

is included in the educational requirements for engineers under the Washington Accord outcomes [13]. In contrast, sustainability is not explicitly required in engineering education under ABET, which accredits the majority of the programs in the US and additional programs across 30 countries. Sustainability is mentioned as a potential consideration in the engineering design process under both the old ABET EC2000 criteria and the new requirements [36, 46]. The new requirements do include considerations of "global, economic, environmental, and societal contexts" within the ethics outcome, but these considerations might be primarily immediate versus long term. Interestingly, more faculty indicated that they teach engineering/computing students about sustainability (42%) as compared to environmental impacts (32%), ranging from 74% in environmental engineering to 15% in biomedical engineering [14].

2.3. Pro bono

The idea of pro bono work is that professions should donate some of their technical expertise to individuals or organizations unable to pay for those services. This can be providing services for free or at a reduced rate. While this is commonplace in professions such a law and medicine [47], the idea just seems to be starting to grow in engineering and is by no means universal [6]. The American Society of Civil Engineers (ASCE) first approved a policy statement on pro bono services in 1996 [48], encouraging engineers *as individuals* to provide services to charitable causes and in emergency situations; however, its real purpose appears directed at liability issues and indemnification. The National Society of Professional Engineers (NSPE) has a policy statement pertaining to liability of "good samaritans" who volunteer their engineering services upon request in times of crisis [49].

Within the codes of ethics for engineering, hints of commitment to pro bono service can be found. The NSPE code [16] states that "Engineers are encouraged to participate in civic affairs; career guidance for youths; and work for the advancement of the safety, health, and well-being of their community"; a similar statement is found in [31]. The ASCE code [17] states that "engineers should seek opportunities to be of constructive service in civic affairs and work for…their communities." However, the mandate for pro bono activity is unclear.

Riley and Lambrinidou [11] suggest that pro bono service should comprise at least 5% of the employed hours of engineers. Interviews with working engineers found that some engineering companies allow donating standard work hours to engineering service, such as to groups like Engineers Without Borders (EWB)-USA [50]. Moulton [51] asserts, "An enormous amount of software development/support is done at low or no cost, for example, public help forums and much of the work toward Open Source/Linux/GNU etc." (p. 334).

In a study of pro bono engineering in Australia in 2011 [52], a high demand for pro bono engineering, reasons for engaging in pro bono activities, benefits from pro bono activities, and challenges were documented. A sense of professional responsibility was identified among the motivations for participating in pro bono activities in engineering. While providing rich information and detailed case studies, the research left unanswered questions such as what percentage of engineering companies or individuals engage in pro bono activities, and to what extent (hours per year).

In a small study (methods described in [8]), working engineers were asked in a survey to rate their agreement with the statement "Engineering firms should take on some pro bono work." Among the 465 respondents, 12% disagreed, 21% were neutral, and 68% agreed; 49% of the survey respondents had recently graduated (within 1 to 2 years) with an engineering degree from a US institution and 27% of the respondents were members of EWB-USA. Differences in opinions were found based on gender (females higher average agreement), discipline (environmental higher agreement than mechanical), and years since earned Bachelor's degree (higher agreement for those who earned degree 6 or more years prior). By comparison, responses from US engineering students (n = 4191, 17 institutions, all ranks and majors, 2011–2014) to the same question were: 11% disagree, 34% neutral, 55% agree (Bielefeldt unpublished data, combined from studies described in [53–55]). Thus, among both engineering students and professionals the majority agreed to some extent that engineering firms should take on pro bono work.

In Australia, the University of Technology Sydney studied the attitudes of their students toward pro bono engineering. Based on a report that students were required to submit after their first internship, it was found that: 20% poorly engaged with the pro bono aspect of the assignment, 10% had not considered pro bono before, 10% acknowledged little knowledge of pro bono in engineering, 30% focused on what they could get out of pro bono work, 20% indicated they might engage in pro bono work in the future, and only 10% showed a clear intention to be involved in pro bono work [51].

Engineering service groups comprised of volunteers are becoming more popular. A prime example is EWB-USA which works to help meet the basic needs of global communities. In 2015, EWB-USA reported 16,800 members in 288 chapters [56]. These chapters include both student chapters (typically affiliated with a university or college) and professional chapters. This is a large number of engineering students/ professionals engaged in donating their time to help others through engineering. EWB International (EWB-I) has 65 organizations that are part of its network [57]. EWB-Australia is particularly active; in 2015–2016 they reported 3275 members/friends, plus 30 university partners with 9513 students engaged in an EWB challenge activity, and 13,000 students engaged via their school outreach program [58]. They state, "our EWB Connect initiative has been pioneering the creation of a pro bono engineering culture across the profession." [58, p. 4]. Other examples of pro bono focused engineering service groups include Bridges to Prosperity, Engineering World Health, and the Community Engineering Corps (an alliance of ASCE, EWB-USA, and the American Water Works Association).

In engineering education, pro bono work can take the form of service-learning or Learning through Service, also termed community engagement [59, 60]. VanderSteen et al. [61] discussed humanitarian service-learning projects locally (in Canada) and abroad (Ghana); both appeared to have impacted students' views of socially responsible engineering. Linkages between community engagement activities among US engineering students and professional social responsibility attitudes were found in a large study [62]. As well, engineering faculty believe that students learn about ethics and societal impact issues via community engagement activities [63].

2.4. Social justice

Social justice relates to the distribution of wealth and privileges in society, as well as issues related to poverty and development. There are a growing number of advocates that engineering social responsibility encompasses social justice issues, including engineering faculty in the US [64, 65], Australia [66], Finland [67], and Colombia [68]. A group devoted to this issue, Engineering, Social Justice, and Peace (ESJP), routinely hosts a conference. But there are also naysayers [69–72], and the majority of the public comments posted with these articles were against social justice education for engineers. For example, one commenter noted "Employers will shun engineers who they suspect may have been indoctrinated with social justice ideas. In short, SJW ideology is a highly destructive virus" [71]. The robust number of comments posted with these essays speaks to their controversial nature; for example, 279 comments on the Washington Times article [72].

Many have asserted that the majority of engineering activities are devoted to benefitting the wealthiest on the planet, versus devoting attention to the large percentage of the global population that survives at a near subsistence level. Engineering education programs to address these concerns in the US include the D80 center at Michigan Technological University [73], the Engineering for Developing Communities Program at the University of Colorado Boulder [74], and a number of other programs [75]. There are also similar programs in Spain [76] and Canada [61].

There does not appear to be widespread formal education of engineering students about social justice and/or poverty issues; only 17% and 15% of engineering faculty taught these topics in courses, respectively [14]. However, these topics are reasonably pervasive in co-curricular engineering service groups (such as EWB-USA). Among faculty mentors of engineering service groups, 90% felt students learned about engineering and poverty and 47% felt students learned about social justice.

2.5. Diversity

There are a number of diversity-related issues in engineering. A primary issue is the persistent lack of diversity within the engineering workforce in the United States and many other parts of the world, which is predominated by men and generally lacks racial/ethnic diversity. Other "non-visible" diversity issues relate to socio-economic status (low income individuals under-represented), cognitive and personality types, etc. [77]. The lack of diversity in the engineering profession is also found in engineering education. Implicit bias and a chilly climate are often cited as potential reasons for the lack of diversity within the engineering profession. It has been argued that this lack of diversity is detrimental to engineering and limits the ability of engineering to best fulfill its mandate to benefit society [77, 78]. It is unclear if one of the social responsibilities of the engineering profession relates to employing the diversity of individuals in society. Statements related to diversity in engineering codes of ethics are summarized in **Table 2**. Generally, these relate to avoiding discriminatory treatment, but the Australia [27] and the UK [29] codes also include language to promote/support diversity. Most recently in the summer of 2017, the ASCE updated its code of ethics to include provisions related to diversity [79]. The ability to work effectively in diverse teams is an explicitly acknowledged

Discipline	Country	Engineering ethics code text related to diversity
Engineering [18]	Australia	"1.3 Respect the dignity of all persons. (A) treat others… without discrimination… (b) …without bias in respect of race, religion, gender, age, sexual orientation, marital or family status, national origin, or mental or physical handicaps; 3.2 Support and encourage diversity; (b) promote diversity in engineering leadership"
Engineering [16]	USA	(None)
Engineering [20]	UK	"Promote equality, diversity and inclusion"
Engineering [29]	The Netherlands	(None)
Engineering [30]	India	"Treat fairly all persons regardless of race, caste, religion, gender…"
Aerospace [31]	USA	Treat co-workers "fairly and respectfully"
Biomedical [32]	Global	(None)
Chemical [33]	USA	"Never tolerate harassment"; "treat all colleagues and co-workers fairly and respectfully, recognizing their unique contributions and capabilities by fostering an environment of equity, diversity, and inclusion"
Civil [17]	USA	"Treat all persons fairly and encourage equitable participation, without regard to gender, race, national origin, ethnicity, religion, age,…. consider the diversity of the community, and… include diverse perspectives"
Electrical [34]	Global	"…treat fairly all persons and to not engage in acts of discrimination based on race, religion, gender, disability, age, national origin, sexual orientation, …."
Mechanical [35]	USA	(None)

Table 2. Diversity-related issues in engineering codes of ethics.

requirement for engineering graduates [20, 46]. However, diversity concerns, like social justice, are not universally embraced as being relevant to engineering [71].

Another important issue with respect to diversity is the extent to which the profession fairly compensates workers, without regard to gender, race/ethnicity, etc. In India, female engineering/computing workers generally earn less than male counterparts [80]. Cech [81] found that wage differences by gender in engineering within the US might be partially accounted for based on the nature of the work being done with respect to a technical:social dualism hypothesis. It was found that women were more represented among less "technical" sub-disciplines in engineering and among more social tasks in engineering.

3. Individual social responsibility development

An individual's perceptions of their social responsibilities as engineers will develop over time via the process of professional socialization. The professional socialization process begins with novice views of the engineering profession. These informal influences may include messages from media (e.g., movies, news, books), family or acquaintances (e.g., parent an engineer), and school (primary and secondary). Some students' pro-social motivations are a driver for their decision to major in engineering [54, 82]. This aligns with efforts to market the social benefits

of engineering, in line with recommendations from the US National Academy of Engineers "Changing the Conversation" report [83]. A higher percentage of female engineering students included helping people, helping the environment, and positively impacting society as reasons they chose their engineering major, based on open-ended responses [84]. Differences were also found among disciplines; a greater percentage of students majoring in environmental and civil engineering described helping goals as compared to students majoring in mechanical engineering [54]. Among UK students given 7 options as to why they decided to study engineering, only 13.5% selected a desire to 'make a difference' to the world; there was no difference between female and male students, and this aspiration was the lowest among 4th year students [82]. There is also some evidence that students who enter engineering with the strongest pro-social motivations leave engineering majors during college at a higher rate than their peers [85, 86].

Professional socialization processes for engineers are more explicitly occurring during higher education and in the engineering workforce. The continuum of the development of professional civil engineers is outlined explicitly in the Civil Engineering Body of Knowledge (BOK) [40]. Here, the acquisition of various knowledge, skills, and attitudes is mapped from the Bachelor's degree in engineering, through a Master's degree or additional formal education, and during mentored experience working under the supervision of a licensed professional engineer. In regards to professional and ethical responsibility, the civil engineering BOK includes proposed affective domain outcomes such as "commit to the standards of professional and ethical responsibility for engineering practice" [40, p. 94]. Within the "attitudes" outcome elements such as honesty, integrity, consideration of others, respect, and tolerance are included [40].

During higher education, in addition to learning important knowledge and skills, students are developing attitudes and affective outcomes associated with engineering. Professional socialization during higher education includes courses and a variety of informal education experiences outside the classroom, such as professional societies or internships in engineering. A number of studies have explored student perceptions related to elements of social responsibility. Despite bringing students with aspirations toward positive social benefits into engineering, there is evidence that these goals may diminish over time [87, 88].

Professional socialization continues into the engineering workforce. While Cech [87] found continuing evidence of decline in the public service beliefs of alumni from engineering programs after 1.5 years in the workforce, counter-evidence suggests that working engineers may become more committed to their professional social responsibilities over time. A survey of working engineers (Bielefeldt unpublished, from the study described in [8]) found that the majority (61% of n = 467) agreed with the statement "Since earning my bachelor's degree, I have become more motivated to help people and society through my work"; only 16% disagreed and 23% were neutral. Responses did not differ by gender but did differ based on years since earning Bachelor's degree (5 or fewer years lower than 6 or more years) and engineering discipline (mechanical lower than environmental). Similarly, the majority (67%) disagreed with the statement, "Since earning my bachelor's degree, I have become less confident of my ability to make positive impacts on people and society through engineering." Responses differed by gender (female stronger agreement than males), years since earning Bachelor's degree (5 or fewer years more agreement versus 6 or more years), and discipline (environmental stronger agreement than civil).

Models have been proposed to explain the development of professional responsibility attitudes in individual engineers. The Professional Social Responsibility Development Model (PSRDM) [89] was based on an ethic of care framework, and drew from Schwartz's [90] altruistic helping behavior model, Ramsey's [91] model for integrating social responsibility into the decision process of scientists, and the Delve [92] Service Learning Model. The PSRDM includes three realms: personal social awareness, professional development, and professional connectedness. The personal social awareness realm describes one's personal feelings of a desire to help others, which is inclusive of the dimensions of awareness that needs exist, feelings that one possesses the ability to help, and a connectedness that motivates one to action. Separate from these personal feelings, an engineer should develop professionally. The three dimensions of this realm include one's belief that a variety of *base skills* are needed for engineers, feelings that engineering has the capacity to help address societal issues (*professional ability*), and an awareness that one should analyze the societal impacts of engineering and include stakeholders from the community in the engineering process. Finally, it is anticipated that a person's individual motivations to help will come together with their engineering professional development, to inform their sense of professional connectedness. A personal motivation to help others through application of one's engineering skills can be fostered through a cycle of engaging in this helping behavior. It will also increase one's sophistication in their awareness of both the costs and benefits of helping and serving others through engineering.

An Input-Environment-Output type of model derived from Wiedman [93] was used by Rulifson [92] to describe the development of professional social responsibility ideas in engineering students. As inputs, individuals bring pre-dispositions toward personal social responsibility and attitudes toward engineering into college. These are developed from family influences and high school, etc. Within higher education, a number of factors have been determined to influence ideas of professional social responsibility. However, Cech [87] notably found that attitudes toward public service decreased among 326 engineering students attending four US institutions. This concerning trend was termed a "culture of disengagement." It is perhaps not surprising given that the majority of engineering studies focus on technical issues, and preference technical issues over the interactions of technology with society. This technical:social dualism may reduce students' focus on the impacts of their work as engineers. However, experiences during engineering studies may counter this decrease in engineering students' ideas of socially responsible engineering. Some engineering students cited courses as impactful to their views of social responsibility [94]. Brodeur [95] suggested a number of ways to integrate social responsibility ideas into engineering education, including the use of the CDIO Syllabus, cooperative learning, constructive controversy, and design-implement projects. Service-learning may advance students' ideas of social justice [96] and social responsibility [62, 95].

4. Conclusions

There are some elements of engineers' professional social responsibilities that are widely agreed upon. These include protection of human health and safety, and protection of the environment. Other engineering social responsibilities have less consensus across countries and

disciplines, including the mandate to participate in pro bono work, strive for social justice, and embrace diversity. Corporations focused on engineering activities and for which engineers work typically have corporate social responsibility statements which document their commitments and contributions to sustainability in the form of their working conditions, the local community, and environmental impacts. Finally, studies are documenting how engineers' develop their sense of professional social responsibility, including their upbringing, college experiences in and out of the classroom, and socialization in the engineering workforce. Some troubling findings are that an individual's commitment to socially responsible engineering may actually decline over time, perhaps as they begin to separate their technical expertise from social commitments or feel that business interests outweigh broader social responsibilities.

There are still a number of unanswered questions in regards to engineers' beliefs of their professional social responsibilities, and factors that contribute to shaping these beliefs. More research that involves working engineers is needed. This should include longitudinal studies. It is unclear how the job roles of an engineer – from a freshly graduated junior engineer, to a more senior engineer with supervisory responsibilities – may impact their views of professional social responsibility. It is also unclear how the work setting – public entity, private consultant, working for industry – might be impactful. Job roles should also be explored – research, design, project management, sales, etc. These studies are needed in different countries and cultural settings, as well as in different engineering disciplines. Due to the widespread impacts that engineers have on society and our planet, it is imperative to understand how to better foster social responsibility commitments among engineers.

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Conflict of interest

The author declares that she has no conflict of interest related to this work.

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