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Evolving Social Responsibility Understandings, Motivations, and Career Goals of Undergraduate Students Initially Pursuing Engineering Degrees

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EVOLVING SOCIAL RESPONSIBILITY UNDERSTANDINGS, MOTIVATIONS, AND CAREER GOALS OF UNDERGRADUATE STUDENTS INITIALLY PURSUING ENGINEERING DEGREES

by

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Engineers impact the lives of every person every day, and need to have a strong sense of social responsibility. Understanding what students think about social responsibility in engineering and their futures is very important. Further, by identifying influences that change these ideas and shape their conceptualizations, we can intervene to help prepare students for their responsibilities as part of the profession in the future.

This thesis presents the experiences, in their own words, of 34 students who started in engineering. The study is composed of three parts: (i) engineering students' ideas about socially responsible engineering and what influenced these ideas, (ii) how students see themselves as future socially responsible engineers and how this idea changes over their first three years of college, and (iii) what social responsibility-related reasons students who leave engineering have for choosing a new major.

Results show that students are complicated and have varied paths through and out of engineering studies. Students came up with their own ideas about socially responsible engineering that converged over the years on legal and safety related aspects of the profession. Relatedly, students identified with the engineering profession through internships and engineering courses, and rarely described socially responsible aspirations that could be accomplished with engineering. More often, those students who desired to help the disadvantaged through their engineering work left engineering. Their choice to leave was a combination of an unsupportive climate, disinterest in their classes, and a desire to combine their personal and professional social responsibility ambitions.

If we want engineering students to push the engineering profession forward to be more socially responsible, we can identify the effective influences and develop a curriculum that encourages critical thinking about the social context and impacts of engineering. Additionally, a social responsibility-related curriculum could provide more opportunities for engagement that keeps those socially-motivated students

in engineering. The engineering profession must also reflect these values to keep the new engineers working towards social responsibility and pushing the profession forward.

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Study Purpose

As society faces unprecedented challenges in future decades, engineers will have an ever-growing role in the welfare of the global community in which we all live. With some critical reflection, all engineers will find that they have many social responsibilities by the nature of their profession and work. As engineering is becoming more important, engineers will need to work in diverse communities and situations. From global warming to global poverty, water conservation to water and sanitation, intellectual property to cybersecurity, engineers are heavily involved in all areas of daily life. Their work contributes to the global supply chains, mass consumerism, and fossil-fuel consuming industries that are potentially destroying the environment. At the same time, they are coming up with energy-saving and alternative energy technologies, closing the digital divide, and improving response during disasters. Engineers have a complicated relationship with society, but from any vantage need to take on this responsibility.

These major issues require a large and capable engineering workforce. However, there are currently too few engineers, and even fewer that represent the diversity needed in order to be sensitive to the changing needs of the society (National Academy of Engineering 2005). Not only will a cadre of diverse engineers help to address the forthcoming issues, but encourage more diverse students to enter engineering when considering potential career paths. In particular, women are underrepresented earning less than 20% of the bachelor's degrees awarded in engineering, and this number has been consistent for ten years (Yoder 2014). Just as significant, women represent less than 10% of engineers in the workforce, so many are choosing a different career even after completing engineering school (Bureau of Labor Statistics 2014). Women have typically been characterized as seeking more prosocial careers, so if addressing these complicated social issues are a major motivation for the engineering profession, more women may be attracted to study and stay in engineering (Grant and Berg 2011; Wilson et al. 2011; Miller et al. 2000).

Given these motivations, we sought to understand through this research how students who started in engineering majors thought about social responsibility and what this meant for their future careers within or outside of engineering. While educational efforts have tried to improve the attitudes of engineering students towards improving society, such as service learning and the integration of a socially contextualized curriculum, students' thoughts about social responsibility have not been collected in their own words. Further, student's changing and developing attitudes are of interest, but few longitudinal studies with engineering students in this regard have been conducted to date.

We had an overarching goal to deeply understand how students were thinking about social responsibility in engineering, and in what ways these ideas changed as they progressed through their college career. Therefore, we used semi-structured, hour-long interviews over three years, paired with a survey for triangulation. Students needed to be given time to explain their ideas, and to be comfortable enough with me to share how they felt they helped others, what they felt were the responsibilities of engineers, and how much they saw social issues of importance coming into their engineering goals in the future.

We attempted to have a highly diverse interview pool (gender, major, university, social responsibility attitudes) to gather a wide range of ideas about social responsibility in engineering. We also wanted to understand the female engineering experience, so the study had a high oversampling of women. The interviewees were gathered from the Engineering Professional Responsibility Assessment (EPRA), which was distributed to five universities in Fall 2012. Students from four of these universities participated in the interviews. Questions in each year ranged from a brief description of their previous year's experiences within and outside of engineering, to their ideal careers in engineering, to how they helped others, their expectations of values in their future engineering careers, social responsibility definitions, and how all of these might be coming together in their futures.

A significant, though initially unplanned, component of this study were the continued conversations with nine students who left engineering at some point during their first three years of college. These 'leavers' provide rare insight to the decision-making process, but then, importantly for this study, how social responsibility was a motivator for their departure as either a push from engineering or a pull into another major.

The results from each of these components provide many opportunities for discussion about what and how students are learning during engineering school, and what they are finding their future profession will value. These results also provide some concrete motivation for improving the engineering curriculum to align better with the values of those who want to have a positive impact on society through their jobs. If the engineering profession is really going to be prepared to deal with the looming, complex problems of the future, both in numbers and a willingness to take social responsibility, engineering education needs to attract a more diverse population and have a more balanced curriculum with societal improvement as the highest priority. Encouraging high social responsibility can help to achieve both of these ends. A first step is to know what students are already thinking about this important subject.

ARRANGEMENT OF THE THESIS

This dissertation was developed as three separate journal articles to be published in the future, each containing a research question, background, methods, results, and discussion. Surrounding this heart of the dissertation, Chapter II provides some of the general background for the work with a literature review around engineers and social responsibility through history up until now in engineering education. Chapter III covers the overarching methods, including the situation of this work within a larger study and the details of the study over the three years – all the student demographics, interview questions, and how the analysis was performed and validated. Chapters IV – VI are the three independent journal articles. Thus, some of the introduction and methods may be a repeat of previous chapters. Each chapter have important, related results that contribute to the body of engineering education knowledge. The dissertation concludes with Chapter VII, which discusses some implications of the research as a whole and ideas for future work, as well as a personal reflection of the value of the research (both in method and content). The appendices contain additional detailed information, data, and analysis to support each chapter and allow readers to access particulars that they may find of value.

CHAPTER II: LITERATURE REVIEW

This literature review describes a very brief history of engineers' social responsibility as the profession grew along with the economic and social changes of the last twelve decades. Engineering's history of professionalism, business, and responsibility is important to know how engineering came to be viewed as it is now, and what it once was. These same issues of concern today have been considered before. Society and technology studies have influenced how the public sees the impact of engineers on society throughout history. How the public interacts with and is affected by engineered technology is very much a concern within an engineer's social responsibility. Then, it shifts to more current understandings of what an engineers' social responsibility could or should be, some curricular efforts to impart these ideas upon students, and how concepts of social responsibility can potentially assist in recruitment, retention, and persistence efforts of underrepresented students in engineering. This general information informed the overall study goals. Additional background literature that is relevant to the specific research questions is presented in the three journal paper chapters IV to VI that form the heart of the dissertation.

A BRIEF HISTORY OF ENGINEERING AND SOCIAL RESPONSIBILITY

Concerns about social responsibility within the engineering profession are nothing new, though the particulars have changed through the decades, as has the political motivation for action to address issues of engineering in society. This review starts in the 1890s based largely on Layton's (1986) *Revolt of the Engineers* (Layton Jr 1986). The Progressive Era brought unprecedented industrial strength and growth in the United States, and the role of the engineer in society grew. In 1890 there were about 1,000 engineering students in the U.S. Within ten years, this number had increased tenfold. At the same time, large corporations in the railroad, automobile, and utility industries created enormous wealth concentrated in the hands of a few, while much of the country continued to struggle. Professional societies such as the American Society of Civil Engineers (ASCE) and the American Society of Mechanical Engineers (ASME) offset the power of business and give the engineer professional autonomy. These societies had varying success to this extent; the ASCE was exclusive and elitist in its membership policies, ASME included far too many businessmen at its highest ranks, and the American Institute of Mining Engineers (AIME) was almost completely focused on improving the business of mining engineering, rather than the profession. As engineers rose in the hierarchy of their companies, this company loyalty outweighed the identification with the profession and a will to improve society.

The ASCE was founded in 1852, but did not adopt a code of ethics until 1914, right after the ASME adopted their code, which followed the lead of the American Institute of Electrical Engineers in 1912 (Vesilind 1995; Luegenbiehl and Davis 1992). It was not until 1950, though, that the ASCE wrote that "the primary responsibility of engineering is to serve the public good." Other components of the code were often to protect the profession's status and prestige in society. It took until 1980 for the ASCE to include anything about improving or preserving the environment (Vesilind 1995). All of these efforts were to provide a resourced that could advise individual engineers on their conduct and understanding the larger goals and values of their chosen profession. While these were an important step, the vague language and lack of consequences have left some to wonder the point of these codes (Ladd 1982).

During the same era of the early 20th century, the ideas of Social Darwinism of Herbert Spencer led some engineers to believe that their work could not be wrong, and must be socially responsible since they represented truth, which led to justice. Engineering solutions were just solutions. They were helping to advance society through technological progress, and were aware of their powerful position to impact society. "Engineers were best suited to solve any problem permanently" (Layton Jr 1986). As such, engineers wanted to improve their status in society by building their prestige and being compensated appropriately. Doctors and lawyers were autonomous and respected, and engineers should be too. One effort was through the Public Health Service that began in 1912, which employed engineers in the areas of sanitation, water supplies and sewage disposal as the government realized that these were the root causes of many diseases in the burgeoning American cities (Holcomb 2000). Civil engineers associated themselves with the conservation movement through which they could plan the natural resource management of the country and be part of a national movement. Frederick H. Newell, who became the

Chief Engineer of the Geological Survey's Reclamation Service in 1902, believed this would be the entry point followed by expansion to transportation and other types of civil infrastructure (Robert M. Utley and Barry Mackintosh 1989). Following World War I, another opportunity was presented – to plan, to engineer, a new society in Europe and in the U.S. after seeing the destruction of war (Layton Jr 1986). As the professional societies tried to take this chance at engineering society, the members could not wean themselves from the material interests that businesses offered, and engineers supported, and lost their independence in, the laissez-faire practices of mildly-regulated industry.

Scientific management emerged as a method through which engineers could govern society. This larger social role would improve engineers' status. Henry Gantt's "New Machine" of 1916 described how plutocrats had ceased to be beneficial, and instead were an "engine of social injustice." Through scientific management, justice could be measured and distributed equally. In the mid-1910s, Morris L. Cooke saw scientific management gaining traction through the engineering societies, which could be a great force, but needed reform in order to make public interest paramount rather than the business interests of a few. He was especially concerned with the utilities industry's hold on the ASME. He inspired younger members to come together to make the Federated American Engineering Societies that would prioritize ethical concerns over capital.

In the 1920s, the profession was inspired by an influential engineer named Herbert Hoover. He was a mining engineer that emphasized a renewed need for social justice following WWI. He saw the engineer as a manager and facilitator between capital and society, but not a leader. Business would lead, but engineers' status would still be improved due to their heavy involvement. Other engineers came to agree with Hoover, even Cooke. They recognized that technology had caused problems, but that engineers were also the ones to fix the issues. Engineers were soon presented with "their greatest challenge and opportunity" in the Great Depression from 1929-1939 (Layton Jr 1986). The public was ready for the profession to engineer their society as they had seen business interests get out of hand, but the engineers did not take advantage of these social sentiments. Individuals were concerned with their own selfish interests rather than their social responsibilities. Some allied with business, such as the

American Engineering Council, took no action at all. Others, such as Roy Wright of the ASME welcomed the public's criticism of engineers in an attempt to engender a sense of defensiveness, which would bring engineers to realize and act upon their responsibilities.

Ultimately, the efforts of the New Deal in the 1930s directed the conversation to a battle between the government and free enterprise. Engineers were working on these projects, but had less responsibility. By the 1940s, social responsibility was an idea that just made some engineers feel better about their work, but it became divorced from professionalism and reform. This gap grew, and the engineering societies sought to fill this gap, rather unsuccessfully. In the following decades, scientific professionalism, and engineering science, became the focus of engineering and skills. Scientific knowledge became more highly valued while the arts and practical working-knowledge were replaced.

Wisnioski's (2012) *Engineers for Change* picks up where *The Revolt of the Engineer* leaves off, and chronicles the challenges of the technological changes of the 1960s in the United States (Wisnioski 2012). Coming out of the materialism of the 1950s in which thousands of engineering jobs were created to design products for the new middle class. The 1960s brought the country deep into the Cold War and space race, and the Vietnam War was ramping up. Many in society were frustrated with technology's ill-effects and were looking for someone to take responsibility. Additionally, large amounts of government spending was going to the military who directly or indirectly employed 70% of the country's engineers, which was the most common profession for white-collar men. Some engineers were vocal in discussions about the role of engineers in managing technology, but these were few of the millions in the profession. Most were advancing technology without a human welfare purpose.

Science and technology studies (STS) grew throughout the 1960s. The powerful elite of the Harvard Program studied the effects of technology on society, and advised the federal government on future plans and funding. At the same time, the engineering societies were trying to find their role in managing the debate, and to what extent they should describe an engineer's influence on the limits of technology. "Responsibility was the faculty of judgement that distinguished him from the skilled laborer, the scientist, and the businessperson as he brought social progress through efficiency and invention"

(Wisnioski 2012). While the societies could provide guidance through their publications and meetings, there was no method for ethical arbitration, and the “rhetoric of responsibility was infinitely malleable and universally desirable” (p.69). As the NSPE reformed their ethical code and the ASME created a Technology and Society committee, other individuals tried different avenues. Victor Paschkis founded the Society for Social Responsibility in Science (SSRS) which grew to a few hundred members by 1960. It continued to grow along with STS generally through the 1960s, and was independent of any professional society. Paschkis said that no engineer “could claim to be only a cog in the wheel,” and each had a role to play in dealing with the injustices that technology had caused such as the rising inequality between those who could afford new technology and those, like recent immigrants, who could not. The efforts of the ASME through their goals to “Make Technology a True Servant of Man” and Paschkis eventually carried over to the other societies such as the Institute of Electrical and Electronics Engineers (IEEE) and the ASCE. Debates continued with reformers advocating for more responsibility, and corporate interests stressing that unintended negative side effects were the cost of technological change and advance. In 1970, the U.S. Environmental Protection Agency (EPA) was established, which regulated air, solid waste, radiation, drinking water and more. The government was now becoming more involved with controlling business and technology (such as the automobile targeted by the Clean Air Act) that was having disastrous effects on the environment (Holcomb 2000; US EPA 2015).

Further into the 1970s, engineers were trying to understand the definition of ‘service,’ which “is one of the few universal values of engineering” (p. 95). Who were engineers really serving through their employment in the military-industrial complex? Bob Aldridge, a former missile engineer, started learning about developing countries, and concluded that “it was impossible to build ‘bombs for a living’ while ‘campaigning for peace as a hobby.’ He and others realized that with so many engineers furthering the military technology, society was lagging far behind where it could be if those efforts were put directly towards social good and justice. A marginalized group considered this and pushed for engineering schools and some companies to channel their research away from the military and towards others like environmental and biomedical engineering. In March of 1971, the Committee for Social Responsibility in

Engineering (CSRE) was formed by electrical engineers, but was unaffiliated with any member society. The CSRE recognized that the engineer had become an “employee-professional” and needed to be a “responsible professional,” and seeked to challenge how engineering could take on this responsibility to address society’s ills. Many examples of how engineers were acting in public rather than military service around the country were compiled into *Spark* magazine, which furthered the conversation until its end in 1975. Ultimately, engineers did not withdraw in droves from military work, but there were outlets for those conflicted between their personal morals and those which they perceived of their employers.

In 1968, the Volunteers for International Technological Assistance (VITA) organization was formed and gained momentum up to a membership of 5,000. Volunteers from many sectors of engineering were involved in this organization that provided engineering services to those in need from Morocco to Central America with solar water heaters and water filtration. It valued users as partners and was one of the pioneers of the Appropriate Technology (AT) movement. Most of the funding for these projects came from the U.S. federal government, and eventually the work became mostly domestic. The group came to focus more on mobilizing human resources than attempting a technological silver bullet. As the Cold War intensified, however, funding was cut to go to military spending and VITA ended until it was reincarnated to some extent in the engineering service programs of today (Wisnioski 2012).

Engineering education debates of the 1960s seemed to be the same as we are having today. A vocal group saw that engineering students were graduating without an understanding of humanity that would be required to manage technology and take responsibility for the ill-effects that may be caused in the political and social conditions of the future. Staunch defenders of the value of technical knowledge of engineers saw any cut or dilution of this material as an affront to the hard engineering science that would give the skills to produce the technology of tomorrow. As mentioned above, society and technology studies grew in the late 1960s, but the majority of students were humanities and social science majors interested in the subjects. Through these debates, some engineering schools tried to integrate humanities lessons into their engineering curriculum mostly through individual courses. Wisnioski describes four different attempts at UCLA, CalTech, Harvey Mudd College, and MIT. UCLA was able to draw on their social science faculty, CalTech tried to reframe its education as "Science for Mankind," Harvey Mudd College was a different type of school altogether with a fresh start at interdisciplinary education from the beginning, and MIT tried to start a new course of study integrated with engineering that was supported financially, but never obtained enough students to be institutionalized. Faculty struggled to integrate the social with the technical knowledge in their courses, and the students reflected these struggles. Somewhat outside, but related to education, the Order of the Engineer was established in 1970 for students graduating from engineering programs at some universities in the U.S. The oath is similar to that of the Hippocrates Oath of medical graduates, and implores engineering graduates to uphold the standards of the profession and serve humanity ("Order of the Engineer" 2015).

The 1980s-90s and the neoliberal agenda of the U.S. government was a contentious time for engineers and engineering educators. Military spending increased and government regulations relaxed under the assumption that the free market would regulate itself. Unethical companies would not receive as much of the market share since when the consumers found out about their reckless behavior. Unfortunately, history, and Juan Lucena in his 2005 book *Defending the Nation*, tell us this was not the case. Engineering science continued to rule the classroom, and their education was reflected in their unwillingness to speak out against or be aware of the damage done by their companies. The economy ruled all decisions, and the U.S. tried desperately to keep up with the Japanese in terms of global technological and market dominance. Engineering excellence was determined by an "unabashed meritocracy" (J. C. Lucena 2005). The nation desired more engineers for improved capacity to compete on a global level compared with the desired diversity of the 1970s to be able to address domestic social and environmental problems.

In this beginning of the 21st century, among others, two significant movements have evolved in relation to social responsibility in engineering. The first is patriotism and engineering for security in the wake of the September 11th attacks. The government was able to use this event to change the ends towards which engineers should work. Intelligence services, continued engineering for the military and some suspension of individual rights have grown. Defense contracts for engineering research have surged along with ubiquitous technology of cellular phones and the Internet (J. C. Lucena 2005). The second wave has been the explosion of engineering service programs. Engineers Without Borders (EWB), which started in 2002, has grown to over 14,000 members in the U.S. alone and continues to expand (EWB-USA 2013). EWB partners with communities in developing countries to address needs such as drinking water, sanitation, shelter, and energy. Engineering students will work at the university on a solution, then some will travel to implement this solution with the community. While there have been some failures, much good has been achieved for the disadvantaged and marginalized of the world. EWB has also expanded to the professional realm in which individual engineers advise engineering students or take on a project with their colleagues. These efforts have sparked other organizations such as Engineers for a Sustainable World, Bridges to Prosperity, and Engineering World Health. Within the classroom, service-learning has become more popular, and in some cases, institutionalized. Engineering Projects in Community Service (EPICS) actually started at Purdue in 1995 before EWB with local projects that help students learn better and develop a relationship with the community. The EPICS model has expanded to 20 other universities and has a high school program as well (EPICS Purdue 2014). Service learning has grown generally but also in engineering. Through these many opportunities at engineering schools currently, more engineering students than ever before are seeing the power of engineering to make a positive impact. It remains to be seen, however, just in what ways these experiences translate to the engineering profession in shaping its character or public image.

Modern Understanding of Socially Responsible Engineering

Recently, a growing number of books and articles have been published with the themes of socially responsible engineering. A textbook with exactly this title, by Vallero and Vesilind (2006), provides many case study examples of engineering works with unintended consequences and engineers that pioneered socially responsible works or tried to lead the profession against business control (Vallero and Vesilind 2006). They are direct in writing to students and academics who would read the text that, “engineers may be surprised to know it, but we are agents of justice,” and this “justice cannot be formulaic." Engineers are being pushed beyond their traditional roles in this new era that the authors of *Citizen Engineer* call the Century of Engineering (Science was the 20th century) (Douglas, Papadopoulos, and Boutelle 2009). This book provides an awareness and impetus for engineers at any level to be ready to accept more responsibility than before to be a "Citizen Engineer." While current engineers did not single-handedly create global warming, they were and are part of the apparatus that made it possible, and are being looked to by the public to manage the issues of today and the future. They point out that rapid distribution and consumption of today's global society make technological advances scale quickly, and have an enormous impact unlike the world has seen before. They also note that engineers make up 20% of the CEOs at Fortune 500 companies, which have great impact on society through business. There are many opportunities for the engineers of today to be socially responsible, citizen engineers – the new green revolution for design that helps the environment, corporate social responsibility (CSR) efforts, a commitment to curb global climate change, and a dynamic intellectual property field. Engineers are also going beyond their affluent communities as engineering efforts are possibly most impactful in developing countries. Within the U.S., though, communities continue to be marginalized. Ottinger (2013) deeply explored this issue in a community in Louisiana that was in a constant battle with the oil refinery for community improvements and environmental health (Ottinger 2013). While the community members were vocal and had some local government on their side and were trying to use citizen science of bucket air sampling to prove their point, the oil refinery failed to take their efforts seriously and looked to hard science over anecdotal evidence. As a result of neoliberal policies of the 1980s and 1990s, businesses took responsibility of environmental issues rather than the government. As the communities nearby the refineries were not the main shareholders, these free market policies disadvantaged the community. With a change in ownership of the refinery, community-refinery meetings were held regularly to help educate and voice concerns. The residents were happier and felt their voices were heard as they saw the concrete results of these conversations. While this CSR effort is commendable, it is not the norm yet, and engineers must take more responsibility for the communities in which they work from the beginning rather than as a result of months of complaints. Perhaps this kind of education would be valuable for the engineers of the future.

An engineers' social responsibility can be conceived in many different ways. Herkert separated some of these ideas into *macro* and *microethical* understandings (Herkert 2005). The former includes the consideration of the larger effects of engineering works and technology through time and space. The latter is confined to safety of particular groups and adhering to the law. In Ottinger's (2013) example, the engineers were meeting environmental standards, though were not considering the larger consequences of the space where they worked, let alone the effects of an industry which helps to emit carbon dioxide into the air (Ottinger 2013). Without considering responsibility *macroethically,* engineering works can be, at best, neutral, rather than beneficial to all of society. Some have posited that in order for engineering to be considered a profession, let alone a socially responsible one, *pro bono* work must be included and institutionalized as it is in law or medicine (Passino 2009). Further, through the past decade, movements in social justice and engineering have gained traction and legitimacy with a growing number of engineering educators. A recent conference paper asked the question, "what if social justice were a core value for engineers?" (Riley and Lambrinidou 2015). Engineers' priorities in projects would change, and the outcomes could be more valuable to a larger community than most are currently. Engineering education would need to change to fit those priorities as well, and caring would become a larger focus of an engineer's responsibility (Campbell and Wilson 2011). Through the book, *Engineering Education for Social Justice*, numerous engineering faculty laid out how they have incorporated ideas of social justice within their curriculum to integrate these ideas with those traditionally taught in engineering education (J. Lucena 2013). From environmentally sustainable energy solutions to human-centered design, many opportunities are prime for this type of integration, and they can start in the education of engineers.

ENGINEERING EDUCATION FOR SOCIAL RESPONSIBILITY

In 2004, the National Academy of Engineering (NAE) published *The Engineer of 2020*, which outlined many attributes that 'future' engineers would need to keep up with the rapid growth and ubiquity of technology, growing global interconnectedness, and persistent influences of social, cultural, political and economic forces on technology (National Academy of Engineering 2004). These included first and foremost, strong analytic skills. Others, though, included communication, creativity, management, leadership, high ethical standards, and professionalism. These last three are all intimately intertwined as the previous 120 years of engineers' struggle to be socially responsible individually and as a group have shown us. In the following year, the NAE published their recommendations for *Educating the Engineer of 2020*, which has provided guidance to achieving their somewhat lofty characteristics (2020 et al. 2005). Some faculty left it up to the writing and humanities experts to achieve the professional and human traits, while others have made a strong effort to weave technical, social, and professional learning into one environment. The member societies have weighed in with documents outlining their Body of Knowledge (BOK), which any practicing engineer should know after a few years on the job. ASCE wrote the BOK and BOK2, stating that "the manner in which civil engineering is practiced must change" (ASCE 2008); they describe 24 outcomes from math and social sciences to sustainability and professional responsibility. While aspirational, these do give insight to the current values of the ASCE. They also created a "Vision for Civil Engineering in 2025" as a result of a conference of practitioners and academics (ASCE Steering Committee 2007). The ASME has a similar document entitled, *Vision 2030: Creating the Future of Mechanical Engineering Education*. It states early on that "Engineers must take leadership roles not only on technical projects, but in society generally," which will require "substantial change in the educational process" (Wepfer and Warrington 2010). The American Association of Environmental Engineers (AAEE) also came up with their own Body of Knowledge with 18 outcomes similar to those of the ASCE. As environmental engineering is newer than the other disciplines, which evolved into its own discipline in the 1980s and 1990s. Its BOK includes the ability to conduct experiments, consider sustainability and societal impacts, and leadership among others (The Environmental Engineering Body of Knowledge Task Force 2009). Environmental engineers are also thinking into the future and how future engineers will need to positively engage with and impact society.

Some engineering faculty have been improving student learning while developing student attitudes and feelings about their responsibility and potential to have a positive impact on the lives of others (Vanasupa et al. 2007). Some have simply made engineering courses more socially contextualized by using a Global Challenges framework or teaching the macroethics of engineering practice (Vanasupa, Chen, and Slivovsky 2006; Herkert 2005). Others have incorporated Learning Through Service (LTS), which includes service learning (S-L) and co-curricular activities such as Engineers Without Borders (EWB), Bridges to Prosperity (B2P), and Engineering World Health (EWH). Multiple studies have shown the benefits of these types of learning experiences, which have been studied in core engineering courses, first-year engineering courses, design courses, and throughout the curriculum (J. Duffy et al. 2008; Zarske 2012; Vernaza 2013; Freeman et al. 2011; Titus, Zoltowski, and Oakes 2011; A. R. Bielefeldt, Paterson, and Swan 2010; Stein and Lynch 2012; J. J. Duffy, Barrington, and Heredia Munoz 2011; Lathem, Neumann, and Hayden 2011). Bielefeldt et al. (2009) showed that students who were involved with project-based service learning (PBSL) early in college were retained at higher levels, women chose to participate more often than men, learned more of the ABET requirements, and were more prepared for professional practice in engineering design (A. Bielefeldt, Paterson, and Swan 2009). Litchfield's 2015 research showed that students involved with EWB were more motivated by helping others than non-EWB members, and some of the students entered engineering due to their interest in EWB. Some learning outcomes were also qualitatively studied, and EWB members had overall increased technical and professional skills (Litchfield and Javernick-Will 2014). While these are important attempts to increase social responsibility in engineering education, they are not yet the norm or valued by most engineering faculty (Strobel et al. 2013). The lack of empathy, political and social relevance in the culture of engineering is still perpetuated in most engineering education and emotion has been stripped out of the engineer's toolkit (Cech 2014; Baillie and Levine 2013; Roeser 2012).

Social Responsibility and Women in Engineering

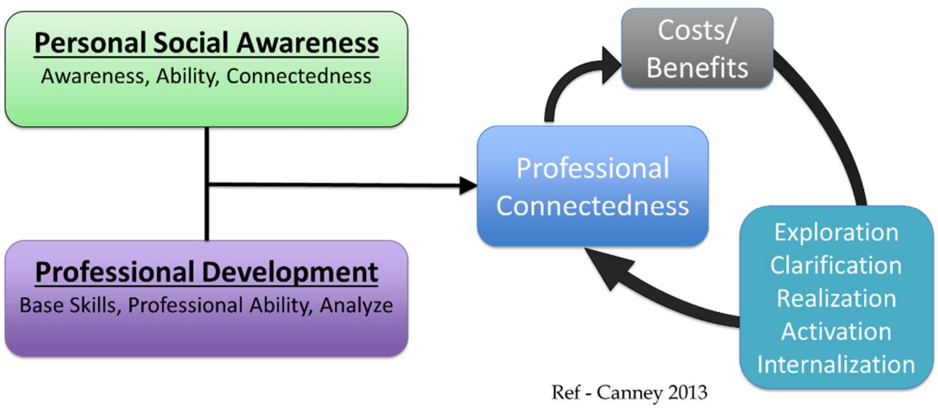
Related to the discussions of engineering and social responsibility are discussions about the recruitment, retention, and persistence of women in engineering. Capobianco and Yu (2014) studied elementary school girls' ideas about what an engineer is and how the ethic of care in engineering could encourage girls to consider that for their future careers (Capobianco and Yu 2014). They mostly saw an engineer as a technician, a builder, and a man. This misconception is an opportunity to show engineering as a more prosocial career path, possibly on par with medicine. Generally, women have shown more prosocial motivation in choosing a career (Grant and Berg 2011). Women in engineering do not seem to be an exception according to surveys of women in engineering majors and within the profession (Sheppard et al. 2010; Pierrakos et al. 2009; Hewlett et al. 2008). Women in EWB-USA were shown to have the highest "helping others" motivation for pursuing engineering, and women had higher social responsibility scores than men (Litchfield, Javernick-Will, and Paterson 2014; N. E. Canney 2013). As mentioned above, PBSL in engineering attracts women more than men, as does humanitarian-focused co-curricular groups (A. Bielefeldt, Paterson, and Swan 2009; Tsui 2010). At the same time, it has been found that women tend to deny parts of their personalities to fit into the dominant engineering culture, or have found role models and mentors for support in pursuing engineering as a career (Ong 2005; Tonso 2006; Lichtenstein et al. 2014; Ureksoy 2011). The combination of these two areas of research leads us to question if engineering were seen as more socially responsible and acted more responsibly, would the culture align better with women's values? Litchfield (2015) found "a trend of EWB-USA female members' disillusionment with engineering careers" and their values did not match those they experienced in the workplace. Thus, if engineering education were to change its culture to be more caring and socially responsible, the profession would need to follow suit or the loss of women engineers after graduation will continue (Bureau of Labor Statistics 2014).

Research into Social Responsibility of Engineering Students

Finally, previous research about engineering students' social responsibility has been performed. Cech (2014) found that all students decreased in their concern for society over their four years in college then again in their first 18 months of employment due to a "culture of disengagement" in engineering (Cech 2014). Women were not different from men in terms of public welfare beliefs, and the institutional environment did not matter. Other results have been published about student responses and a framework that explains their professional social responsibility development. This study used the following definition of social responsibility: "an obligation that an individual (or company) has to act with care and objectivity, aware of the impacts of their action on others, able to see issues from the perspectives of others, and with particular attention to disadvantaged populations." Female engineering students had higher levels of social responsibility on average than male students (contrary to Cech's findings), but over one year, social responsibility was found to decrease more on average for women than men – 23.6% of first-year women decreased, while only 9.1% increased; 15.1% of men decreased while 19.8% increased (A. Bielefeldt and Canney under review). Further, service learning courses improved social responsibility levels, students in environmental engineering averaged higher scores than civil engineering majors, who were higher than mechanical engineering majors (A. R. Bielefeldt and Canney 2014). High activity in a students' chosen religion seemed to transfer to significantly higher levels of social responsibility than those with low or no religious activity (N. Canney and Bielefeldt 2013). Finally, engineering students' perceived importance of the social impacts of engineering (such as "professional/ethical responsibilities" and the "consequences of technology") were found to decrease from the first to fourth years indicating a "culture of disengagement" in engineering education (Cech 2014). Canney developed the Professional Social Responsibility Development Model (PSRDM) to describe how students were coming to different levels of SR depending on their involvement. With a basis in the Ethic of Care, Canney integrated three theoretical models to inform the details of the PSRDM. First, Scwhartz's (1977) altruistic helping behavior model tracks the personal development of a person in taking action to help others (Schwartz

1977). Ramsey's (1993) model for integrating social responsibility into the decision process of scientists was translated to the engineering process that describes the professional social responsibility development component (Ramsey 1993). Finally, Delve et al.'s (1990) Service Learning Model was used, which proposes five phases of development for those involved with community service (Delve, Mintz, and Stewart 1990; N. E. Canney 2013). Together, they form the Realms and Dimensions of the PSRDM which combine to make the full model. See Canney (2014) for more details beyond the figure below (N. Canney and Bielefeldt 2014).

Figure 1: Canney's Professional Social Responsibility Development Model (2014)



This rich and contentious history with social responsibility in engineering leads to the current study of students who started in engineering, and what are their thoughts about social responsibility as an entity, a career path, and a motivation.

CHAPTER III: METHODS

This study is part of the final three years of work supported by the National Science Foundation under Grant No. 1158863. The first two years were mostly exploratory, survey development, and interviews with alumni of learning through service (LTS) programs. For details about the survey (EPRA) development and validity, see Canney 2013 (N. E. Canney 2013). This largely quantitative work included first year students, seniors, and graduate students majoring in civil, environmental, or mechanical engineering at 5 institutions. The results of EPRA were used as criteria to select individual students initially and their written responses within the survey were used as supplementary data about the interviewed students. Additional quantitative work has since been extended to 17 institutions and all undergraduate engineering ranks and years, as well as a survey of practicing engineers.

The research that is the focus of this dissertation aims at gaining a "how" and "why" understanding of social responsibility development in engineering students. Therefore, qualitative methods seemed the most appropriate to execute the majority of this research. The research also drew on some quantitative data in order to have a fuller picture of the students' beliefs, and have data for triangulation as a validity check.

Qualitative research has gained trustworthiness (Lincoln and Guba 1985) in engineering education due to the growing number of studies with mixed quantitative and qualitative methods (Borrego, Douglas, and Amelink 2009; Strobel et al. 2013; N. E. Canney 2013; Winters, Matusovich, and Carrico 2012), or solely qualitative methods (Matusovich, Streveler, and Miller 2010; Walther et al. 2011). Studies have also been performed about how to most effectively use qualitative research in engineering education, and how to ensure the quality of the work (Walther, Sochacka, and Kellam 2013; Case and Light 2011). With this growing body of literature to support this type of work, we chose yearly, hour-long interviews for the main method by which we could gather information from 30 students (we ended up with 34 in the first year in case some students dropped out). Other qualitative methods such as focus groups or observation could have yielded some interesting results on students' surface-level thoughts about social responsibility (SR) or how they acted on their own SR interests. We came to interviews both pragmatically and with the belief that deeper ideas could emerge with a one-on-one conversation.

Maxwell (2012) provides a research design map to organize how the study would unfold. The goals, methods, conceptual framework, and validity all fit into the research questions to be asked, and hopefully answered to some extent, through this study (Maxwell 2012). Not only do my own goals come into this research, but my advisor, the original researcher and grant writer, and the undergraduate student who helped with significant components. My advisor has been an engineering educator striving to teach her students to be socially responsible through civil and environmental engineering. This research can provide more direction for how to better engage students with society. The original researcher wanted to understand how service impacted engineering students' desire to help others personally or professionally. He hoped that the study would help the profession recognize how engineering service "can help foster a more well-rounded engineer that approaches problems with humility and care." The undergraduate architectural engineering student who worked on this project was part of the interview pool and became very interested in the research after being asked questions that made her think more critically about social responsibility. She wanted to learn more and continue to be involved.

Figure 2: Design Map of Research (from Maxwell 2012)

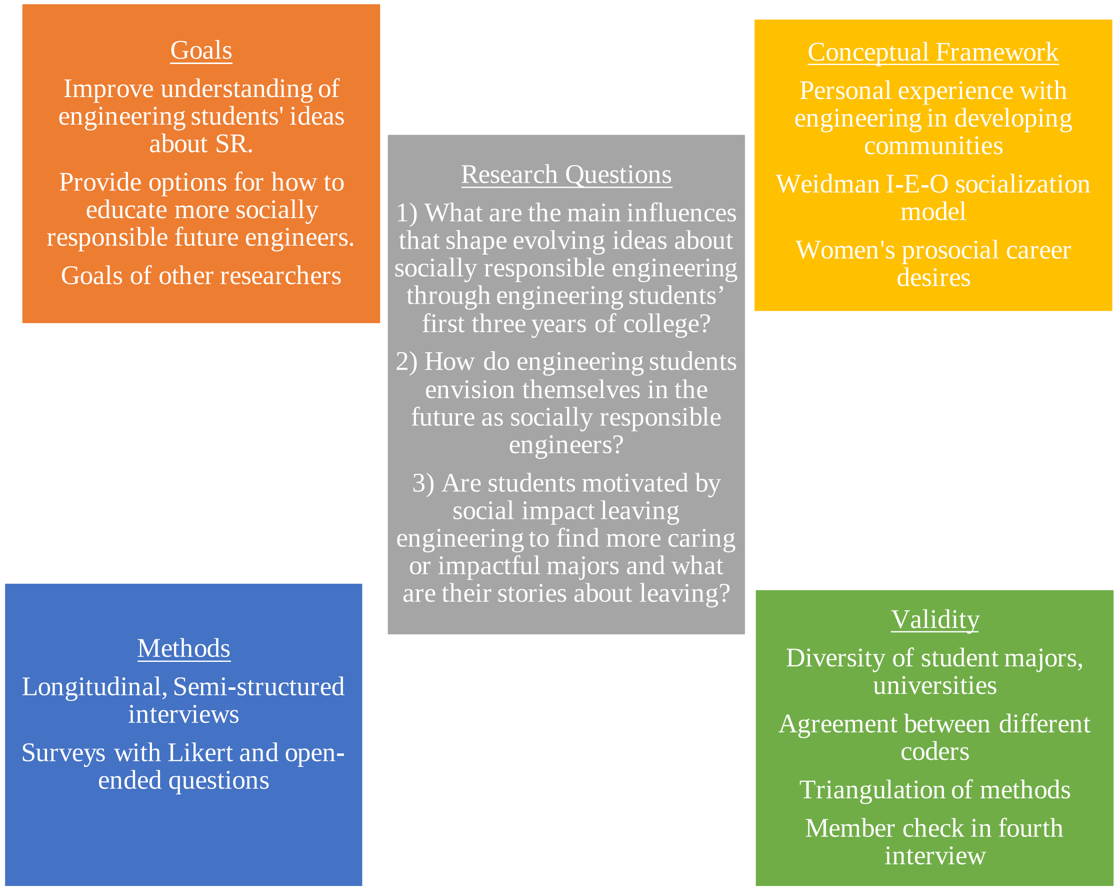
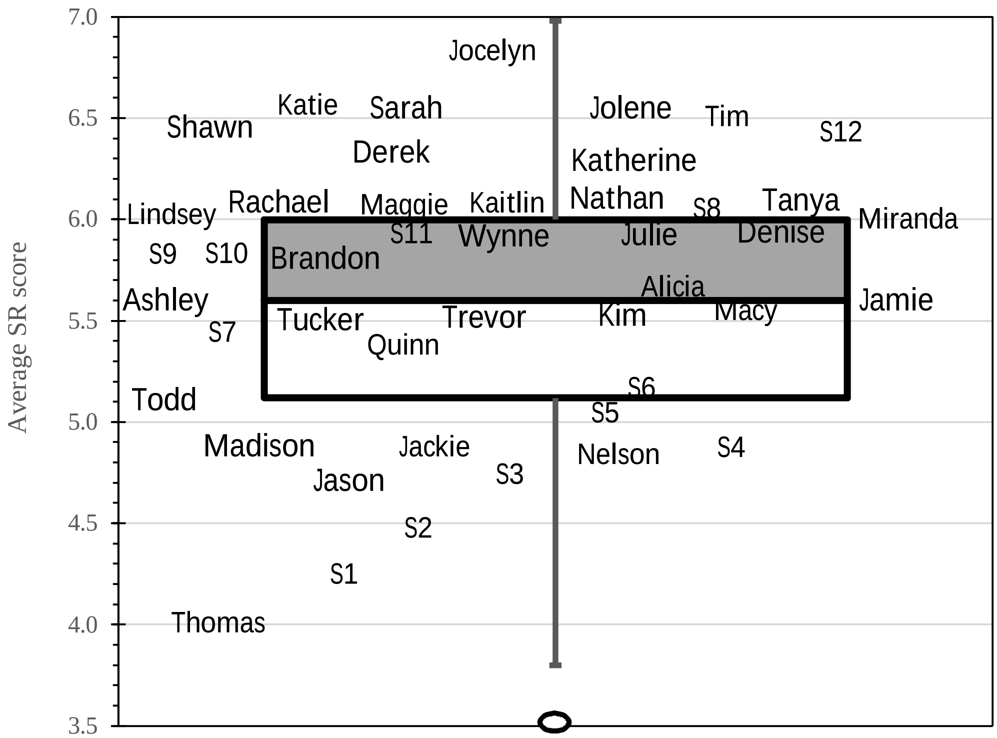


Figure 3 below shows the 34 students who started in engineering that responded to the interview request in February 2013 with their associated pseudonyms. It also shows the students contacted who did not respond labeled with 'S1, S2, S3….'

Figure 3: Y0 Average SR Scores for First Year Students Contacted to be Interviewed



Notice that more students in the higher range of SR scores responded to the interview request and were thusly interviewed. This skew may be due to the subject matter of social responsibility that they were not particularly interested in discussing.

These students attended one of five universities as shown in the table below. Only 75 of these students, however, checked the box at the end of the survey which asked them if they would be willing to be contacted about an interview regarding similar issues as the survey. No compensation for participating in an interview was mentioned, and we do not know why the other 169 students did not give consent to be contact about an interview. Students from the Military Institution were not permitted to be interviewed.

Table 1: Universities Represented in Year 1 Interviews

Institution	Enrollment Size	Region	Carnegie Basic & UG classifications	Public/Private
LPU	> 15K	West	RU/VH, A&S+Prof/HGC	Public
TechU	5K – 15K	Midwest	RU/H; Prof-F/HGC	Public
MPU	5K – 15K	Northeast	RU/H; A&S+Prof/HGC	Public
PrU	5K – 15K	Northeast	RU/VH; A&S+Prof/HGC	Private

By the end of the third year's interviews, four more universities were represented as students transferred to different universities for various reasons. These are shown in Table 2 below.

Table 2: Additional Universities to which Students Transferred

Institution	Size	Region	Carnegie Basic & UG classifications	Public/Private
LPU2	> 15K	Northeast	RU/VH, A&S+Prof/HGC	Public
LPU3	> 15K	Northeast	RU/VH; Prof+A&S/HGC	Public
LPU3	> 15K	Southeast	RU/VH; Bal/HGC	Public
MPU2	5K – 15K	Midwest	Master's L; Bal/SGC	Public

Dr. Canney and Dr. Bielefeldt did an initial analysis of all the survey results and put the students into one of five quintiles based on their overall EPRA score, as calculated by adding the average scores (ranging from 1 to 7) in each of 8 dimensions. Later, the 'Average SR' score, the average score across the

50 Likert items (resulting in possible scores from 1 to 7), was found to be a better representation of overall SR attitudes and was used in future analysis and publications. Dr. Bielefeldt and I made every attempt to have the widest diversity in the sample to gather the largest range of experiences. Twelve students, mainly in the lower two quintiles, did not respond to my interview request email. Thus, substitutes were contacted, who had higher scores overall than those originally desired for the interview pool diversity. Further, it was difficult to find many environmental and civil engineering students at the lower quintiles. Since the main criteria of this small sample were to have a range of SR scores and an oversampling of women, other demographics such as race, ethnicity, age, and socioeconomic status were not considered explicitly during participant selection in order to broaden the diversity. The participants who did and did not agree to participate are given below with pseudonyms and their demographics provided in their initial Fall 2012 survey; students invited who did not participate are simply labeled "Student 1," etc.

Table 3: Interviewee Demographics from Initial Fall 2012 Survey

Total SR Score	Pseudonym	Gender	Major (Pre-/Interview)	Institution
35 – 39.5 (< -1.5σ)	Student 1	M	ME	TechU
	Thomas	M	ME	LPU
	Travis	M	EnvE	MPU
	Student 2	F	ME	TechU
	Student 3	M	ME	TechU
39.8 – 44.1 (-1.5σ to -0.5σ)	Student 4	M	ME	TechU
	Quinn	M	CE/CompE	LPU
	Jason	M	ME	TechU
	Nelson	M	EnvE	MPUU
	Jackie	F	ME	LPU
	Todd	M	ME	TechU
	Madison	F	ME	TechU
	Student 5	M	CE	MPU
44.1 – 48.5 (-0.5σ to .5σ)	Student 6	F	Other	PrU
	Student 7	F	EnvE	TechU
	Kim	F	EnvE	LPU
	Trevor	M	EnvE/CE	MPU
	Tucker	M	CE	LPU
	Alicia	F	ME	LPU
	Macy	F	Other/ChE	PrU
	Ashley	F	Other/ChE	PrU
	Student 8	F	CE	TechU
	Jamie	F	ME	TechU
	Denise	F	Other/ME	PrU

	Student 9	F	EnvE	TechU
	Student 10	F	EnvE	MPU
	Wynne	F	CE	LPU
	Miranda	F	Other/ChE	PrU
	Kaitlin**	F	EnvE	MPU
48.7 – 52.1 (.5σ to 1.5σ)	Brandon	M	EnvE	TechU
	Lindsey	F	Other/Biomedical	PrU
	Student 11	M	CE	TechU
	Julie	F	Other/ME	PrU
	Nathan	M	CE	TechU
	Maggie	F	CE	MPU
	Sarah	F	CE	TechU
	Tanya	F	EnvE	TechU
	Derek	M	Other/ME	PrU
	Katherine	F	EnvE	MPU
	Rachael	F	Other/CompSci	PrU
	Tim	M	ME	LPU
	Student 12	F	ME	TechU
	Shawn	M	EnvE	LPU
52.2 – 54.2 (> 1.5σ)	Jolene	F	CE	TechU
	Katie	F	CE	LPU
	Jocelyn	F	ME	LPU
Total		Men: 13 Women: 21	ME:12 CE: 8 EnvE: 9 Other: 5	LPU:11 MPU:6 TechU:9 PrU:8

Further information about how these students progressed through different majors and universities can be found in the Appendix B. Although the students started in three majors plus “other” engineering attending four universities, they ended up in 15 majors at eight different universities. Two more students were no longer attending college during the third interview. This further diversity made it difficult to compare across any groups, but did shed light on a wider array of student experiences. Most students responded to all three interview requests. One student was only interviewed the first year, one student missed the second year interview, and two students missed only the third interview.

EPRA Survey Participation

During the same timeframes that the interview were conducted, students were also invited to take the EPRA survey, with a $10 incentive to complete the 50 question online survey. Some students did not complete all four distributions of the EPRA survey despite multiple reminders. The open-ended questions on the EPRA survey varied somewhat across the distributions. In year 3, the engineering professional social responsibility questions were reworded to be relevant to the students who were no longer engineering majors, and asked them to consider social responsibility in the context of their current majors and envisioned careers.

INTERVIEW QUESTIONS

We developed different questions each year depending on what information seemed to be most interesting to gather with the intention of a semi-structured format. In the first year, the students had no familiarity with me, and were assumed to not be very forthcoming about some of their deeper ideas about engineering, helping others, and social responsibility. Therefore, questions became more pressing as the interview progressed. The interview questions can be seen below. Notice that they start with a very general question that would be easy to answer and yet, allow the students to give more details about which I could ask to gain a deeper understanding of their experiences. The interview questions progressed from engineering to helping others to a combination of the two and what they see for their futures. The interviews were meant to be semi-structured so that I could follow up on an interesting comment that may have given more insight. For example, when if a student responded to the question, “What do you like about engineering?” with a response about their introductory course, I could ask about which parts of this course most interested them to see if it related to a desire for more socially contextualized engineering courses. These questions were reviewed by another researcher on the same grant and tested on a practicing engineer as well as an undergraduate student who was not part of the interview pool.

Table 4: First Year Interview Questions

1. What are your major and year in school?
a. How is engineering going?
b. What were some positive experiences?
c. What were some difficult or frustrating experiences?
2. What interests you the most about engineering? What led you to choose engineering as a major?
3. What is your current vision for an ideal engineering career?
4. Describe experiences in your life prior to college or during college that influenced your view of the engineering profession.
5. Describe experiences in your life prior to college or during college that influenced your view of social responsibility.
6. In what ways do you feel you help others?
a. At any scale: globally, locally, within your family/friends

	b. How and why are you involved? What are the benefits you see for them and yourself?
7.	What are some important social issues to you?
	a. What were some of your influences that made these important issues to you?
	b. How do you see yourself involved in these?
	c. Do you see engineering playing a role in addressing these issues?
8.	Does your sense of social responsibility move you towards or away from an engineering career?
9.	Is there one issue that you feel particularly passionate about trying to address? Why?
	a. Can your engineering abilities help with this goal?
	b. Can other majors in engineering better help you to reach this goal?
10.	How confident are you that you will get an engineering degree and practice engineering after graduation? What are your main concerns?
11.	Is there anything else you would like to share, or questions you have?

At the very beginning of three interviews, the student disclosed that they were no longer interested in pursuing an engineering major. We did not prepare questions for this situation in the first year, so I came up with questions on the fly. I encouraged the student to think and talk about their last year in engineering and proceeded with the original questions leaving enough time at the end of the interview to discuss their reasons for leaving engineering and asked about their new planned major.

In the second year, an ongoing component of the larger grant influenced our questions. I was interviewing engineers who make hiring decisions about the value they see in learning through service activities in which potential employees participated. I also interviewed engineers involved with engineering service activities at the professional level to try to understand how they managed value and compensation for their work within the structure of their engineering companies. The final component was a review of the engineering service and corporate social responsibility advertising certain companies used on their websites to investigate what messaging students would see in their searches for internships or jobs. I wanted to compare what these two groups were saying with the perceptions of the engineering students with regard to what is valued by engineering companies and what the students valued in a company for which they would be happy working. Thus, while some of the questions from the first year carried over to the second year, new questions were also added to capture some of the students' professional perceptions. These questions were tested on the same practicing engineer from the first year for content and length.

Table 5: Second Year Interview Questions for Engineering Students

1. Are you still a _______ major? (*If not*: why did you switch? [*Move to SWITCHER set of questions*]) How is the second year going? What are some big events that occurred in the last year? What are some things you have enjoyed? Found difficult or frustrating?
2. Why do you like engineering? What is motivating you through the tough classes? a. What are your particular interests within _______ engineering?
3. What is your ideal career now? Why?
4. What are some specific qualities of a job <u>and</u> company that you are looking for? Why are these qualities important? a. Do you already know of companies where you'd like to work? If so, which ones? b. Which quality is the most essential? Why?
5. What do you think engineering employers are looking for in an interview?
6. How do you think about social responsibility? How would you define it? a. Describe experiences in this past year that have influenced this understanding of social responsibility. b. *If very different from previous definition*: what do you think influenced these changes?
7. How do you expect social responsibility will be part of your future engineering career? How strongly? In what ways?
8. Does your sense of social responsibility move you towards, away, or neither from an engineering career? In what ways? Has this changed significantly since last year?
9. Is there anything else you would like to share, or do you have any questions?
Used these questions if interviewee did not offer many thoughts about social responsibility initially:
10. Volunteering a. *If there were significant ways that they described helping others in the previous interview:* Are you still involved in [reference previous interview]? i. YES: Describe some of your experiences with that in the past year. ii. NO: Why not? Are there other activities you are involved with instead? b. What are some new ways you have been involved with volunteering in the past year? *i. If none or few or difficult question to answer*: what are some reasons you did not volunteer (much) in the last year?
11. Important Social issues a. What social issues matter to you? Why? i. Are you currently working to address these in any ways? *b.* In our last interview, you mentioned [reference previous interview] as an important issue. Have you become/stayed involved with addressing this issue? c. Do you see engineering playing a role in addressing these issues? d. How do you think your engineering abilities could help with this goal? *e.* Do you think other majors in or outside of engineering could better help you to reach this goal? Why?

Questions were also developed for the students who left engineering in the first year and who we anticipated would have left in the second year. Many questions were the same between the two sets with 'engineering' replaced by 'your major.' I also asked questions about the differences between the majors and if the student felt better able to address social responsibility with their new major.

Table 6: Second Year Interview Questions for Non-Engineering Students (Leavers)

1. Are you still a _______ major? And how is the second year going? What are some things you have enjoyed? Found difficult or frustrating?
2. Why did you change majors?
3. What are the main differences you have found between your major and engineering? a. People, ideas, classes, professors, topics, extracurriculars
4. What are some of your particular interests within [new major]? Something exciting on the horizon?
5. What is your ideal career now? Why?
6. What are some specific qualities of a job and company that you are looking for? Why are these qualities important? a. Which of these qualities are most important, the deal-makers and breakers? Why? b. Do you already know of companies where you'd like to work? If so, which ones and why?
7. What do you think employers are looking for in an interview? a. Do you think this is different from what an engineering employer is looking for?
8. How do you think about social responsibility? How would you define it? a. Describe experiences in this past year that have influenced this understanding of social responsibility. b. *If very different from previous definition*: what do you think influenced these changes?
9. Do you expect social responsibility will be part of your future career? How strongly? In what ways?
10. Are you better able to address your social responsibility related goals with your current major than with engineering? In what ways specifically?
11. Does your sense of social responsibility move you towards, away, or neither from a career in your field? In what ways? Has this changed significantly since last year?
12. Is there anything else you would like to share, or do you have any questions?
Use these questions if interviewee does not offer many thoughts about social responsibility initially:
13. Volunteering a. *If there were significant ways that they described helping others in the previous interview*: Are you still involved in [reference previous interview]? i. *YES*: Describe some of your experiences with that in the past year. ii. *NO*: Why not? Are there other activities you are involved with instead? b. What are some new ways you have been involved with volunteering in the past year? *i. If none or few or difficult question to answer*: what are some reasons you did not volunteer (much) in the last year?
14. Important Social issues a. What social issues matter to you? Why? i. Are you currently working to address these in any ways? b. In our last interview, you mentioned [reference previous interview] as an important issue. Have you become/stayed involved with addressing this issue? c. What were some of your influences that made these important issues to you? d. Do you see [their major] playing a role in addressing these issues? e. Do you think other majors could better help you to reach this goal? Why? *i.* What about engineering?

In the third year, some questions carried over, but many were new. We decided it would be interesting to have the students consider characteristics that the American Society of Civil Engineers wants all of its graduates to graduate with through its Body of Knowledge in addition to qualities valued in the Ethic of Care (ASCE 2008; Moriarty 1995). Further, we wanted to be more direct about answering our research questions and understand how the students were connecting social responsibility with engineering practice. We also wanted to know how the students were prioritizing what they felt engineers did in their work and for what they were responsible generally. Since this was the last year of interviews as part of this dissertation, we wanted to explicitly ask how the students felt their ideas around social responsibility had changed throughout college. If the students could remember what they said in previous years, this acted as an informal member check. The final component regarded *pro bono* work in engineering as some have suggested that it must be incorporated in order to call a practice a profession (Passino 2009). These questions were then reviewed by a faculty member in the school of education and two other engineering professors. Finally, the questions were tested on the same practicing engineer as the first and second year as well as an undergraduate student who was not part of the study for content and length.

Table 7: Third Year Interview Questions for Engineering Students

1. Are you still a _______ engineering major? (*If not*: why did you switch? [*Move to LEAVER set of questions if major is now outside of engineering*])
2. Tell me about the last year, some highlights and events or activities that were especially important to you.
3. Read the eighteen characteristics I emailed you (see below). *Do not read aloud to interviewee*.
    a. Select the five characteristics that you think are most representative of engineers.
    b. Are there additional characteristics that you typically associate with engineers?
    c. Select the five characteristics that you think are most representative of you.
    d. Are there additional characteristics that you typically associate with yourself?

care	fairness	positivity
commitment	flexible	respect
confidence	high expectations	sensitivity
consideration of others	integrity	thoughtfulness
curiosity	judgment	thoroughness
empathy	persistence	tolerance

These are characteristics that the American Society of Civil Engineers wants students to have as they become new engineers. It's pretty similar to what _________ engineering wants too.

4. What are the responsibilities of an engineer? Why do you think so?
    a. Who are engineers responsible for?
5. What is the engineer's role in impacting people in society? **reword (how does, *could*, or *should* an engineer impact society?)

6. What are some ways that you think about social responsibility? a. Has your understanding changed much in the last year? Why do you think that is? b. How has it changed during college? Why do you think that is? c. How could any person act on this understanding of SR? [*non-engineering*]
7. How do you think your ideas around personal social responsibility influence your ideas about professional responsibility and vice versa? d. *If different from responsibilities of an engineer, ask how they deal with the difference.*
8. How does engineering play a role in social issues?
9. Think aloud through the drawbacks and benefits of incorporating social responsibility into your engineering career. e. How about pro bono work?
10. As a practicing engineer in the future, how do you expect to incorporate your personal sense of social responsibility with your professional practice, if at all?
11. Is there anything else you would like to share, or do you have any questions?

Questions were again explicitly developed for the leavers in the third year. With the intention of gathering the leavers' narratives, these interviews started with a request to tell their story about leaving engineering for their new major. Next, the questions were similar to those for engineers. The final section was a direct question soliciting recommendations for how to improve engineering education such that they would consider staying in engineering. Not all of the sub-questions in question 8 were asked of every student.

Table 8: Third Year Interview Questions for Non-Engineering Students (Leavers)

1. Tell me about your experience from freshman year until now in your new major. Tell me any significant events or activities that affected this experience. - I'm interested in how you decided on engineering, came to the decision that engineering was not the best fit for you, and then chose your new major.
2. What do you think was the most significant motivations for you to switch from engineering to your new major? [*try to find out how significant difficult courses were, chilly climate, outside environ*]
3. Read the eighteen characteristics I emailed you (see below). - Select the five characteristics that you think are most representative of you. - Are there additional characteristics that you also typically associate with yourself? - Select the five characteristics that you think are most representative of [*student's major]*. - Are there additional characteristics that you also typically associate with [*student's major]*? - Select the five characteristics that you think are most representative of engineers. - Are there additional characteristics that you also typically associate with engineers?

care	fairness	persistence
commitment	respect	positivity
confidence	flexible	sensitivity
consideration of others	high expectations	thoughtfulness
curiosity	integrity	thoroughness
empathy	judgment	tolerance

4. What are some ways that you think about social responsibility? - Has your understanding changed much in the last year? Why do you think that is? How has it changed during college? - How could any person act on this understanding of SR?
5. How do you think social responsibility is demonstrated in engineering, if at all?
6. In what ways does your major allow you to impact society? - How important is that to you?
7. Does your future career choice allow you to better address your commitment to social responsibility than engineering? In what ways?
8. Do you think you would have considered stayed in engineering if… - Socially responsible engineering had been more prominent in your classes? - Discussion of ethical issues had been more prominent in your classes? - your sophomore year's classes were more socially relevant? - you had been more exposed to applications of engineering? - you had more opportunities to take other classes on campus? - some connection was made to other classes on campus? - you could have connected engineering with your own personal experiences? - “ “ social issues you care about? - “ “ helping others?
9. How do you think your engineering education could be more socially engaged/relevant?
10. Is there anything else you would like to share, or do you have any questions?

The questions above in each year went through multiple iterations in an effort to have a set that would elicit the best information without making the students uncomfortable with questions that were too personal. It was a delicate balance, but we believe these three sets of questions were the best for gathering the ideas we desired with the time allotted.

INTERVIEWS

Building from the scheduling of the interviews and the question development each year, I personally performed all of the interviews. In the first year, we did not know if in-person or phone interviews would be more effective to elicit the best responses from the students. Thus, at LPU, six of the interviews were conducted in person, three by phone, and two through Skype. As the phone interviews were perceived as being equally or more candid than the in-person interviews, all future interviews were conducted by phone. I intentionally did little preparation for the interviews; in particular, I did not look at the students' SR scores after the original attempt at score diversity. I did not want to have any opinions about how the students would respond to questions before I asked them.

All interviews proceeded closely to the order of the questions except when a student unexpectedly left engineering in the first year. As the interviews were semi-structured, I was able to follow up on interesting threads that eventually provided deeper information about their beliefs around engineering, helping others, and social responsibility (Saldaña 2012; M. A. Eisenhart et al. 1998).

Most of the first round interviews took place through April 2013. Some were in May after the school year ended, and one was not until August when the student responded to the interview request. Also, one student had to be re-interviewed in June because her recorded interview was deleted before it was transcribed. In this first round of interviews, we realized some of the potential effects that the interview itself could have on the students. Four mentioned at the end that they had not really thought deliberately about social responsibility, or been asked to talk about it, before (Macy, Nathan, Sarah, Shawn); three more mentioned this in the second year (Brandon, Tucker, Alicia). It is unclear how much of an effect these interviews had on the students and their conceptualizations, but through the students' responses, it seems to be rather marginal when compared to their classes, co-curriculars, and internships. Further, I am male, and most of the students were female. Possibly, they did not share some experiences which they felt I would not be able to understand or empathize. The students did not know anything about me personally except that I was interested in social responsibility as evidenced by the survey and the consent form. If students did ask, I answered honestly and briefly.

The second round of interviews in Spring 2014 representing the sophomore year began in late February with emails to the students asking when they would be available for another interview. Multiple students did not respond for weeks, and two did not respond at all. Later, we discovered that one switched universities, and since the first interview was in person, we did not have a phone number for this student. The other was interviewed in the third year, and it seems he just never responded to the multiple solicitations in the second year. The interviews started in the middle of March 2014 and ended in the middle of April. One interview (Todd) was performed through Skype as the student was studying abroad in China.

With a similar schedule to the second year, the third year of interviews to represent students' junior year started in February 2015 with email solicitations to all the students who had participated previously. Two additional students did not respond in the third year, one student who continued to not respond, and one student who came back into the study after not responding in the second year. By this third interview, the students were more comfortable with the questions, and me as an interviewer, so I could ask deeper questions sooner without as much concern about making the student uncomfortable with sharing personal experiences. On the whole, these interviews went very smoothly, and in many cases, long (minimum of 56 minutes, and a maximum of 112 minutes). They began in March 2015 and finished at the end of April. One interview was executed through Skype as the student was studying abroad in Chile.

ANALYSIS

Initial steps each year were the same. The audio of all interviews was recorded. After the first interview, each interviewee was assigned a pseudonym using standard conventions (Ogden 2008). Interviews were transcribed verbatim into Microsoft Word using Dragon voice recognition software (*Microsoft Word* 2013; *Nuance Dragon Speak* 2013). Then, each interview transcript was carefully read through and edited while listening to the interview to produce a more accurate record. Over the three years, part of this task was performed by undergraduate research assistants (a second year in architectural engineering and a third year in civil engineering). This accurate transcript was then imported into Nvivo 10 for continued qualitative analysis (QSR International 2013).

As the first round of interviews was exploratory, inductive coding methods (Miles, Huberman, and Saldaña 2013) were used. Three researchers (myself, faculty advisor, sophomore architectural engineering undergraduate research assistant) co-developed a code book based on a sub-set of 13 diverse interviews (four per person plus one in common). Originally, four large theme groups emerged from the interviews: definitions of SR, influences on SR, connections of engineering and SR, and the importance of SR in motivating students to pursue engineering. These were the only common information that all raters were using to find their codes. After creating individual code books by reading their five interviews, all three raters discussed which were important to explicitly include, which could be ignored, and which should be combined. With a full code book established through this discussion, we all coded three interviews out of the original 13 using this code book. Then we discussed which codes we found and any mismatches until we were satisfied. In some cases, we could not come to an agreement if a code was appropriate based on the context of the interview. An inter-rater reliability (IRR) (Krippendorff 1970) of 91% was reached. With this final code book (Appendix C), the undergraduate research assistant and I divided the 34 interviews equally and coded all of the interviews. Since many codes resulted from the initial reading, some were combined into one code that encapsulated multiple, more unique codes. For example, while students have different ways of interacting with and being influenced by a mother, father, sibling, or other relative that is an engineer, we did not find enough value in keeping them separate, and combined into 'Engineers in the Family.' The first year results were presented in 2014 at the ASEE Annual Conference (G. A. Rulifson, Bielefeldt, and Thomas 2014).

The second year's coding built upon the first year's code book, though new codes emerged as a result of the different questions that revolved more around professional ideas. In the first pass, we focused on coding how the students defined SR and what were the main influences that caused the changes between the first and second years. My advisor and I compared codes found in four different interviews, then one in common. We came to agreement on an updated code book, which was used for the rest of the interview coding that I did on my own. Much of this was combined with the third year interviews as I was looking for changes over the three years.

In the third year, I used the updated code book and added more codes that aligned with the questions about the responsibilities of engineering, explicitly how the student integrated personal and professional SR, and their thoughts about *pro bono.* A final step in the analysis of the engineering students was translating the codes created through the three years into the Weidman I-E-O vocabulary such that it could be integrated with the goals of the Chapter 4 – to show the students' changing influences on their ideas about socially responsible engineering over time. The Weidman I-E-O model provided categories for the influences. See Chapter 4 for more details about the Weidman model.

In all three years, the students who left engineering responded to different questions about their reasons for leaving engineering, their experiences in their new major, and how their ideas on SR impacted their decisions and satisfaction. We decided that, to more deeply capture the ways these students were talking about their decisions, that narrative analysis would be an appropriate methodology. Three students' narratives were chosen of the nine leavers to showcase students who left engineering in three different years and had reasons related to SR. I followed the method outlined by Riessman (1993), in which I identified stanzas of speech separated by natural pauses in their narratives through a closer listening to a portion of their full interview.

Limitations and Validity

First, I have my own bias that we made every effort to mitigate. As mentioned in the introduction, my reasons for taking on this research were personal as well as professional. My own experiences doing structural engineering development work (home reconstruction, disaster risk mitigation) in multiple countries has led me to believe that engineers, and the engineering profession, need to more to act on their social responsibility gained through their skills and status. This opinion did drive some of the questions, and possibly some of the follow up questions as well. For example, I was very interested when Jocelyn discussed her interest in the Peace Corps, and asked more questions about this goal than I did of Madison who consistently stated her plan to work in a manufacturing plant. I believe my own tendencies to be more curious about subjects that interested me are entirely human, but also allowed the students to expand on their ideas about social responsibility. I told one student (Katie), when she asked me directly, about my own experiences with engineering and development work. I have no reason to believe that this disclosure had any impact on her eventual new major and path. I do intend on asking each student if they feel the interviews themselves had an impact on their ideas about engineering, social responsibility, the connection between the two, and their own personal plans to integrate these ideas.

We were faced with multiple limitations as a result of the study design and some unforeseen circumstances. While the data is very rich, we only have about three hours of audio and four surveys (which some did not take very seriously) for each student. In any of these points in time, the student may have been more heavily influenced by something that was very present in their lives: an exam that went poorly, a project that was received well, a romance, a breakup, family, or personal issues. We also could not ask every question we desired, as we were only asking for one hour of the student's time for each interview. Some that may have been particularly salient for a particular student may have been left out. This study originally targeted only civil, environmental, and mechanical engineering majors. While mechanical and civil have the first and second highest number of bachelor's degrees awarded, environmental is the 16th highest and has a higher representation of women than is typical. In addition to other majors, this study did not deliberately include electrical, computer science, or chemical engineering – the third, fourth, and fifth largest engineering majors, respectively (Yoder 2014). Each university represented in this study is a medium or large, research intensive, doctorate-granting institution with a long history. The students' experiences and influences could be much different at an all undergraduate institution, a small university, or a religious university. Bielefeldt and Canney showed through another distribution of the EPRA survey that students attending religious universities do have different attitudes about social responsibility (N. Canney and Bielefeldt 2013). By looking at the demographics of the students in the interviewee pool, the lack of racial, ethnic, age, and socioeconomic status diversity is clear. Underrepresented and nontraditional students likely have different opinions about social responsibility based on their previous experiences. Some students did not participate in all interviews, and their experiences and opinions could have been valuable to this study. One student was involved with ROTC, another was a computer science major with an interest in political science, and a third was the president of Tau Beta Pi. They all would likely have enlightening comments on socially responsible engineering and how they plan to be socially responsible engineers. Finally, I did develop a rapport with the students over the three rounds of interviews. It is possible that they would have wanted to answer my questions positively and stretch the depth of their own participation in helping others or being socially responsible in the future. This rapport is also a strength, and I believe it led students to be more, rather than less, honest with me in their responses.

Validity was built into this study in multiple ways at multiple times throughout the three years. As described above, researchers with varying backgrounds and life experiences worked together which helped temper any particular bias in interpreting the words of the interviewed student. We have no reason to believe at this time that students described experiences were construed in any way other than what the student meant. In the forthcoming fourth year of interviews, we will be able to perform a member check and ask the students if our interpretations were valid and if they agree with the findings of the study. With reference to Maxwell's (2013) methods for validity, this research achieves all but one of the tests. See Table 9 below for the details.

Table 9: Validity Tests: A Checklist (Maxwell 2013)

Validity Measure	**Method**
Long-Term Involvement	Longitudinal interviews over three years; four surveys over three years
Rich Data	Detailed transcription of each interview from audio recordings; written responses to open-ended survey questions
Respondent Validation	Attempted in Years 2 and 3 with questions about how they feel their ideas have changed. Planned explicitly for Year 4 by asking the interviewees if our conclusions are accurate.
Intervention	Not included – wanted to understand the natural changes that occur through a student's college experience
Discrepant Evidence and Negative Cases	Comparison of students' survey scores, which did not necessarily match our perceptions from their interviews; Leavers – became clear that no one reason was responsible for their departure, could not generalize.
Triangulation	Three interviews, four sets of survey responses
Numbers	For example - counted how many had the same influences, were of the same SR Type, and if there were similarities between majors or universities.
Comparison	Between students, the same student in different years, majors, SR Types

Further efforts to ensure validity include the reading of the findings of the study by individuals who were closer and farther away from the study. The undergraduate researcher employed following the first round of interviews was asked to review the findings of the following chapters after reading the series of interviews that matched the students who were discussed in more detail. This researcher and I discussed some findings she felt were not justified strictly through the words of the student.

SUMMARY

We worked to be as deliberate as possible with these semi-structured interviews, and make the most out of the short time we had with each student. Qualitative research is complicated, and the nuance of each student's story became very clear within the first few interviews. We were forced to make tough decisions about what to include and what to leave out of the following manuscripts. This experience points to the value of qualitative research in engineering education. The interviews still contain much more information to be mined. These are a rich repository of the lived experiences of engineering students told in their own words, and these fairly unfiltered ideas, opinions, and prioritizations have embedded value for instructors, administration, and other students at multiple levels of education. While qualitative research may be uncomfortable and difficult to pin down at times, it does fill a significant gap in our understanding of what students are actually experiencing without the confines of Likert bubbles and one sentence answers.

The next three chapters are stand-alone manuscripts that are nearly ready for publication. Thus, I wrote them in the 'academic' style of the passive voice to match the journals in which we would like to publish. Further, the chapters will contain some repeat information as they have introductory, background, and methods sections that have been described in the previous chapters.

Chapter IV: Evolution of Students' Varied Conceptualizations about Socially Responsible Engineering: A Three Year Longitudinal Study

Abstract

Engineering students must learn how to act on their responsibility to society during their education. At present, however, it is unknown what students think about the meaning of socially responsible engineering. This paper synthesizes three years of longitudinal interviews with engineering students as they progressed through college. The interviews revolved broadly around how students saw the connections between engineering and social responsibility, and what influenced these ideas. Using the Weidman Input-Environment-Output model as a framework, this research found that influences included required classes such as engineering ethics and some technical courses, pre-college volunteering and familial values, co-curricular groups such as Engineers Without Borders and the Society of Women Engineers, as well as professional experiences through internships. Further, some additional experiences such as technical courses and engineering internships contributed to confine students' understanding of an engineer's social responsibility. Overall, students who stayed in engineering tended to converge on basic responsibilities such as safety and bettering society as a whole, but less concerned with improving the lives of the marginalized and disadvantaged. Company loyalty also became important for some students. These results have valuable, transferable contributions, providing guidance to foster students' ideas on socially responsible engineering.

Keywords: social responsibility; qualitative research; ethics;

Introduction and Background

Engineers impact every person in society through designed products, the built environment, and all of the engineering expertise that is used throughout major events like war and natural or man-made disasters. While the impacts of engineers may be easy to see, the extent to which engineers feel responsible for these impacts remains largely unknown. An engineer's professional social responsibility must encompass protecting public welfare, and may also extend to concerns around sustainability (National Society of Professional Engineers 2007), the social context of their engineering designs (Herkert 2000), empathy and caring (Hess et al. 2012), striving for social justice and peace (Riley 2008; Baillie and Catalano 2009), and pro bono work (Passino 2009). Understanding how students think about what socially responsible engineering is, or could be, will give insight to what they feel is their social responsibility as engineers.

Regardless of a college student's major, university education can and should play a significant role in personal social responsibility development as students transition into adulthood and acquire responsibilities through their careers (O'Neill 2012; Crebert et al. 2013; Association of American Colleges & Universities 2014). Some engineering students seem to be defining their social responsibility to include assisting those who are less fortunate, as evidenced by the growing number of students choosing to be involved with Learning Through Service (LTS) activities like the EPICS service-learning (S-L) program and co-curricular activities such as Engineers Without Borders (EWB) (EPICS Purdue 2014; EWB-USA 2013; A. R. Bielefeldt, Paterson, and Swan 2010; Litchfield and Javernick-Will 2014; Schneider, Lucena, and Leydens 2009; J. Lucena and Schneider 2008).

While these efforts are important and more current students than ever before seem to be thinking of engineering as a helping profession, some studies have shown that many engineering students' attitudes towards the importance of considering social impacts and ethics in engineering decrease as they proceed through college (Cech 2014; A. Bielefeldt and Canney under review). This concerning trend could mean that engineering students are learning through their college education that the engineering profession is not driven by caring, and/or that those students who do highly value engineering's positive impact on society are leaving engineering majors prior to graduating from college. Previous research has found that women are more motivated to service and helping through their careers than men, which has implications for recruitment, retention and persistence (Schreuders, Mannon, and Rutherford 2009; Eccles 2007; Miller et al. 2000).

In order to attract and keep more students in engineering with a relevant and engaged curriculum, engineering education needs a baseline to understand what students are already experiencing. Clearly, the lives of engineering students are complicated and they are impacted beyond the classroom (Barron 2010). These extramural influences contribute to student development and what students consider important at all stages – past, present and envisioned future. However, the majority of engineering education research to date has focused on in-class interventions and quantitative instruments to measure mastery of the material and, to a lesser extent, attitudes. While valuable, this gap in the understanding of students' complicated lives must be addressed.

This study aims to develop a better understanding of how these many experiences and people influence students' ideas about socially responsible engineering. Thus, Weidman's updated Inputs-Environment-Outputs (I-E-O) model of undergraduate socialization (Figure 4) (Weidman 2006) was adapted and used. Weidman et al. (2014) performed a meta-analysis of studies that have used the Weidman (1989) model to help shed light on the process of college students' socialization (Weidman, DeAngelo, and Bethea 2014). Weidman (2014) states, "Foremost among [these insights] is the recognition of the importance that the normative contexts experienced by college students can exert lasting influences on students' academic, social, and personal development." From the results of these diverse studies, the Weidman model has proved itself to be effective at tracking and categorizing student experiences in a wide range of contexts.

Weidman describes that "socialization outcomes are the resultant changes (values, beliefs, and knowledge) that occur in students" (Weidman 2006). These O*utcomes* are the result of *Inputs*, which the student brings into college and the *Environments* in which students act. Environments include the higher education loci of socialization such as the classroom and co-curricular activities (clubs, professional societies, sports, and sororities) (National Survey of Student Engagement 2011). *Environments* include not only intramural spaces where formal learning and peer interaction take place, but also students' *Personal* and *Professional Communities* where more influences affect student dispositions and identities within and outside of their major. For this study, the "socialization outcome" of interest is the students' conceptualization of socially responsible engineering. Specific *Inputs*, *Environments*, and O*utcomes* for each student were identified and tracked each year through methods described in the next section.

Figure 4: Conceptualizing Organizational Socialization of Students in Higher Education (Weidman 2006)

Previous research that studied engineering students' social responsibility has found that high school community service activities and religious beliefs are two important *Inputs* (A. R. Bielefeldt and

Canney 2014; N. Canney and Bielefeldt 2013); service learning (S-L) is a normative context has been shown to be an important *Environmental* influence. A wealth of research has shown how internships, family, and friend groups affect students' knowledge and dispositions through college (Stevens et al. 2008; Erickson, McDonald, and Elder 2009; Tonso 2007), and these *Environmental* influences may also impact students' understanding of social responsibility.

This study attempts to answer the following research questions:

RQ1: What are the main influences that shape evolving ideas about socially responsible engineering through engineering students' first three years of college?

RQ2: As a result of these influences, what understandings of socially responsible engineering do students have at the end of their third year of college?

METHODS

Qualitative research methods – interviews, supplemented by written survey responses – are undertaken here to capture the complex experiences that are not well understood through a simple quantitative survey (Chism, Douglas, and Hilson Jr 2008; Borrego, Douglas, and Amelink 2009). Interviews were conducted with twenty engineering students at the end of the first year in college (19 in March to June, 2013, one in August 2013). These same students were interviewed in each of the following two years in March to June of 2014 and 2015. The second and third years of the engineering curriculum, and students' attitudes during these "middle years," have not been well-studied to date (Tsai, Kotys-Schwartz, and Knight 2015; S. M. Lord and Chen 2014) as compared with the first year and fourth year (Sheppard et al. 2010). By checking in with the students each year, it was possible to understand how the students' attitudes evolved. Further, each student's influences before and during college varied greatly; some were persistent, while others changed quickly and drastically through college. By designing a longitudinal study, students answered questions about what they believed and were experiencing at the time of the interview, and also reflected on their past each year.

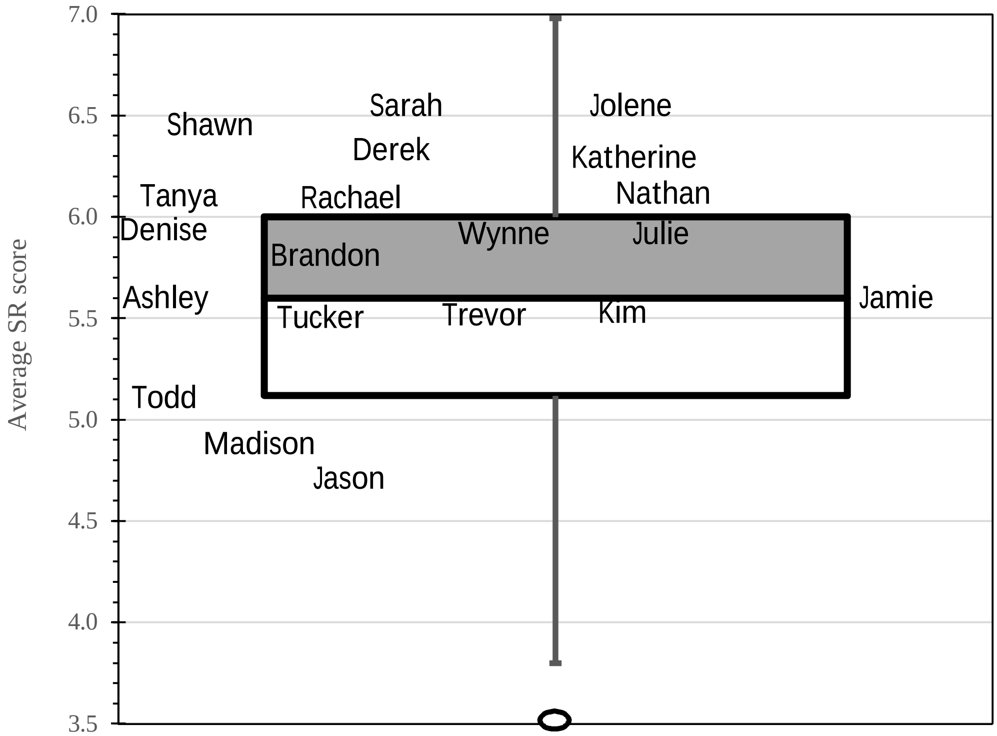
Using criterion-based selection (Miles, Huberman, and Saldaña 2013), the students in this study initially represented (i) a range of attitudes toward social responsibility (SR), (ii) a high oversampling of women in engineering, (iii) four universities, and (iv) primarily three engineering majors. Students' attitudes about social responsibility were initially assessed quantitatively via the Engineering Professional Responsibility Assessment (EPRA) instrument administered within the first month that the students entered college at five institutions – referred to in this paper as the "initial" survey and abbreviated as 'Y0' (N. E. Canney 2013). There were 236 first-year student responses to the survey, and 75 of these students indicated a willingness to participate in an interview at a later date. Average SR scores were computed by averaging the responses to the fifty 7-point Likert items. Therefore, SR scores could potentially range from 1 to 7; actual Y0 SR scores ranged from 3.51 to 6.98. Females were over-sampled to participate in interviews due to literature indicating that helping others in their careers is more important to women than men (Wilson et al. 2011; Pierrakos et al. 2009); Y0 SR scores for first-year students averaged 5.8 for females versus 5.4 for males (N. E. Canney 2013). Students were initially majoring primarily in mechanical engineering (ME), civil engineering (CE), and environmental engineering (EnvE); at two institutions students did not start with declared engineering majors, so students were asked about their likely engineering major. The students selected for interviews were initially enrolled at four institutions: a large public research-intensive university (LPU), a technically-focused medium-sized public university (TechU), a medium-sized public university (MPU), and a medium-sized private research intensive university (PrU); students at a Military Institution participated in the EPRA survey, but none consented to participate in the interviews. A summary of the demographics of the 20 individuals who remained in engineering and participated in the interviews all three years are shown in Table 10. This represents a subset of the 34 students initially interviewed at the end of the first year, the lower number due to students leaving engineering and those who did not participate in interviews for three consecutive years.

Table 10: Initial Demographics of 20 Interviewed Students

Pseudonym	Gender	Major	Institution	Initial SR Avg Score
Jason	M	ME	TechU	4.68
Madison	F	ME	TechU	4.86
Todd	M	ME	TechU	5.12
Tucker	M	CE	LPU	5.48
Trevor	M	EnvE	MPU	5.52
Kim	F	EnvE	LPU	5.54
Ashley	F	Other	PrU	5.62
Jamie	F	ME	TechU	5.62
Brandon	M	EnvE	TechU	5.82
Wynne	F	CE	LPU	5.88
Julie	F	Other	PrU	5.88
Denise	F	Other	PrU	5.96
Tanya	F	EnvE	TechU	6.10
Rachael	F	Other	PrU	6.10
Nathan	M	CE	TechU	6.12
Katherine	F	CE	MPU	6.28
Derek	M	Other	PrU	6.34
Shawn	M	EnvE	LPU	6.46
Sarah	F	CE	TechU	6.55
Jolene	F	CE	TechU$^{0-1}$/SmPU$^{2-3}$	6.55

Figure 5 shows how these 20 students fit into the larger pool of first year students in terms of average SR score. More students in this study are in the upper quintiles than is representative (n=8), and fewer in the lower quartile (n=3). This may represent a bias in the students that indicated a willingness to participate in interviews; also, the 12 students who were willing to be interviewed, but did not respond to the interview requests, had an average SR score of 5.33. The student in this study had an average of 5.82.

Figure 5: Interviewed Students' Y0 Average SR Score Compared with all First Year Students in EPRA Study (Box One Standard Deviation from the Median, Bars Two Standard Deviations from Median)



While the above criteria were the only used to select the interviewees, other potentially impactful demographics were gathered in the EPRA survey. Denise was the only student of the 20 who identified as Hispanic, and she was a first-generation college student. Tanya was the only African-American and was a first-generation college student. Sarah was the third and final first-generation college student in the cohort. Derek was 21-23 years old at the start of college, while all other interviewees were 18-20. Tanya and Jolene described themselves as “very active” in their religious activities.

All of the research was conducted according to methods and protocols approved by the University of Colorado Institutional Review Board for Human Subjects Research, Protocol 11-0414, and included informed consent before each interview and online survey.

INTERVIEWS

Interview questions were developed each year to best elicit the students’ ideas about socially responsible engineering. In the first year, questions were generally about the student’s reasons for entering engineering, their social issue awareness and involvement, and finally how they connected engineering and social issues. For more details regarding the interview questions and methods for the first year, see the earlier conference publication from the authors (G. A. Rulifson, Bielefeldt, and Thomas 2014).

The second round of interview questions built upon the first round, but led students to comment more explicitly on their *Professional Communities*; therefore, the questions were balanced between their experiences over the past year within and outside their major, potential and ideal careers in the future, and connections between these three broad areas in relation to social responsibility. More details about the methods for the second round can be found in Rulifson and Bielefeldt (2015).

The third round of interview questions scaffolded upon the exploratory first and second round questions and findings. Third round questions were more direct than previous interviews as the research objectives became more focused on understanding how students conceptualized socially responsible engineering. These questions were developed by the authors initially, then were critiqued by a professor in the school of education familiar with the research.

Semi-structured, audio recorded interviews up to 90 minutes in length were conducted by the same male doctoral researcher from February-August 2013, March-April 2014, and March-April 2015. An incentive of $100 was offered for each completed interview. To test which interview media was most comfortable for the students, the format at LPU varied during the first year: six interviews were conducted in person, three by phone, and two through Skype. The phone interviews were the most candid and easiest to conduct, so all future interviews were conducted by phone. Staying on script through a structured interview may have limited students' deeper expression, so the conversation was allowed to flow naturally and return to the interview questions when appropriate (Saldaña 2003; M. A. Eisenhart et al. 1998).

After the first interview, each interviewee was assigned a pseudonym using typical conventions (Ogden 2008). Interviews were transcribed verbatim into Microsoft Word using Dragon voice recognition software. Then, each interview was read through and edited while listening to the interview to produce a more accurate transcript. This transcript was then imported into Nvivo 10 for identifying and classifying the multiple themes around socially responsible engineering and related influences.

INTERVIEW ANALYSIS

As the first round of interviews was exploratory, inductive coding methods (Miles, Huberman, and Saldaña 2013) were used. Three researchers (PhD student, faculty advisor, and an engineering undergraduate) co-developed a code book based on a sub-set of 13 interviews (four per person plus one in common), achieving an inter-rater reliability of 91%. Further details regarding the first year analysis can be found in Rulifson et al. (2014).

For the second round of interviews, the reliable code book developed from the first round was used while remaining open to codes emerging as students expressed new ideas. More codes were also developed to capture answers to the new interview questions. A similar coding process was followed as in the first year, but between just two researchers (PhD student, faculty advisor). Finally, changes in SR understandings and connections to engineering between years one and two were found. For more details about the second year's analysis, see Rulifson and Bielefeldt (2015).

In the third year, analysis was similar to the first and second years in the use of the original code book while remaining open to more codes, as required for the new questions. After this initial coding, student interviews were mapped to the Weidman (2006) model (Figure 4). This provided a theoretical framework as well as a way to organize and better conceptualize the path through which engineering students came to understand connections between engineering and social responsibility.

ONLINE SURVEY

The students in this study were also asked to complete the online EPRA survey each year (N. E. Canney 2013). Students were provided $5 compensation for completing the initial EPRA survey at the start of their first year (September 2012) and $10 compensation for completing the EPRA survey in the spring of 2013, 2014, and 2015. This gave another resource to learn more about the students, which ideas about socially responsible engineering changed, and helped to address the concern that while the interviews may have been deep, some ideas may not have surfaced in the approximately sixty minutes allotted each year. The EPRA survey included 50 Likert-items used to measure social responsibility attitudes; an overall "average" quantitative measure of social responsibility was derived by averaging the responses across all 50 7-point Likert items. Paired, two-tailed t-tests across the 50 items for each individual were used to determine if there were statistically significant changes in the average SR scores at different points in time. The survey also included questions to quantify the extent of participation in community service activities and personally desirable attributes of a future engineering career. A few open-ended questions were included on the survey and varied somewhat across the different years. Common open-ended questions asked students to define social responsibility, identify college courses that influenced social responsibility attitudes, and events/people that were influential to their views of community service and/or social responsibility. The survey concluded with demographic questions including engineering discipline, gender, race/ethnicity, and religious/spiritual beliefs and activity.

Multiple journal papers have been published from the analysis and findings of the larger EPRA survey distribution regarding engineering students' social responsibility attitudes – for example, gender differences, differences between disciplines, longitudinal changes in individual scores, and the impact of service learning (N. E. Canney 2013; A. Bielefeldt and Canney under review; A. R. Bielefeldt and Canney 2014). For this study, mainly the open-ended responses of all four distributions of the EPRA survey were read for each student, (highlighted in Appendix A) and compared to all the interviews after the third round was complete. This was particularly useful in revealing what other activities students were involved with and significant influences not mentioned in the interviews. At the same time, the interviews shed light onto some of the vague responses within the survey, and complemented each other to get a fuller picture of how a student came to their understanding of socially responsible engineering. Finally, the combined survey and interview package allowed for identification of contrasting ideas on socially responsible engineering, which will be asked about in the fourth round of interviews as discussed in the Future Work section.

RESULTS

This section has four parts. First, the students' SR scores in each of the four survey distributions will be presented as an indicator of quantitative changes in personal attitudes toward professional social responsibility. Next, a general discussion of the students' influences and experiences is presented. Third, a synthesized Weidman model of all the students will be described. Finally, four students will be discussed in greater detail to provide a more nuanced understanding of the evolution of students' ideas in their own words.

Table 11 presents the majors and quantitative SR scores of the 20 students over time; students are presented in order of increasing initial SR scores. As an example of how to interpret the table, Trevor was majoring in environmental engineering on the initial survey (Env^0) and had switched to civil engineering by the end of his first year (CE^1) when the first interview occurred. By the end of junior year (indicated as ^{3}), the students spanned six different majors (8 CE, 6 ME, 2 ChE, 1 EnvE, 1 ArchE, 1 CompSci). Note that "MPU2" is the Medium-Sized Public University to which Jolene transferred after completing one year at TechU. MPU2 was not part of the original institutions in the study. The majority of the students (n=12) did not experience a statistically significant change in their average SR score between the beginning of their first year of college and the end of their junior year; some had changed at the end of their first year or sophomore year, but then shifted back to their original score ('Variable' below, n=5). Six students had an overall decrease in their SR score; three fell by the end of their first year, and three fell in the junior year. Two students increased their SR scores.

Table 11: Changes in Student Majors and SR Scores over Three Years

Pseudonym	Major	Average SR score				SR Score Trend
		Y0	**Y1**	**Y2**	**Y3**	
Jason*	ME^{0-3}	4.68	4.96	4.74	5.08	Increase[3]
Madison	ME^{0-3}	4.86	4.94	5.06	4.46	Decrease[3]
Todd	ME^{0-3}	5.12	5.24	5.22	5.38	No change

Tucker	CE$^{0-3}$	5.48	5.48	5.60	5.40	No change
Trevor	EnvE^{0} / CE$^{1-3}$	5.52	5.34	--	5.34	No change
Kim*	EnvE$^{0-2}$ / CE^{3}	5.54	5.46	5.52	5.66	No change
Ashley	Other^{0}/ChE$^{1-3}$	5.62	--	--	5.76	No change
Jamie	ME$^{0-3}$	5.62	5.96	5.43	5.46	Variable^{1,2}
Brandon	EnvE$^{0-1}$ / CE$^{2-3}$	5.82	5.71	5.86	6.08	No change
Wynne	CE^{0} / ArchE^{3}	5.88	5.60	6.24	6.26	Increase^{2}
Julie*	Other^{0} / ME$^{1-3}$	5.88	5.74	5.49	5.70	Variable^{2}
Denise	Other^{0} / ME$^{1-3}$	5.96	5.80	5.70	5.96	Variable^{2}
Tanya	EnvE$^{0-3}$	6.10	5.41	5.90	5.96	Variable^{1}
Rachael	Other^{0} / CompSci$^{1-3}$	6.10	5.72	5.92	5.72	Decrease^{1}
Nathan*	CE$^{0-3}$	6.12	6.14	5.96	5.94	Decrease^{3}
Katherine	CE$^{0-3}$	6.28	--	--	6.04	Decrease^{3}
Derek	Other^{0} / ME$^{1-3}$	6.34	6.20	6.08	6.16	No change
Shawn	EnvE$^{0-1}$ / ChE$^{2-3}$	6.46	6.02	6.08	6.16	Decrease^{1}
Sarah	CE$^{0-3}$	6.55	6.72	6.12	6.44	Variable^{2}
Jolene	CE$^{0-3}$	6.55	5.78	5.94	6.14	Decrease^{1}

-- survey not completed in this distribution
* indicates one of the highlighted students to be discussed further in the Analysis Section

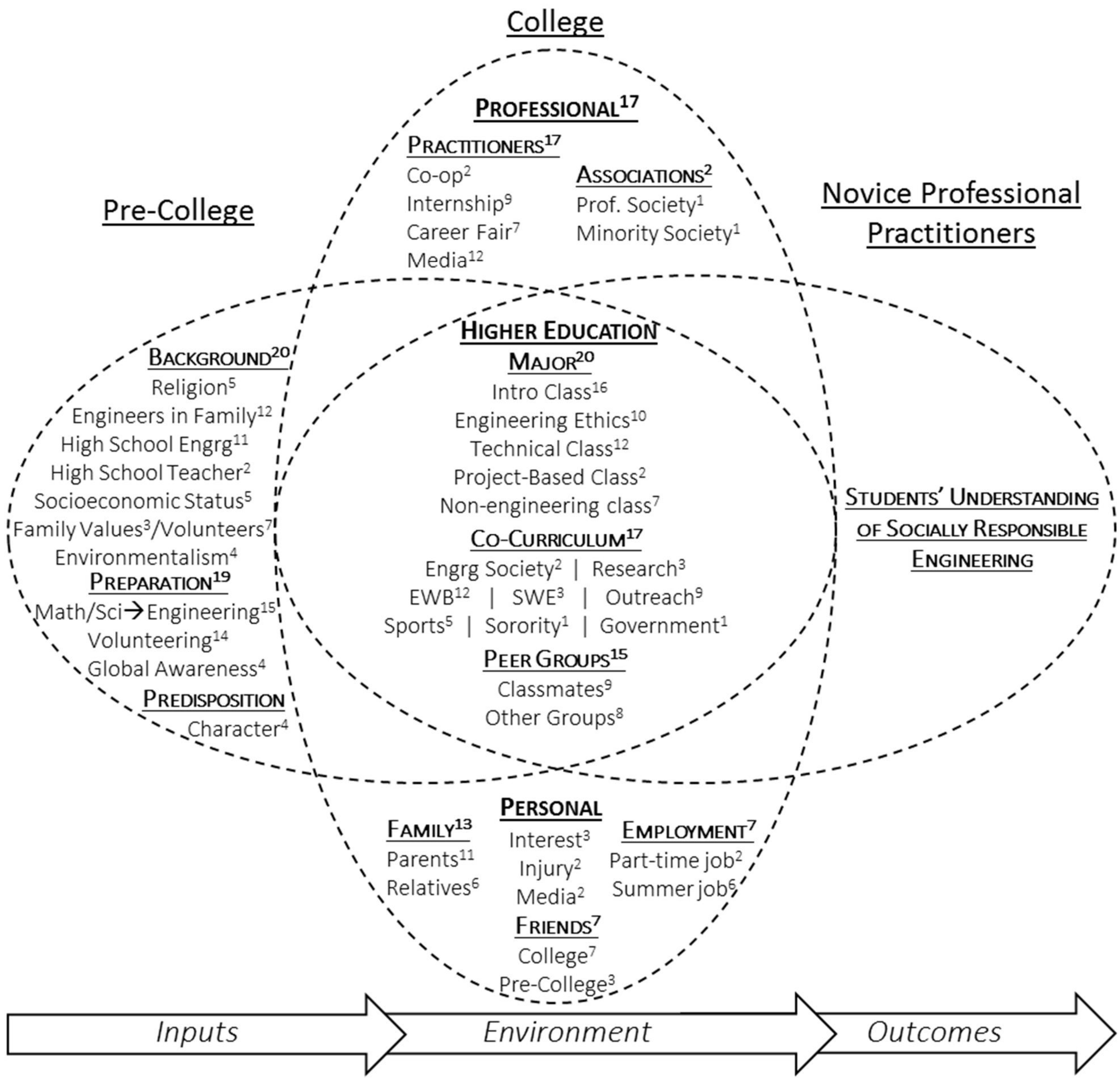
During the interviews, students described and spoke about socially responsible engineering in many ways. This was expected based on the purposeful sampling of students with a range of social responsibility scores from the EPRA instrument. For example, and using the Weidman model terminology, students described: *Inputs* such as 'a love for the environment' and 'high school engineering'; *environmental* influences such as 'familial situations' during college, 'popular media', 'introductory engineering courses', and 'co-curricular organizations' like the Society of Women Engineers (SWE) (note that these influences can contribute to a more or less advanced consideration of SR in engineering); and *outcomes* in the ways they see SR influencing their decision to pursue engineering through technical skills that produce safe highway bridges, alternative energy technologies, or a foundation for development in a disadvantaged community.

In addition to the anticipated influences, the following are some examples that show the diversity of influences on student ideas of socially responsible engineering (SRE) just in this sample of twenty students: a father who leads mission trips to Ethiopia; has family that lives in Colombia; an ROTC cadet; spent three years between high school and college playing hockey in Alaska; suffered a serious concussion in college while playing club sports; has a sister adopted from Guatemala; suffered a severe head trauma during college while on a construction site; worked 20 hours per week at an internship with a full course load; is a first generation college student from Detroit; is the captain of the club soccer team; studied abroad in China; did not have an engineering internship through three years.

Beyond the diversity of responses overall, some influences had a persistent impact and others changed significantly over the three interviews. In the first year, most students cited influences that occurred before college (*Inputs*) such as a family value to volunteer or certain high school engineering experiences. Additionally, many students described their college experience in the first year as very influential on their social responsibility ideas, such as: introductory engineering ethics courses or modules, EWB, or discussion with classmates. Over the following two years, engineering internships became a much larger influence in addition to technical courses (these experiences in some cases increased and in other cases decreased SR and engineering connections) and further leadership opportunities in their co-curricular activities.

Most of the commonly discussed influences were synthesized into a Weidman model that combines all 60 student interviews (**Error! Reference source not found.Error! Reference source not found.**). The superscripts represent how many of the 20 students mentioned a particular theme in one or more of their interviews or online surveys. These are influences within categories that seemed to shape students' ideas about socially responsible engineering. Cross-over between influences was common. The categorization was based on how the student discussed a particular influence. For example, the Society of Women Engineers (SWE) could be a co-curricular community within the university structure, a professional society that provided increased exposure to engineering practice, or an outreach organization. And, as there were outreach programs outside of SWE represented in the interviews, these programs were combined into one category called 'Outreach.'

Figure 6: Synthesized SRE Weidman Model representing 20 Students (superscripts are number of students)



It became clear through the interviews that it was not only important to track which influences were helping to grow a students' understanding of socially responsible engineering, but also which influences may have limited their understanding. Examples of this phenomenon are a brother that worked in a corporate mechanical engineering firm who did not talk about the social impact of his work and entering college with the idea that math and science proficiency is the main quality needed to become a good engineer.

Students most often discussed that upon entering college their ideas about engineering were shaped by engineers in their family (n=12) and high school engineering courses (n=11). These gave them an idea of what engineering was in the 'real world.' They also commonly cited that they knew engineers were good at math and science (n=15), and possibly little more. Fourteen students also commented that volunteering before college was important to them and gave them an idea of who could be impacted by engineering. Table 12 to Table 15 provide example quotes from the interviewees that correspond to some of the *Inputs* listed above. More example quotes can be found in the following sections and, for the first and second years, Rulifson et al. (2014) and Rulifson and Bielefeldt (2015).

Table 12: Example Pre-College Influences

Code	Representative quote
High School Engineering	Shawn, Y1: We had a program called River Watch…. We took accurate samples, we got to go back to our school and did some basic titrations to figure out dissolved oxygen or something like that, and then we actually sent it into the US Fish and Wildlife Service.
Volunteering	Rachael, Y1: I volunteered a lot when I was in middle school and high school. I worked at the Children's Museum. I volunteered there weekly and everything and it was really fun and I guess it shaped how I saw, like, social responsibility.
Engineering if Math and Science Proficient	Y1 Survey: *What factors led you to choose your current major?* Trevor: I've always preferred math and science as opposed to humanities. I like the job opportunities that come with it, and I feel engineering is a good honest way to make a living.
Environmentalism	Brandon, Y1: I wanted to do something related to the environment almost and I always enjoyed nature and stuff and I guess the environmental engineering aspect of it,…it's kind of your job.

Table 13: Example Higher Education Influences

Code	Representative quote
Intro Class/ Engineering Ethics	Denise, Y1: The closest thing I got to social responsibility was learning about ethics in engineering. We had a class and we spent a whole day talking about ethics.
Technical Class	Katherine, Y2: I think especially my environmental systems class has really opened my eyes to the kind of work that I can do as far as water pollution and air pollution.
Outreach	Ashley, Y3: I think the pro bono work would mostly be probably with tutoring or, yeah mainly with tutoring that is connected with engineering.
Classmates	Shawn, Y1: I mean, it's hard to set a straight set of guidelines for what your own social responsibilities are but I think that's something that you figure out through your life and definitely through college, because right now, being an intellectual habitat, that's where these conversations are to be had.

Table 14: Example Professional Influences

Code	Representative quote
Internship	Sarah, Y3: …getting more exposure through my co-op…it hits home a little bit, seeing the impact that engineers have on the rest of the world kind of shows how much social responsibility I think engineers should have….
Media	Julie, Y3: I read a lot about the case where Chrysler, like, their ignition switches were not working, were faulty or something. So thousands of people ended up getting in car accidents and just reading about the engineer who literally just signed off on things that came across his desk….
Minority Society	Tanya, Y2: …with the Society of Black Engineers and what the organization does, what we do is go to schools locally and go to different high schools in Detroit and teach about what it is and do activities that involve engineering, and talk about what engineering is all about, and find what interests them.

Table 15: Example Personal Influences

Code	Representative quote
Parents	Jolene, Y2: …my dad's company now where we're working, he just went over all the values in our Monday morning meeting and so there are a list of values there and core goals of the company that I really can appreciate and relate to.
Friends – College/ Religion	Jamie, Y1: She was, just out of the blue, at the computer, and she asked me 'hey, do you ever consider the fact that you kill people?' 'Well, I don't yet, but yeah, I will.' 'Oh, how does that fit with your Christianity?' 'I hope that if I'm good to people that I'm going to be okay.'
Summer Job	Denise, Y3: I feel like we also, there is some responsibility of teaching…getting more people who are interested in engineering because even if they don't end up being an engineer, I think a lot of the engineer design process can be applied to many different things.

In addition to the synthesized model, individual Weidman I-E-O models were created for each student from their three interviews combined (Appendix E). This single figure represents the influences that contributed to their particular understanding of socially responsible engineering, and in which year they discussed the influence, represented by a superscript – '0' for the initial survey, and '1,2,3' for the year of the three following surveys and interviews. The '/' through the number indicates that the student specifically mentioned they no longer were involved with this activity during that year's interview. Influences written in the online survey, but never mentioned in the interview, are italicized. Influences that were commonly found in this study but not a factor for the individual are shown faintly in gray text.

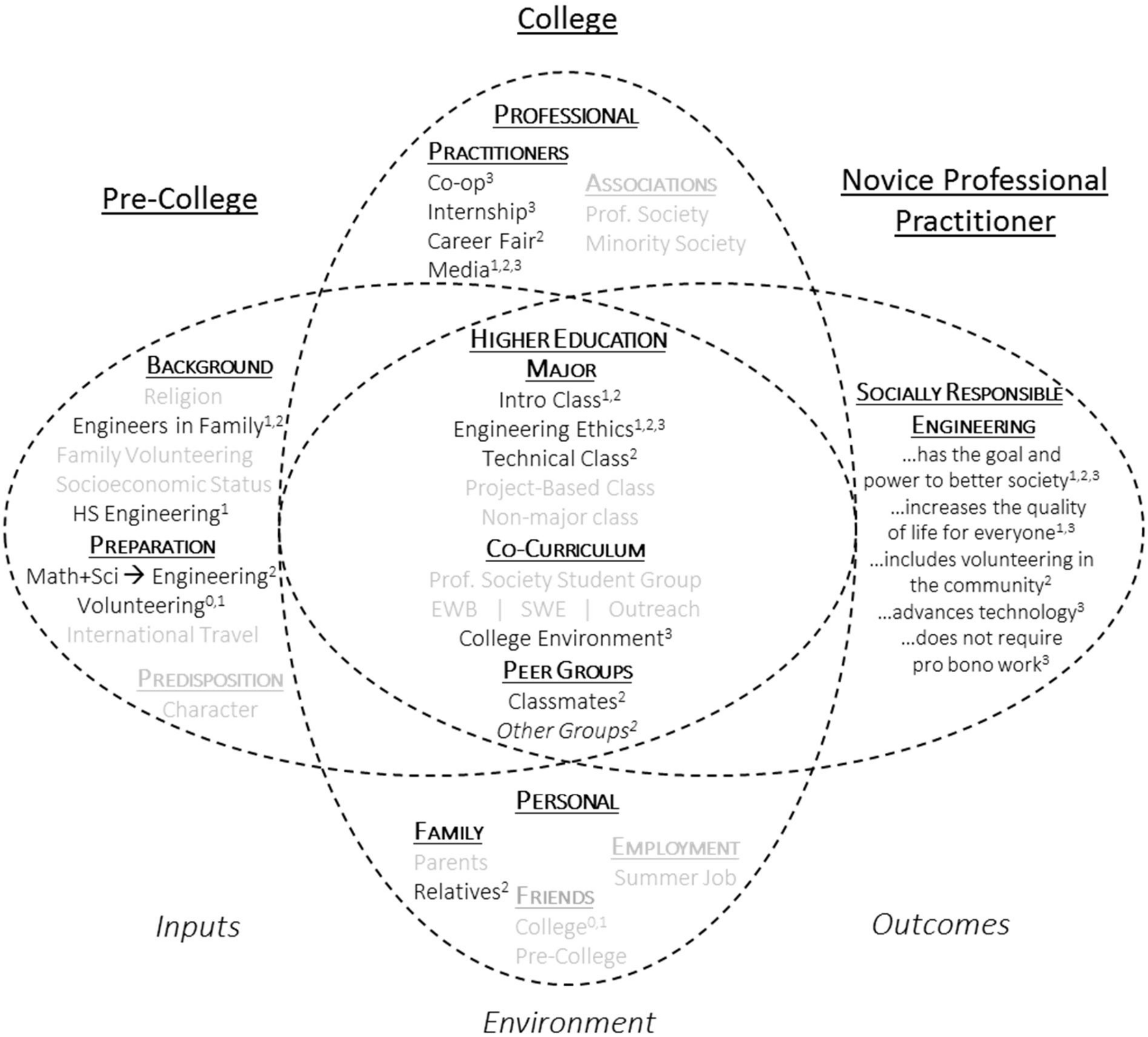
The original Weidman model (Figure 4) had an *Outcomes* section with *Knowledge, Skills,* and *Dispositions*. 'Socially responsible engineering' can be considered Knowledge, a Skill, and/or a Disposition: having a conceptualization (knowledge) of socially responsible engineering, believing that including socially responsibility in engineering requires skill, and having a disposition that guides a student's ideas about socially responsible engineering are all related, but different *Outcomes*.

In the following section, four individual students are presented to show detailed information found both in the survey responses and the interviews. The students also represent three of the four original universities, all three original majors, and different trends in their average SR scores.

Student 1: Jason

Jason was a mechanical engineering student at TechU, and notably was one of only two students who increased their average SR score between the beginning of college (4.68) and the end of his third year (5.08). He also started with the lowest average SR score in the group. The larger pool of longitudinal data found those with lower SR scores were more likely to increase in SR score over time (A. Bielefeldt and Canney under review). Jason's Weidman I-E-O model is shown in **Error! Reference source not found.**.

Figure 7: Jason (ME, TechU) Weidman I-E-O Model



Originally, Jason understood that preventing failure and generally improving society were SRE. Three main threads carried through the interviews and survey that seemed to shape Jason's understanding of SRE: (i) family influence on his initial understanding of engineering, paired with his regional focus on the northern Midwest for his future engineering career, (ii) his engineering courses that discussed engineering ethics, and (iii) his internship/co-op at a large engineering company during the summer before and spring semester of his third year. These influences combined to develop Jason's more complex third year understanding that SRE is the ethical engineering industry with its power to improve local, and possibly global, society at large, mainly through advances in technology that will make life easier and improve the economy.

JASON - *INPUTS*

Jason described that engineers in his family, specifically his uncles and brothers, encouraged him to try engineering at TechU. He also wrote in his second year survey, that, “math and science have always been natural for me.” He thought engineering would give him a “good job outlook” in terms of stability, salary, and flexibility of job roles. He volunteered some in high school mentoring younger students by reading with them and coaching football. He said these experiences helped him develop his SR understanding. His volunteering experience in high school seemed impactful to shape his understanding of social responsibility as evidenced by his survey responses.

One event that Jason discussed, which combined the different threads of importance, started with what he had learned in his high school engineering fundamentals course: Jason was from Minnesota, and he mentioned the 2007 I-35 bridge collapse in Minneapolis when asked what he likes about engineering, further stating, “it helped me realize that engineers have a huge influence on society.” This course may have set him up to engage more deeply with the idea of SRE leading him to the combined understanding that engineering has the power to improve societies with this “huge influence,”; however, the more traditional engineering roles of his family tempered his ideas about what engineers in his field actually are required to do.

Table 16: Jason – Inputs Coding Examples

Code	Representative quote
Engineers in Family	Y1: …my older brothers and some of my uncles are all engineers and they have nothing but good things to say about going to college and getting a job. They all got a job right away, and a job they enjoy.
Engineering Ethics	Y1: …it helped me realize that engineers have a huge influence on society. …Going back to that [Minnesota] bridge collapse, that was an engineering failure and a bunch of people died. So that is kind of an engineering social responsibility right there.
High School Engineering	Y1: … in high school I had an engineering fundamentals class and we talked about [the I-35 bridge collapse] a little bit there.

JASON – *ENVIRONMENT*

Jason wrote in his second year survey that his introductory engineering courses in his first two semesters "talked a lot about ethics," and in the interview he described how these gave him tools to deal with ethical dilemmas in the workplace should they arise. Also, Jason seemed to have been generally exposed to how engineers can have a positive impact – he said that "maybe Biomed could be more direct with helping humans with stem cells or prosthetics or whatever." It is unclear if he learned this through media or the same introduction to engineering class.

In the second year, Jason discussed the engineering profession more than the previous year seemingly due to his increased involvement -- he had joined the American Society of Mechanical Engineers (ASME) student group, attended more career fairs ("I go to all of them."), and interviewed for summer internships through his second year. These *Professional* influences seemed to help develop his understanding of the engineering profession beyond the experiences and opinions of his brothers and uncles. Jason said that he mostly skied, played sports on campus, and spent time with friends and family in his free time – the little that he had outside of his technical classes and studying. He did not prioritize helping others with his spare moments.

One of the most salient components to Jason's second year interview was the foreshadowing of the power that his future internship and exposure to the business side of engineering would have on his understandings of what is valued within the engineering profession. He explained, "I would gain valuable experience and get a feel for what I want to be doing once I get out, once I graduate." Loyalty to one's employer seemed to be something that Jason felt was very important and a significant part of an engineer's social responsibility. He described the consequences that resulted from unethical practices in the banking industry, which "hurt society and…just those important things are being honest, staying true to your employer and your customer, and giving it an honest effort and giving your best work." He was seeing himself as an engineer, and, building from his first year ethics module combined with his awareness of the general causes of the Great Recession, Jason saw the above components of SR being most important in engineering.

Jason had many more professional experiences by the third interview. His summer internship "was creating [computer-based] sales tools for the salesmen to use." In the Spring of his third year, rather than taking courses at the TechU campus he accepted an offer for a cooperative educational experience (co-op) at the same company, but in the hands-on "failure lab." He enjoyed and learned much from these experiences saying, "I'm glad I went into engineering based on these first two jobs." His co-op was in his home state of Minnesota, and being near family has been a priority that carried through all three interviews.

Jason's engineering courses also seemed to be important because he could now see the direct application of the theory and some of his more practical classes to his internship and co-op. Further, he described a junior year professional practice course that included microethical dilemmas, but little about an engineer's impact on society.

JASON - *OUTCOMES*

In summary, Jason's ideas about socially responsible engineering did seem to strengthen over the course of his three years in engineering at Tech U. In the beginning, he felt that engineers had the "power to do great things." In his second year, he focused more on ethics, and being honest through education because that will translate to an engineer's capacity as a professional. He saw some ways that engineers could help others, but not very easily through In the third year interview, when asked directly what he thought were the responsibilities of an engineer, Jason replied:

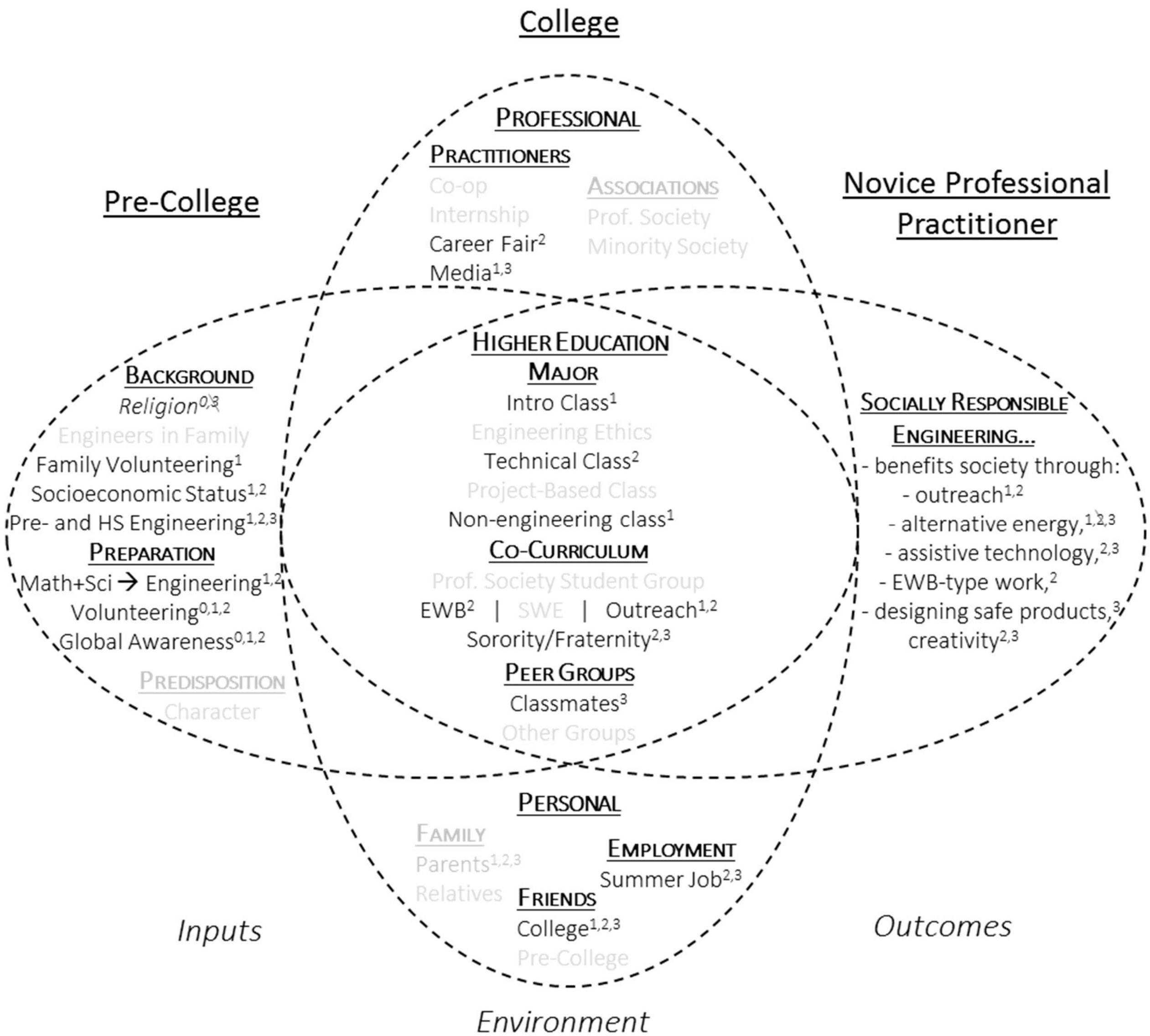
> I think the responsibilities of an engineer for a company are to work hard, be honest and work with ethics in mind as far as safety. Don't design something that you think is unsafe, don't take a shortcut that applies to safety where other people could be affected by it. Part of engineering is making the world a better place. Better inventions and that our design is to help society as a whole, the company I work for and society as a whole.

He came to an understanding in the third year that was more advanced and informed than his first year understanding, but still a similar idea – engineering inherently does impact the world in positive ways through technological progress, and engineers have the power to do good, so they should. His influences also seemed to evolve away from his courses in high school and what his brothers told him. During the second year, but particularly the third year, engineering courses that discussed social responsibility in some way as well as his observations at engineering career fairs seemed influential. Possibly most significant for Jason, though, was his co-op during the second semester of his third year. He seemed to have the time and context to really see how an engineering company interacts and affects society, which expanded his understanding of what engineering is, but also what socially responsible engineering may be. One foreseeable issue, though, is that there don't seem to be many future opportunities for Jason to further advance his understanding of social responsibility. This may be a ceiling of understanding for Jason.

STUDENT 2: JULIE

Julie was an engineering student at PrU where first-year students do not choose a particular major until the start of their second year – she chose mechanical engineering. She started with an initial SR score in the third quartile (5.88), experienced variability over time (low of 5.49 at end of sophomore year) but had an SR score at the end of her junior year that was not significantly different than her initial score (5.70). Julie's Weidman I-E-O model (Figure 8) summarizes the influences that she discussed in her interviews and wrote in her surveys over the three years, as well as her ideas about socially responsible engineering.

Figure 8: Julie (ME, PrU) Weidman I-E-O Model



In her first year, Julie though of SRE generally, as solving problems through new technology, alternative energy, and K-12 outreach to bring more students into engineering. Three major, persistent influences and ideas led Julie to her understanding of SRE in her third year: (i) her passion for engineering without much familiarity of what engineers actually do, (ii) her multiple engineering courses that were socially relevant and interesting, (iii) her involvement with engineering outreach activities through her university and her summer job along with occasional volunteering. To Julie, socially responsible engineering included safe technology advancements that hopefully, but not necessarily, improve society at large (i.e. alternative energy), or particular people (i.e. assistive technology or prosthetics); part of SRE could also include outreach and volunteering outside of or through their company with the time and resources they have available.

JULIE – *INPUTS*

Julie described that even before entering college, she developed a love for engineering. She participated in a pre-engineering summer session before starting college, and her mentors were mechanical engineers. This *Preparation* led her to choose MechE and associate it with fun; she learned that, while she had "always been best at science and math type things," engineering would allow her to embrace her creative side by innovating and having some autonomy in how to achieve her professional goals. Somewhat different from many engineering students, however, Julie "hadn't known too many engineers personally, so [she] didn't have a really good view of what they did as a job…." She thought an engineer "use[d] math and science knowledge to, like, solve problems and create new technologies that, like, improve people's lives." Additionally, she described her impactful involvement with volunteering during high school, as she wrote in her initial survey (in Table 17 below). This participation set the stage for her to include engineering with her desire to help others.

These combined experiences seemed to give Julie a rather high social awareness that had the potential to combine with her college engineering courses and co-curricular activities to develop into an advanced understanding of SRE.

Table 17: Julie – Inputs Coding Examples

Code	**Representative quote**
High School Engineering	Y1: I had a really limited view of engineering sort of as antisocial engineering science nerd people. Then after attending the program, I realized that engineers are just pretty much normal people who liked math and science.
High School Volunteering	Y0: *Partaking in Amnesty International illustrated to me very clearly that there are people who are not as fortunate as I am and that it is inexcusable to just ignore their lack of basic needs and human rights. However, volunteering in a homeless shelter in my town showed me that there are people in need of basic resources living within miles of me who should not be overlooked.*
Global Awareness	

JULIE - *ENVIRONMENT*

Julie’s continued enthusiasm around engineering was obvious from the first interview’s commencement. When asked how the first year had gone, she replied, “It was great, I loved it. [PrU] is a great school, especially for me. It's like, a perfect fit. And I love engineering so far, and I'm having a great time.” Some of her courses in the first and second years were particularly impactful for understanding what engineers, and mechanical engineers in particular, could design. Her Structural Art class exposed her to iconic buildings and some of the engineering behind them. She reflected on one of the impacts of the class, “…I just sort of decided it was too much responsibility, like, if my bridge collapsed. That's a much bigger problem than if my robot short-circuits.” She set up a hierarchy of SRE by discipline, from what she understood after her first year. In the second year, she learned more about ME’s potential to benefit society through her Human Factors Engineering course, which discussed assistive technologies and devices.

Due to Julie’s own positive experiences on the receiving end of outreach before college, and a first-year non-engineering seminar that informed her about the broader issue of “science literacy,” she wanted to give back in a similar way. She explained, “I feel really blessed to have always been a really great math and science student and to have had the great teachers in my life. So I wanted to sort of give back in that regard of like, well now I could be an inspiration or a teacher to another child who like, could someday become interested in engineering.” Thus, she applied and was hired by an on-campus engineering outreach program all three years. Her job was to (Year 1) “go into the elementary school and teach them engineering concepts,” (Year 2) “teach robotics to students in Chinatown,” and “go into a fifth-grade classroom every week and teach robotics.” Also, her summer job following her first and second years was in a similar field – working at a pre-engineering summer session leading middle and high school students through projects that represented different disciplines. In the summer after her second year, she was the program director, and had more responsibility, but less interaction with the students. Further, Julie continued to volunteer with friends and with her sorority, through which she gained more responsibility by being elected chief education officer in her third year.

Because Julie did not yet have an engineering internship by the third year when she was interviewed, she still did not have an intimate or particular understanding of the engineering profession. She admitted in her second year that, "this was the summer I was supposed to get an internship, but I'll just have one more fun summer and then next summer I'll get an internship." In the third year, at the time of the interview, Julie was "hop[ing] to be [at PrU] doing research with a professor, but other than that, just kind of chilling." She was accepted into the ME master's program, so she would be at PrU for one extra year. It seemed that while Julie loved engineering as she understood it, she could easily go through her entire education without working in a non-academic engineering setting. Her classes did have an impact. She said, "…what I'm doing now is actually real," then continued to describe how she enjoyed her classes more than before.

JULIE - *OUTCOMES*

Julie's understanding of SRE evolved from her first year in which she believed engineering inherently benefited society and included an outreach component. In her second year, these were still true with the specific example of human factors engineering. Her ideas were similar. Combining all of her influences from multiple years, Julie developed an interesting understanding of SRE by her third year, which she discussed at length in the third interview. When asked about an engineer's responsibilities, she replied, "…maintaining safety standards…and making sure that whatever they are working on is not, like, detrimental to any, like, group or, like, the environment or something like that." When she was asked about engineering's impact on society, she had difficulty answering. In contrast, when asked about how engineers *should* impact society, Julie responded remarkably:

> I think that people who realize that they have these skills and also can be creative and make something to really help people are the people who should be engineers and end up doing the most good as opposed to people who are just like in, in the machine who just want to make money and are not particularly innovative or necessarily doing their work to benefit anyone.

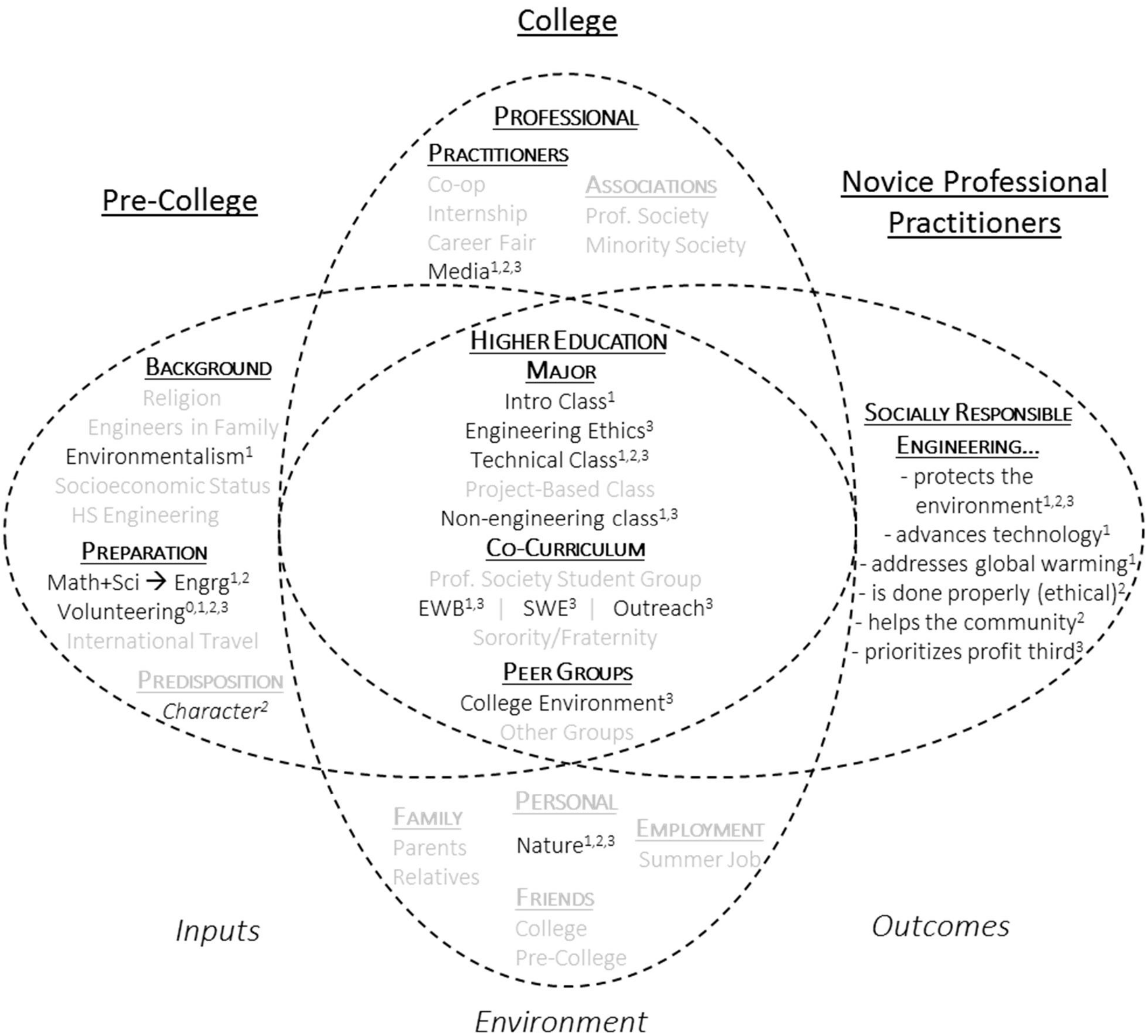
This description could be interpreted as the opposite of her understanding of SRE. She reiterates later in the interview that "intentionally not being innovative is part of a major problem," which she seems to have been exposed to largely through her friend who she believed was being irresponsible with his professional decisions to work in the petroleum or finance industries. This tension between a high salary and positive social impact that frustrated Julie seemed to come from her background of volunteering and passion about engineering's potential to make major changes to society and individual's lives through creative technological advances.

In summary, while Julie had more experience with volunteering and was in a university environment that was very active and supportive of service activities, she still did not connect these directly with engineering. She ultimately decided that pro bono work for marginalized communities was not required for socially responsible engineering, "but if you have time and are willing to do that, then more power to you." The resistance to require volunteering likely comes from her sorority and high school volunteering experiences, which felt forced without the personal motivation to participate. It seemed that overall and as evidenced by the previous quote that Julie, like Jason, believed that the mechanical engineering profession with its advancement of technology, would benefit society at large.

STUDENT 3: KIM

The third student, Kim, started college as an environmental engineering major at LPU. She switched to civil engineering after her second year. She began with an average SR score of 5.54, and this score did not appreciably vary over the next three years. Kim's Weidman I-E-O model (Figure 9) shows the influences and outcomes regarding SRE that she discussed in her interviews and wrote in her surveys over the three years.

Figure 9: Kim (EnvE → CE, LPU) Weidman I-E-O Model



At the beginning, Kim's idea of SRE was mainly confined to protection of the environment and a vague advancement of technology. Kim had three persistent lines of influence on her understanding of socially responsible engineering: (i) she was not as academically prepared for engineering as many of her peers; (ii) she entered engineering largely due to her love for the environment; and, (iii) her courses, both within and without engineering, were impactful. These led to her understanding that socially responsible engineering preserves and protects the environment, is done properly and safely, prioritizes the environment and society over profits, and should be accessible to all who are interested regardless of their pre-college educational backgrounds.

KIM – *INPUTS*

Kim grew up in a small mountain town near LPU where she enjoyed the outdoors, and developed an appreciation for the environment. She decided to pursue engineering while touring engineering schools, combining her love for the environment and the fact that she "always liked math and science more than writing papers…." She described that at her high school, however, few advanced math and science classes were available that allowed many of her future engineering classmates to be more prepared. Additionally, it seemed through the survey and the first year interview, that helping people and volunteering was an important part of Kim's life. As evidenced by her Y0 survey, her community service activity frequency was the highest of the four highlighted students, and the second highest of the twenty students in this study. This community service activity changed significantly, however, once she started college.

Table 18: Kim – Inputs Coding Examples

Influence	Representative quote
Non-engineering upbringing	Y1: I can't really think of anyone, really the only engineers I know, I guess, are my teachers and stuff, honestly.
Volunteering	Y0: Volunteering experiences included weekly "Nursing Home" and "events around the community," as well as bi-weekly tutoring and monthly food bank participation.
Environment	Interviewer, Y1: So do you think the environment part is particularly important to you? Kim: Yeah. I don't know, just like growing up in the mountains, it's kind of my background I guess.

KIM – *ENVIRONMENT*

As Kim began college without a strong idea of engineering, her time in college was very influential on her understanding of socially responsible engineering. Through the three years, it was interesting to hear her growing confidence that engineering was the right choice and aligned well with her *Input* influences.

At the start of the first interview, when Kim was asked how engineering is going, she replied, "It's hard, but it's good." She went on to say about her first year courses, "I feel like a lot of people have taken them in high school and I haven't." Interestingly, when asked what she believed engineers do, she said they "create stuff to better society." She learned this from her introduction to environmental engineering course, which included guest lectures from practicing engineers.

In the first and second years of college, as evidenced by Kim's surveys and interviews, her volunteering dropped to nearly none. Also, even though she tried, Kim did not have an internship or research experience that contributed to understanding of environmental or civil engineering practice (her internship was in aerospace), so her idea of socially responsible engineering emerged almost entirely from engineering courses (which emphasized microethics such as safety) and professors' values combined with her personal background.

Kim's third year of college was significant in many ways – she switched to civil engineering and found that she enjoyed the courses, especially geotechnical engineering. She also began volunteering with the Society of Women Engineers at a STEM-focused elementary school, through which she found a community where she could help students who were possibly like her as a child.

KIM - *OUTCOMES*

In each of Kim's interviews she discussed a lack of time, due to a part-time job and a consistently heavy course load in order to finish in four years. This may have prevented her from learning more about how engineering could be socially responsible. Her first year understanding of SRE focused largely on the environment since that was her main motivation for entering the engineering major. In her second year, her ideas did not advance much more, but she included that engineering work needs to be done properly, "so it's not like, a waste of time and money." In her third year, she often referred to her perception that companies prioritized profit over the environment and society. It was unclear where this idea originated. For example:

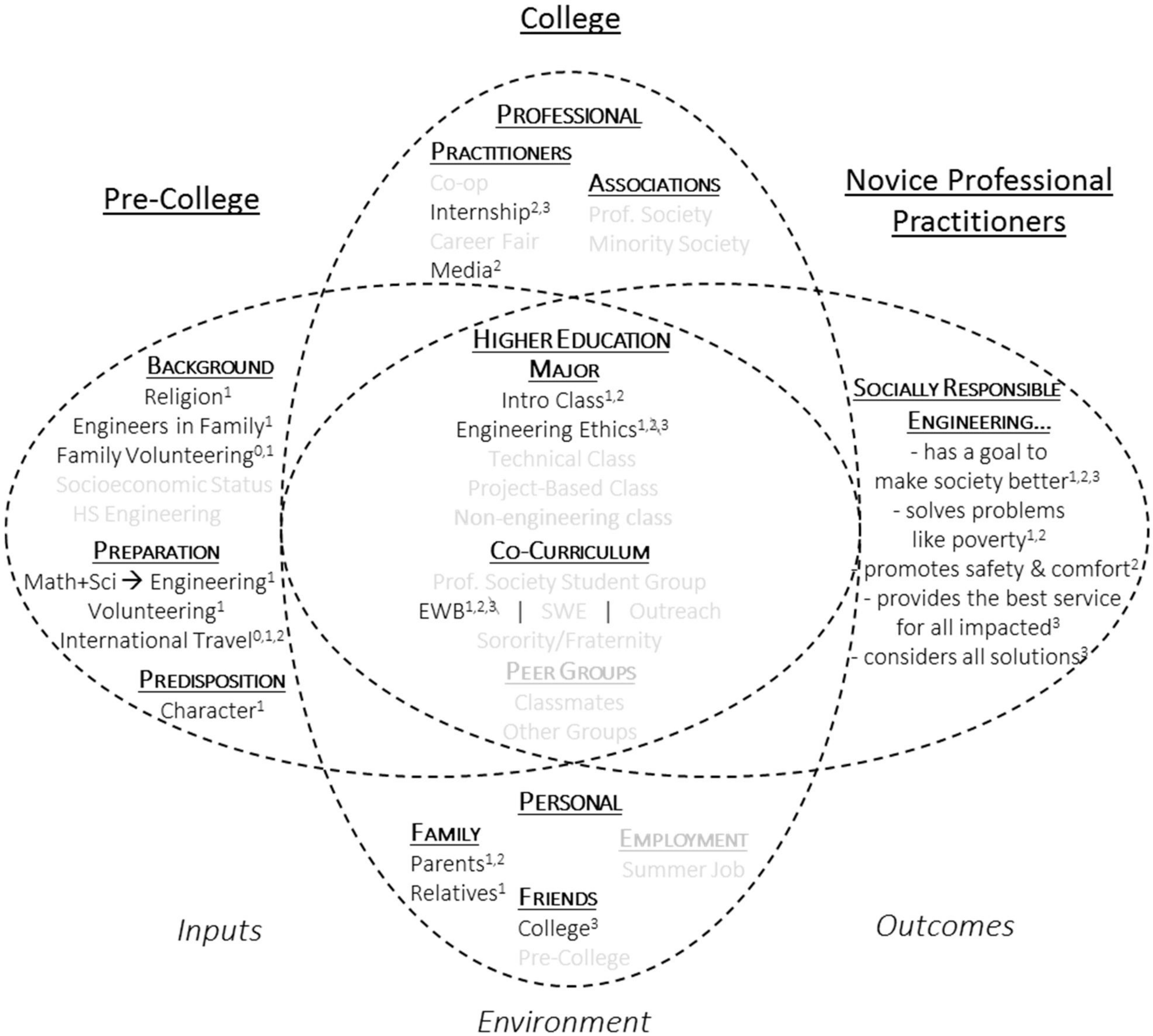
> Interviewer: So do you think that the environment is kind of the number one, I guess, responsibility? Like something you have to be considering and prioritizing?
> Kim: Like, over society or?
> I: Just sort of like, all the things that would come into a decision.
> K: I feel like it should be, but it never is.
> I: So what's above it?
> K: Probably like, making money.

Kim's story shows how much influence professors and courses have on many students who are not as well prepared for engineering, but choose to struggle through those difficult first years. In her third year, she had potential to learn more about socially responsible engineering as she persevered and enjoyed engineering more, but seemed not to have influenced her ideas. On the whole, Kim's ideas around socially responsible engineering still were vague at the end of her third year of college and related to her initial perceptions of engineering.

STUDENT 4: NATHAN

The fourth student, Nathan, was majoring in civil engineering at TechU. Nathan's initial average SR score (6.12) was on the higher end through his first year, but had decreased by the end of junior year (5.94). He was one of six students whose average SR score decreased and did not rebound. Nathan's Weidman I-E-O model is shown in Figure 10.

Figure 10: Nathan (CE, TechU) Weidman I-E-O Model



In the first year, Nathan believed that SRE was solving the world's problems including major ones such as poverty in developing communities. Nathan's main influences were his (i) family, both in developing his character and motivating him to pursue engineering, (ii) involvement with Engineers Without Borders, and (iii) engineering courses that reinforced what he learned in his local internships. These led to his third year understanding that SRE is most of the engineering industry that provides the best service possible for all impacted stakeholders by considering all available and reasonable solutions.

NATHAN - *INPUTS*

In his first interview, Nathan described that his family was always supportive of volunteering, he participated in church service activities in high school, and that his family adopted his younger sister from Central America. He traveled there and witnessed a vastly different world than his own (see Table 19).

In the first interview, Nathan continued to reflect on his ideas about poverty he has seen in cities near and far. He seemed to think deeply about the plight of people who "spend their whole lives trying to get out of the hole that they're in and they don't get a lot of the chances that we get." This family background, and his own willingness to engage with tough problems stayed with him as he entered college at TechU.

Table 19: Nathan – Inputs Coding Examples

<table>
<tr><th>Influence</th><th>Representative quote</th></tr>
<tr><td>Family</td><td rowspan="2">Y1: …[my sister's] orphanage, going and seeing all of these kids. I never really knew what an orphanage was and when you see it firsthand…it kind of shifts you. And you see all these kids who don't have, well they have a home, but they don't have a family. And that's kind of hard to deal with sometimes.</td></tr>
<tr><td>International Travel</td></tr>
<tr><td>Volunteering</td><td>Y1: We did this thing called "Jesus on the Streets" in [ ] where we just go on a Saturday or Sunday at 7 AM in the morning and hand out food to the homeless people in [ ].</td></tr>
</table>

NATHAN - *ENVIRONMENT*

Nathan learned through his first-year introductory engineering course's ethics module that "the goal [of engineering] is to make society better. So, social responsibility is kind of big." In contrast, he said about his second year curriculum, that discussions of SR were not part of his classes. Outside of his courses, Nathan joined EWB upon entering college, which happened to be working in the same Central American country where his sister was born. EWB seemed to be highly influential on his ideas about the potential of engineering to affect issues such as health and sanitation, which he described in his first interview. When asked if he felt engineering played a role in addressing poverty, he said, "[EWB is] trying to give them their basic needs of nourishment by giving them water they can use for drinking or whatever they need it for." In his second year survey, Nathan wrote succinctly about influences on SR, "My involvement in Engineers Without Borders has increased my desire to help people with engineering.

Mainly the adoption of my little sister has influenced my desire to help people in need." He also described that his main reason for pursuing engineering was to give back to his current family and provide for his future family. In Nathan's third year interview, he explained that he stopped participating in EWB because the team "stopped doing work because they were in between projects and they were just deciding on what the next budget would be and it just got a little bit frustrating."

Discussions with professionals at career fairs and his own online research, were possibly the most significant influences in his second year. His ideas started leaning toward the U.S. and local context and included safety, energy efficiency, and quality roads. He made an important comment about engineering: "I make something that's not going to fall down and kill a bunch of people and that is just, that just seems like human decency, but it's something that I would like to make and to not only be safe, but also to be helpful to the community." For him, SRE still went beyond safety and legality. Connecting with his desire to continue EWB as a professional, he also glimpsed what poverty alleviation could be as a practicing engineer through a discussion with his future boss about participation in an Indian water treatment organization. Nathan's third year interview largely revolved around his internship that impacted his ideas about how engineers impact local communities.

NATHAN - *OUTCOMES*

In the first year, Nathan had a strong understanding that SRE made society better overall, and should help others in poverty domestically and abroad. In his second year, his understanding additionally included an engineer's promotion of safety and comfort through their work. Nathan's third interview revealed that his ideas of socially responsible engineering had continued to become more local and aligned with on-the-job microethical dilemmas. His internship did provide a better understanding of how engineers directly impact communities as he traveled to the company's project sites, but also seemed to push him to believe that his main responsibility as an engineer is to satisfy the client. One influential class in his junior year was about being a practicing engineering professional where he learned about "situations where you have a boss telling you that you have to do this one way and you know that's wrong…, but at the same time, they were getting around the law somewhere." He also described how an engineer needs to consider all who would be impacted by a decision, research multiple options, and ensure the negative effects are mitigated.

Towards the end of the third interview, when asked about his family and sister from Central America, he replied, "I don't know if I see it happening with my career as much now as I did before, but I definitely would still want to take the time to go on some sort of trip or plan something and try to help these communities." Nathan still saw engineers as having great social responsibility, but rather than to bring people out of poverty, engineers can fulfill this responsibility by researching all solutions to any given problem confined by the company and client for whom the engineer works.

Comparison of Jason, Julie, Kim, and Nathan

In summary, each of these four students conceptualized socially responsible engineering in different ways, though some common threads did emerge. Jason and Nathan believed that status quo engineering practice is socially responsible; they believed that, by its nature, engineering makes society better for everyone. Similarly, mechanical engineering students Jason and Julie both believed that technology, which engineers advance, improves society at large. Julie and Kim both had ideas that beyond technical work, underrepresented groups needed to be included in engineering through outreach and accessibility. Julie and Kim also included environmental protection, though in different ways. See Table 20 for a condensed statement of these students' third year ideas about socially responsible engineering.

Table 20: Highlighted Students' Understandings of SRE in Year 3

Student	Socially Responsible Engineering…
Jason	is the ethical engineering industry as it is now, which is powerful enough to improve local, and possibly global, society at large, mainly through advances in technology that will make life easier and improve the economy.
Julie	advances technology that hopefully, but not necessarily, gives back to society at large (i.e. alternative energy), or helps particular people (i.e. assistive technology or prosthetics); and, could include outreach and volunteering outside of or through a company with the time and resources they have available in order to increase opportunities for others.

Kim	preserves and protects the environment, is done properly and safely, prioritizes the environment and society over profits, and should be accessible to all who are interested regardless of their pre-college educational backgrounds.
Nathan	is most of the engineering industry that provides the best service possible for all impacted stakeholders by considering all available and reasonable solutions.

DISCUSSION

Socially responsible engineering is a complicated idea, and students are reaching their personal conceptualizations of SRE from diverse influences within and outside of the higher education environment. These 20 students give insight to the differential weighting of any particular experience's impact on students across different majors and universities. Further, some influences change over time, and others persist. The four highlighted students explained in their own words how certain influences were more powerful and what specifically led them to access these experiences or discussions with individuals.

While the *Inputs* are not completely under the control of the university, many efforts could be made across the permeable boundary before the students enter college in order to prepare the students to have an advanced and accurate idea of what to expect in engineering related to social impacts. Twelve of the 20 students were impacted by EWB; while none of them continued involvement through their third year due to a lack of time or organization within the group, this awareness expanded engineering's connection to helping humanity in these students' minds. On the other hand, 15 of the 20 students discussed the message they received from high school teachers, parents, and their own research, that 'if one was good at math and science in high school, then engineering would be a good fit.' Entering college with this mindset might already close students off to the other crucial traits that they should develop as future engineers such as care, empathy, and passion (Moriarty 1995, Capobianco 2011, 2014).

Additionally, if faculty can be more generally aware of engineering students' pre-college experiences and interests in volunteering, travel and high school engineering, faculty can make their courses more directed. Students spoke of the high impact of courses connected with the 'real-world,' but this was usually only in the first-year introduction to engineering course or not until the third year.

As other studies have discovered, a major component of the dearth of diversity in engineering, is that the profession became inaccessible or uninteresting to potential future professionals (National Academy of Engineering 2005; M. Eisenhart et al. 2015; Capobianco et al. 2011). Thus, the *Inputs* dimension deserves a more focused and ideally, longitudinal study. Collaboration with early education and sociology researchers would be productive since they have a longer history with this type of research.

Impacts through the Higher Education *Environment* are the ‘low-hanging fruit’ that has been studied intensely. Engineering ethics courses are important, though still seem to teach limited understandings of the responsibilities of engineers (microethics vs macroethics) (Herkert 2005), and what they are required to do to avoid lawsuits and loss of life rather than the larger impacts of engineering work (Winner 1990). Engineering ethics course are another important opportunity for professors to increase students’ awareness of the “social context of engineering” (Herkert 2000).

Eleven students said in the third year that an engineer’s responsibility is to the company and make a profit for the company. They said this first – before safety or impacting society in a positive way. Though we did not ask the exact same question in the first year, the general feeling was that students were initially more interested in bettering society through engineering than making money for a company. This is a troubling change of priorities between the first and third years. Based on these interviews, this seemed to result from a combination of a lack of macroethical messaging within the engineering curriculum and witnessing what was valued highest in their engineering internships.

At the porous boundary of the Professional and Higher Education *Environments* lies the powerful engineering internship. Pressure from advisors, and university at large, to get an internship may need to be tempered. From these longitudinal interviews, it can be seen that initial humanitarian priorities may fall below the company’s profit-driven priorities. If students are fully immersed in a company culture that only promulgates microethical responsibilities such as cost-efficiency, correct calculations, and occasional donations, students like Nathan and Jolene will come to believe that these are the only social responsibilities of a practicing engineer. Students also talked about messages through the media and career fairs. If advertising is mainly about ‘cool technology’ rather than the potential positive impact of engineering, students who do have an advanced understanding of socially responsible engineering may begin to dissociate themselves from the profession, and those who have a limited understanding will have their ideas reinforced. This perpetuates the cycle that Cech (2014) described as a "Culture of Disengagement."

At the same time, students did engage in ways that exposed them to how engineering can act on a high level of social responsibility. Co-curricular activities such as K-12 outreach, with which nine students were involved, research, and engineering societies play a large role in shaping students' ideas. If the activities and messaging in the co-curriculum were more connected with the curriculum, students may begin to see the skills and values in volunteer or outreach as aligned with engineering practice rather than on the margins of 'real' engineering.

Overall, these conversations show many opportunities in different spaces through which students travel that could improve students' understanding of the potential impacts of the engineering profession, and possibly to push the profession to be more socially responsible once these students become "Novice Professional Practitioners."

Limitations and Validity

As it is not possible to understand the students' complete ideas on any issues, interpretation of the students' words by the researchers was necessary. Both authors have backgrounds in civil and environmental engineering. It became clear through the interviews, but also through discussions about this study, that the authors have a particular lens through which they see student experiences, and the role of engineers and engineering educators. As described in the methods, the authors reached out to one professor in mechanical engineering, one undergraduate student, and another reviewer in the School of Education who has a wealth of experience with qualitative studies in science and engineering education. Each of these reviewers brought their own perspectives and expertise to help ensure a balanced understanding and presentation of the students' ideas.

Of the 236 first year students with validated responses to the EPRA Survey, 75 checked a box that they would like to be interviewed. The incentive of $100 for completing the interview was not mentioned when the students would make this decision of whether or not they would like to participate in an interview. Perhaps, the students in this study were more interested in speaking about social responsibility than other engineering students. This may also account for why more students in the lowest quartile of EPRA scores did not participate in the interviews associated with this study. Besides these issues, there is little reason to believe that the students are drastically different from the larger pool of engineering students overall. Relatedly, the first interview with Kim was in person, and possibly that setting made her more uncomfortable and less willing to deeply explore and share her ideas. Further validity and reliability measures are planned at the end of this study, which is still ongoing, and those are described in more detail in the 'Future Work' section below.

FUTURE WORK

The students in this study will be interviewed a fourth time at the end of their fourth year of engineering school. Based on future plans described at the end of their junior year, some students will likely graduate after 4.5 or 5 years, some will pursue graduate degrees, and one will graduate early and already be a practicing engineer. Most will be interviewing and getting job offers. The specific interview questions have yet to be developed, but this will be a chance to find out the students' thoughts about SRE as they are on the precipice of the profession. Additionally, this will be an opportunity to perform a member check to get the interviewee's opinion and feedback about the research group's interpretation of their experiences.

The authors are concurrently continuing additional research into engineering students' ideas about SR. One study focuses on how engineering students envision themselves as socially responsible engineers in the future and how these ideas change through college; it involves students' discussions around how they balance and mesh their ideas around personal and professional responsibility over three years of interviews (Chapter 5). A second related study analyzes the social responsibility-related narratives of nine students who left engineering, and how students' backgrounds and ideas around SR influenced their decision to leave for another major and anticipated profession (Chapter 6).

CONCLUSIONS

Socially responsible engineering does not have a single, agreed-upon definition by engineers, engineering educators, nor the engineering students in this study. These twenty students, and particularly Jason, Julie, Kim, and Nathan, illustrate different visions of socially responsible engineering. Engineering students' enter college with complex backgrounds. Some give students a predisposition for wanting to help society through engineering – experiences such as volunteering (domestically and internationally), which lead to a larger awareness of situations in society. Some students developed their ideas of SRE in engineering classes and co-curricular activities such as EWB and outreach. These seem like powerful avenues through which engineering can be seen to help. Other students, however, did not experience a college environment that fostered an idea that engineering could or should be connected strongly with their own perceptions of social responsibility. Instead, they interpreted from engineering professors, professionals, and sometimes family members that engineering is a "good job" that is inherently socially responsible if the codes of ethics are followed and the public is kept safe. These influential members of a student's environment could instead increase an engineer's sense of responsibility to consider the marginalized global society that has not historically been as positively impacted by engineering advances.

Trying to understand over multiple years the strongest influences for any particular student shows the diversity of thought and experiences in an engineering student's college career. Overall, it seems like more communication and discussion about what engineering practice could entail with regards to social responsibility would allow students to make more informed decisions about their future. The balance of where engineering efforts are spent needs to be addressed, and more role models concretely striving for a more just world through a commitment to a more ambitious understanding of SRE should interact with students. Engineering students should be encouraged to make changes within the spaces they operate, or will operate - amongst their peers, their internships, and their future jobs. As students become 'Novice

Professional Practitioners,' they can collectively change the status quo of engineers failing to ask their employers, and themselves, 'who is this really benefitting?' The students in this study have shown unsurprisingly that engineering students are caring in their own ways, but it's also clear that they need more opportunities to discuss, engage with, and serve society in meaningful ways. Then, they can begin the process of fulfilling the engineering's potential to be wholly socially responsible.

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CHAPTER V: DEVELOPMENT OF ENGINEERING STUDENTS' DESCRIPTIONS OF THEIR FUTURE SOCIALLY RESPONSIBLE ENGINEERING PROFESSIONAL SELVES: A THREE YEAR LONGITUDINAL STUDY

ABSTRACT

All engineering students develop and mature through their four or more years in college as they prepare to become part of a socially impactful profession. Presently, students' ideas about how they will be socially responsible engineers in the future remains unknown. Understanding more about students' evolving ideas about how they plan to integrate their motivation to be socially responsible with their chosen profession can give insight into how to improve the alignment between students' personal and professional lives. This study includes three years of longitudinal interviews with engineering students. The interviews consisted mainly of questions regarding experiences with social responsibility, engineering, and the combination of the two. The interviews were analyzed using an Ethic of Care framework, which allowed for the students to be categorized into one of four types that emerged from the student responses. These types described how strongly students integrated their social responsibility values with their motivation to pursue engineering. Each year, some students switched types and some left engineering altogether. Most engineering students seemed to settle on the idea that engineering improves society overall. For some, this was a major motivation, and for others it was a nice bonus of the profession. These results assist in developing the baseline for what students are experiencing and thinking through their years in college, gives insight into how students are internalizing their experiences. The results also provide some guidance in developing an engineering educational experience that promotes a more socially responsible and caring career path.

Keywords: social responsibility; qualitative research; longitudinal; alignment

Introduction and Background

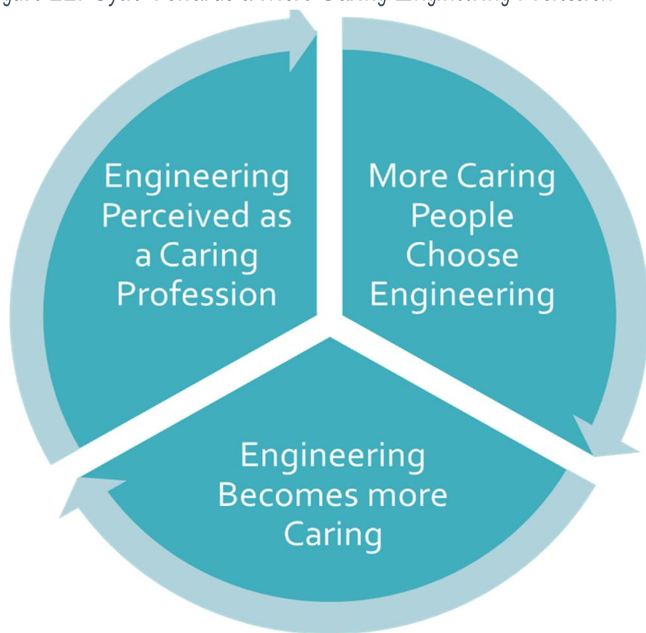
Due to the nature and significance of their work, the engineering profession must consider its impacts on society. In this study, social responsibility is defined as an ethical duty one has to act in ways that benefit all of society and the environment proportional to the opportunities and skills which one has been afforded. For engineering students to recognize that they will have this social responsibility through their profession, and to feel empowered by it, is important. An open question, however, is how students are conceptualizing what this responsibility will be and how it will manifest itself in their future engineering practices.

In 2004, the National Academy of Engineering published a document describing the *Engineer of 2020* that would be able to address the complex problems of today and tomorrow such as climate change, extreme inequality, and the impact of rapid technological growth in a global world (National Academy of Engineering 2004). All of these issues, and more, relate to how responsible an engineer feels for society, and how they act on these recognized obligations within the varied societal structures of business, culture, and geography. Some engineering faculty have been growing programs to improve student learning while developing attitudes and feelings about their responsibility and potential to have a positive impact on the lives of others (Bielefeldt 2015, Vanasupa et al. 2007).

At the same time, some believe that current engineering education does not adequately provide a space for thinking and learning about care and social responsibility in engineering (J. Lucena 2013; Zandvoort et al. 2013; Didier and Derouet 2013). Further, perceptions of engineering as masculine and uncaring may contribute to the low representation of women in engineering (National Academy of Engineering 2008); women comprise about 20% of engineering Bachelor's graduates (Yoder 2014) and only about 10% of engineers in industry (Bureau of Labor Statistics 2014). Possibly, if engineering education can be more socially relevant and caring, it will attract and retain more women, whom the profession needs (Capobianco and Yu 2014; Campbell and Wilson 2011; National Academy of Engineering 2005).

This study uses a framework of the Ethic of Care to help understand how social responsibility fits into the practice and perception of engineering. Moriarty (1995) described how the *ethos* of engineering, which is stronger and more ingrained than codes of ethics, could change to be about care (Moriarty 1995). In this way, engineers could be oriented outwards, thinking of others in their work, rather than continuously adhering only to the microethical constraints of law and safety. An issue for developing an ethic of care in engineering is the many levels that separate most engineers from the societies they impact. Noddings (2013) described that care relies on reciprocity, and with bureaucracy separating engineers from clients and communities, care has not penetrated in the same way as medicine or law (Noddings 2013). Strict, technical engineering can be applied in a near vacuum. As engineering students describe how they plan to practice engineering in the future, viewing their ideas through a lens of care allows for a classification of students on a spectrum of care ethics. Further, previous work conceptualizing social responsibility posits that one cannot reach his or her full social responsibility potential if it is not integrated with one's career and personal life, and that personal and professional cyclically influence each other (Moriarty 1995). This study builds on Canney's (2014) understanding as explained through the Professional Social Responsibility Development Model, where individuals can develop their ethic of care and personal social responsibility ideas independent of their profession, and that one can develop their social responsibility due to or encouraged by a caring profession. In order to reach the highest levels of personal and professional social responsibility, individuals must act on their social responsibility through their personal and professional lives (N. Canney and Bielefeldt 2014). With caring individuals as part of this profession, the profession would become more caring, and be perceived as such; more caring people will choose this profession as it aligns with their personal values (Wilson et al. 2011; Matusovich, Streveler, and Miller 2010). This cycle is shown in Figure 11. For more sustainable and deeper integrations, care would permeate both one's personal life and profession (Delve, Mintz, and Stewart 1990; N. Canney and Bielefeldt 2014). Further, Pantazidou and Nair (1999) write that if engineering design is practiced with an ethic of care, by focusing on relationships and orienting oneself outwards, more equitable and socially responsible engineering services would be provided consistently (Pantazidou and Nair 1999). These types of efforts would help to "Change the Conversation" about what an engineer does and who an engineer is or can be (National Academy of Engineering 2008). If engineering students would talk about their social responsibilities as engineers in this way, with a focus on others that will benefit from creative engineering work, the engineering profession could become more caring.

Figure 11: Cycle Towards a More Caring Engineering Profession



With a lens of care ethics, this study attempts to understand how engineering students envision themselves in the future as socially responsible engineers, and how this idea of their future selves changes as they progress through their first three years of engineering school.

METHODS

Qualitative research methods (interviews and coding) were used for this study to answer the 'how' questions posed above. Quantitative research can be effective for large, surface level understanding of engineering students' social responsibility, but the value of deep interviews quickly became apparent. At the end of their first year of college, 34 engineering students were interviewed (33 in March to June 2013, one in August 2013). Most of these same students were interviewed in each of the following two years in March to June of 2014 and 2015, at the end of their sophomore and junior years, respectively. Students' attitudes during these "middle years" have not been well-studied to date (Tsai, Kotys-Schwartz, and Knight 2015; S. M. Lord and Chen 2014). It was important to understand how the students' developed as it was happening, rather than just the beginning and final year results (Sheppard et al. 2010).

Using criterion-based selection (Miles, Huberman, and Saldaña 2013), the students in this study initially represented (i) a range of attitudes toward social responsibility (SR), indicated by their average SR score on 50 Likert items (with a potential range from 1 = low SR to 7 = high SR; actual range 4.00 to 6.80) (ii) a high oversampling of women in engineering (62% in this study vs. ~20% enrolled in engineering), and (iii) four universities. Students' attitudes about social responsibility were initially assessed quantitatively via the Engineering Professional Responsibility Assessment (EPRA) instrument administered within the first month that the students entered college, resulting in the so-called Y0 SR average score (N. E. Canney 2013). The fifty items that map to SR are actually grouped into 8 dimensions; the professional connectedness (PC) dimension is most relevant to this study. PC was defined as "a sense of moral obligation to help others because of the professional skills that one possesses" and includes "public safety, environmental protection, pro bono work, and viewing engineering projects as service" (N. Canney and Bielefeldt 2014).

A summary of the demographics of the 20 individuals who remained in engineering and the nine who left engineering and participated in the interviews all three years are shown in Table 21. The students were initially majoring primarily in mechanical engineering (ME; n=11), civil engineering (CE; n=9), and environmental engineering (EnvE; n=9); at two institutions (PrU and Military Institution), students did not start with declared engineering majors, so the students were asked about their likely engineering major (n=5). The students selected for interviews were initially enrolled at four institutions: a large public research-intensive university (LPU; n=11), a medium-sized technically-focused public university (TechU; n=9), a medium-sized public university (MPU; n=6), and a medium-sized research-intensive private university (PrU; n=8); students at a Military Institution participated in the EPRA survey but none consented to participate in the interviews. The majority of this demographic information was supplied by the students via the online survey (EPRA, see Canney 2013). In Table 21, the students are presented in order from highest initial SR score to lowest among those who stayed in engineering (listed first) and left engineering (listed at the bottom of the table). Of the 34 students initially interviewed, one stopped attending college and four did not participate in the interviews during all three years; these individuals are therefore excluded from *Table 21*. Of the 29 students who participated longitudinally, 19 were female and 10 were male, two students were non-Caucasian, four were first generation college students, and four were somewhat or strongly affiliated with a major religion. All of these students entered college immediately following high school with the exception of Derek, who started college at age 21.

Table 21: Initial Demographics of 29 Interviewed Students (those who left engineering are listed below the solid line)

Pseudonym	**Gender**	**Race/Ethnicity**	**First Gen**	**Y0 Major**	**Institution**	**Y0 SR Avg Score**
Sarah	F	White	**Yes**	CE	TechU	6.55
Jolene	F	White	No	CE	TechU	6.55
Shawn	M	White	No	EnvE	LPU	6.46
Derek	M	White	No	ME	PrU	6.34
Katherine	F	White	No	CE	MPU	6.28
Nathan	M	White	No	CE	TechU	6.12
Tanya	F	Afr-Am	Yes	EnvE	TechU	6.10
Rachael	F	White	No	CompSci	PrU	6.10
Denise	F	Hispanic	Yes	ME	PrU	5.96
Wynne	F	White	No	CE	LPU	5.88
Julie	F	White	No	ME	PrU	5.88
Brandon	M	White	No	EnvE	TechU	5.82
Ashley	F	White	No	ChE	PrU	5.62
Jamie	F	White	No	ME	TechU	5.62
Kim	F	White	No	EnvE	LPU	5.54
Trevor	M	White	No	EnvE	MPU	5.52
Tucker	M	White	No	CE	LPU	5.48
Todd	M	White	No	ME	TechU	5.12
Madison	F	White	No	ME	TechU	4.86
Jason	M	White	No	ME	TechU	4.68
Jocelyn* **	F	White	No	ME	LPU	6.80
Katie**	F	White	No	CE	LPU	6.58
Kaitlin*	F	White	Yes	EnvE	MPU	6.08
Maggie*	F	White	No	CE	MPU	6.02
Lindsey**	F	White	No	BiomE	PrU	6.00

Miranda**	F	White	No	ChE	PrU	5.98
Alicia**	F	White	No	ME	LPU	5.64
Nelson*	M	White	No	EnvE	MPU	4.82
Thomas***	M	White	No	ME	LPU	4.00

* Student left engineering by the first interview; **by the second interview; ***by the third interview
Additional Engineering Majors: CompSci – Computer Science; BiomE – Biomedical; ChE - Chemical

Semi-structured interviews up to 90 minutes in length were conducted by the same male doctoral researcher from February-August 2013, March-April 2014, and March-April 2015. Only the audio was recorded. An incentive of $100 was offered for completion of each interview. In the first year, six interviews were conducted in person, three by phone, and two through Skype to discover which medium elicited the best responses. All future interviews were conducted by phone. A structured interview protocol might have limited students' development of ideas, so the interview was allowed to flow naturally and the interviewer asked the written interview questions when appropriate (Saldaña 2012; M. A. Eisenhart et al. 1998). After the first interview, each interviewee was assigned a pseudonym using standard naming conventions (Ogden 2008). Interviews were transcribed verbatim into Microsoft Word using Dragon voice recognition software (*Microsoft Word* 2013; *Nuance Dragon Speak* 2013). Then, each interview transcript was read through and edited while listening to the interview to produce a more accurate record. This transcript was then imported into Nvivo 10 for continued qualitative analysis (QSR International 2013).

Each interview included about ten open-ended questions, which encouraged students to (i) think about engineering, (ii) helping others and their thoughts about social responsibility, and (iii) combining the two large concepts, which may or may not have been connected for each student. *Table 22* shows the interview questions from each year that are the most relevant for this study.

Table 22: Relevant Interview Questions from Years 1, 2, and 3

Year	Question
1, 2	What is your current vision for an ideal engineering career?
1, 2, 3	Does your sense of social responsibility move you towards or away from an engineering career? [Y2, Y3] Has this changed significantly since last year?
1	Is there one issue that you feel particularly passionate about trying to address? Why? Can your engineering abilities help with this goal?
2	What are some specific qualities of a job that you are looking for? Why are these qualities important?

Year	Question
2, 3	How do you expect social responsibility will be part of your future engineering career? How strongly and in what ways?
3	What are the responsibilities of an engineer? Why do you think so? - Who are engineers responsible to or for?
3	What is the engineer's role in impacting people in society? - How should an engineer impact people in society?
3	How do you think your ideas around personal social responsibility influence your ideas about professional responsibility and vice versa?
3	Think aloud through the drawbacks and benefits of incorporating social responsibility into your engineering career. How about pro bono work?

Additionally, specific questions for each student were developed for the third year, which followed up on a particularly interesting and potentially influential experience that the students had discussed in the previous years. This process yielded many interesting results, and some of them are presented in the next section.

In the first year, a code book from these interviews was developed between three researchers that included specific codes under the larger headings of students' definitions of social responsibility, influences on their understanding, students' connections of engineering and social responsibility, and how the students were motivated to pursue engineering due to social responsibility-related reasons. These exploratory codes gave the research team a base from which to grow in the next two rounds of interviews and identify changes in students' ideas.

All of the research was conducted according to methods and protocols approved by the University of Colorado Institutional Review Board for Human Subjects Research, Protocol 11-0414, and included informed consent before each interview and online survey.

Results and Discussion

On the whole, students went through many changes during college that opened them up to ideas about what they could do as future socially responsible engineers, but also closed or pushed aside some other loftier goals that some of the students held when entering college. The general results of this study are similar to the results seen in the quantitative study of social responsibility ideas of engineering students – the students who started with a lower SR score increased, and those with a higher score decreased or left engineering (A. R. Bielefeldt and Canney 2015).

Overall Findings – SR Type Categorizations in Year 1

Students were categorized based on their beliefs about how they would incorporate their own ideas about social responsibility into their future engineering jobs, as revealed through their interview responses. This grouping in the second and third years built from the 'Types' defined using the first-year, exploratory interviews. More details about this analysis are available in Rulifson et al. (2014). In order from Type 1 to Type 4, students in each have a more to less advanced and caring idea of how they want to act on their social responsibility through engineering. With these ways of thinking about how the students describe themselves, the researchers were able to compare their responses in each year to this conceptualization. The SR type descriptions are shown below in Table 23 with the students who fit into these categories during the first year. Also, students' average SR and PC scores from Y1 are shown. The PC score is the 'professional connectedness' score which was determined from a subset of the EPRA survey. These questions all related to how strongly the students felt that engineering and helping others were connected. The average SR and PC scores of Type 1 and Type 2 students are similar; both of these Types have higher average SR and PC scores than Type 3 and Type 4 students.

Table 23: 'Type' Descriptions - How Engineering Students Personally Integrate Engineering and Social Responsibility

Type	**Students**	**Y1 SR Score**	**Yr1 PC score**	**Type Description**
1	Katie**	6.94	6.88	Students' reasons for choosing engineering as a major and future profession were strongly related to their own strong sense of social responsibility that involved an acknowledgement of the inequalities present in the world from which the marginalized and disadvantaged suffer. Typically, these students also had significant experience with volunteering and/or international travel that exposed them to issues, with which they believed engineering could help.
	Jocelyn***	6.31	6.21	
	Nathan	6.14	5.95	
	Maggie*	6.15	5.76	
	Jolene	5.78	5.74	
	Kaitlin*	5.76	5.63	
	Miranda**	5.69	5.47	
	Alicia**	5.54	5.32	
	Wynne	5.60	5.00	
	Nelson*	4.74	4.47	
	Average	**5.87**	**5.64**	
2	Sarah	6.70	6.65	Students wanted to better society at large with engineering, and this environmental or social
	Shawn	6.02	5.68	

Type	Students	Y1 SR Score	Yr1 PC score	Type Description
	Denise	5.80	5.63	responsibility, which was often broad and vague, was a reason for choosing engineering. For example, some students wanted to conserve the natural environment for their future job, so they chose environmental engineering.
	Jamie	5.96	5.53	
	Lindsey**	6.08	5.53	
	Brandon	5.70	5.42	
	Kim	5.46	5.37	
	Tanya	5.44	4.68	
	Average	**5.90**	**5.56**	
3	Derek	6.18	6.05	Students enjoyed volunteering and believed helping others was important, but did not associate this sense of social responsibility with their own engineering vision. Their job in the future was more to be stable and interesting, rather than helping society. Possibly through their employers or the salary they would make, they would be able to volunteer, but not necessarily as an engineer.
	Julie	5.74	5.21	
	Rachael	5.72	5.05	
	Trevor	5.34	4.53	
	Jason	4.96	4.16	
	Madison	4.94	4.00	
	Katherine	-		
	Ashley	-		
	Average	**5.48**	**4.83**	
4	Tucker	5.48	5.21	Students had thought little about social responsibility or the social context of engineering at the time of the interview, and possibly had not participated in much non-required volunteering. For these students, their responsibility was largely limited to legality, safety, and microethical adherence. Many were focused strictly on their studies and those closest to them.
	Todd	5.24	4.53	
	Thomas***	4.80	4.28	
	Average	**5.17**	**4.67**	

* Student left engineering by the first interview; **by the second interview; ***by the third interview

Their Y1 SR score and PC score is also shown for comparison with the types. Some students did not participate in the Spring 2013 EPRA distribution (Katherine, Ashley). Notice that the EPRA average scores generally correlate with the types. For some students, changes in their score between Y0 and Y1 were significant as a result of finding out more about what engineering actually is and what engineers do. At the time of the Y1 survey during the second semester of their first year of college, 79% of the students described being influenced by their engineering classes, and six of these explicitly discussed learning ethics in their introductory engineering class. It is also possible that students' ideas changed between their Y1 survey (February 2013) and their interview (April-May 2013). As expected, higher SR and PC scores are generally associated with the Type 1 and Type 2 students, but some lower scores, such as Nelson, are surprisingly found in the 'higher' SR types, which were determined exclusively by their first year interview. The following are example quotes from students that represent each of the types above.

Type 1 – Wynne, Y1 – "…we have so many communities abroad that are deficient and we have so many resources available to us and we do…there are things that people do to help but I think we can do more. And I think that's one of the reasons I'm involved with EWB because I feel like I can make a difference somewhere."

Type 2 – Shawn, Y1 – "I think engineers have a big part of that, as a society were always trying to move forward and I think science and engineering stuff like that, we're pushing everything forward in our making advances were making people's lives better, so I think it's a great thing."

Type 3 – Katherine, Y1 – "I don't think [SR] is deterring me from an engineering career but I also wouldn't consider it my motivation to become an engineer. I think those are sort of like 2 separate spheres of my life. Sort of what I want to do academically and career-wise and what I want to do on a philanthropic and personal level. And I think that those two roads will meet but they just haven't intersected quite yet."

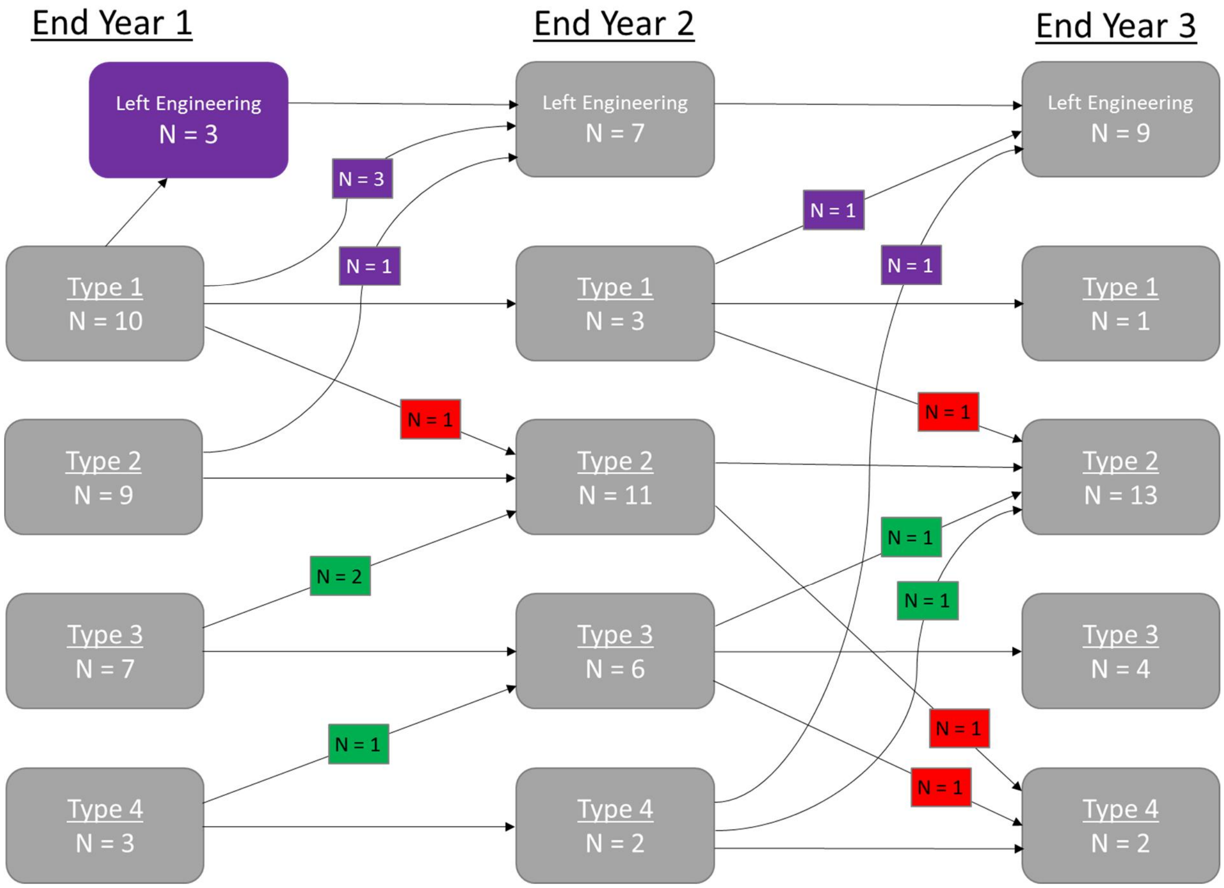
Type 4 – Todd, Y1 – "I know there are a lot of paths I can go down with engineering that could potentially improve the social atmosphere, but I don't know about me doing them as of right now."

Students described some particular influences that seemed to shape their ideas about how they would be socially responsible engineers. Naturally, as they progressed through college, these influences changed from more personal (relatives, friends, high school teachers) to educational (professors, technical courses, peers) and professional (internships, professional societies). Each student had their own unique story, but certain common threads became apparent – largely, that students who stayed in engineering conformed to the ideals of the engineering profession as it was presented to them in career fairs and in classes, and as they experienced in their internships. The following section describes three students who represent some of this diversity.

Overall Findings – Changes in SR Types for Engineering Students Over Three Years

Figure 12 summarizes the SR types of the students with respect to their engineering aspirations over time.

Figure 12: SR Type Pathways over Three Years (Purple - students who left engineering; Green - students who increased in SR Type; Red – students who decreased in SR Type)



First, seven of the 10 engineering students classified as Type 1 at the end of their first year of college had left engineering by the end of year 3. In fact, 7 of the 9 students who left engineering were Type 1 at the end of their first year. This 69% retention (31% "loss") of students out of engineering majors is fairly typical (Yoder 2014; Ohland et al. 2008). However, it appears that Type 1 students were more likely to leave engineering than those students whose vision of engineering is less driven by a strong sense of SR. Type 1 students have the strongest desire to care for others through engineering. This is concerning, and a possible impediment to the cycle illustrated in Figure 11 if the most caring students don't earn engineering degrees and have the opportunity to affect the engineering profession. The students who left engineering will not be discussed further in the current paper; they are the subject of Chapter 6.

Table 24 shows individual students who stayed in engineering and their SR Types inferred from each of the interviews. The superscripts show what year the students changed their SR Type. Some did not change, so there is no superscript. The average Professional Connectedness (PC) score from the EPRA survey is also shown for comparison. In some cases PC scores changed, but overall SR type did not (i.e. Sarah). This illustrates the differences in the depth of understanding achieved from the student interviews, versus the information that can be obtained from Likert items.

Table 24: Student Pathways Through Engineering and SR Types

Pseudonym	Major	Institution	SR Type	PC Score (Y1/Y2/Y3)
Nathan	CE	TechU	$1 / 2^{3}$	5.95 / 5.79 / 5.79
Jolene	CE	TechU / $MPU2^{2\text{-}3}$	$1 / 2^{2\text{-}3}$	5.74 / 6.16 / 5.71
Wynne	CE^{0} / $ArchE^{1\text{-}3}$	LPU	1	5.00 / 6.05 / 6.00
Sarah	CE	TechU	2	6.65 / 6.00 / 5.29
Shawn	$EnvE^{0\text{-}1}$ / $ChE^{2\text{-}3}$	LPU	2	5.68 / 5.42 / 4.79
Denise	ME	PrU	2	5.63 / 5.53 / 5.64
Jamie	ME	TechU	2	5.53 / 4.50 / 5.14
Brandon	$EnvE^{0\text{-}1}$ / $CE^{2\text{-}3}$	TechU	2	5.52 / 5.53 / 5.00
Kim	$EnvE^{0\text{-}1}$ / $CE^{2\text{-}3}$	LPU	2	5.37 / 5.16 / 5.21
Tanya	EnvE	TechU	2	4.68 / 5.53 / 5.79
Derek	ME	PrU	3	6.05 / 5.79 / 5.36
Julie	ME	PrU	3	5.21 / 4.63 / 4.86
Rachael	CompSci	PrU	$3 / 2^{2\text{-}3}$	5.05 / 5.26 / 4.71
Trevor	$EnvE^{0}$ / $CE^{1\text{-}3}$	MPU	$3 / 2^{2} / 4^{3}$	4.53 / 5.32 / 4.93
Jason	ME	TechU	$2 / 4^{2} / 2^{3}$	4.16 / 3.79 / 4.64
Madison	ME	TechU	3	4.00 / 3.79 / 3.00
Katherine	CE	MPU	3	- / - / 5.79
Ashley	ChE	PrU	$3 / 2^{3}$	- / - / 5.00
Tucker	CE	LPU	$4 / 2^{3}$	5.21 / 5.32 / 5.21
Todd	ME	TechU	$4 / 3^{2} / 4^{3}$	4.53 / 4.16 / 4.79

At the beginning of each EPRA survey, students were asked to prioritize what they desired in their engineering careers by putting a total of ten stones into eight bins. The bins were salary, helping Others, Working on industrial or commercial projects, community development, living domestically, living internationally in a developed country, living internationally in a developing country, and owning a business. Table 25 below shows each student's responses over the four surveys.

Table 25: Prioritization of Helping Others and Community Development Over Four Surveys

Pseudonym	Helping Others	Community Development Projects	Sum
Nathan	4 / 2 / 2 / 2	1 / 2 / 2 / 2	5 / 4 / 4 / 4
Jolene	3 / 5 / 3 / 4	2 / 1 / 2 / 1	5 / 6 / 5 / 5
Wynne	1 / 0 / 2 / 2	1 / 0 / 2 / 2	2 / 0 / 4 / 4
Sarah	3 / 3 / 3 / 3	3 / 2 / 2 / 2	6 / 5 / 5 / 5
Shawn	4 / 3 / 0 / 1	0 / 3 / 0 / 0	4 / 6 / 0 / 1
Denise	1 / 2 / 2 / 3	2 / 2 / 2 / 2	3 / 4 / 4 / 5
Jamie	7 / 5 / 2.5 / 2	0 / 2 / 0.5 / 0	7 / 7 / 3 / 2
Brandon	2 / 1 / 2 / 1	2 / 2 / 2 / 3	4 / 3 / 4 / 4
Kim	1 / 2 / 3 / 2	2 / 1 / 1 / 2	3 / 3 / 4 / 4
Tanya	2 / 2 / 2 / 2	2 / 1 / 1 / 4	4 / 3 / 3 / 6
Derek	5 / 4 / 3 / 4	2 / 3 / 1 / 3	7 / 7 / 4 / 7
Julie	2 / 1 / 2 / 3	1 / 1 / 1 / 1	3 / 2 / 3 / 4
Rachael	2 / 2 / 1 / 2	0 / 1 / 1 / 2	2 / 3 / 2 / 4
Trevor	1 / 1 / 2 / 1	1 / 1 / 0 / 0	2 / 2 / 2 / 1
Jason	1 / 1 / 0 / 1	0 / 0 / 0 / 0	1 / 1 / 0 / 1
Madison	1 / 1 / 0 / 0	0 / 0 / 0 / 0	1 / 1 / 0 / 0
Katherine	3 / - / - / 3	4 / - / - / 2	7 / - / - / 5
Ashley	3 / - / - / 3	1 / - / - / 2	4 / - / - / 5
Tucker	2 / 2 / 2 / 3	1 / 1 / 1 / 2	3 / 3 / 3 / 5
Todd	2 / 1 / 2 / 1	0 / 1 / 0 / 0	2 / 2 / 2 / 1

The results above generally follow the order of the SR Types, but some do not align well with the SR Types assigned through the interviews alone. For example, Jamie and Derek highly prioritized helping others in their future careers in their survey responses (though Jamie decreased significantly), but did not discuss this importance during their interviews when given the opportunity. These potential contradictions show the value of mixed methods research and will guide some of the questions that should be asked in the fourth year member check.

Among the 20 students who remained in engineering majors during the study, 12 stayed the same SR Type through all three years, although most changed to some extent within their SR Type. For example, a student who believed in the first year that their engineering career would improve life for everyone in the world, while in the third year they commented that they see themselves mostly impacting the local community. A local or general desire to impact society with engineering resulting in a Type 2 for all students is something towards which engineering education should strive. In comparing the first year and the third year, three students increased their SR Type (ex. Type 4 to 2), and three students decreased their SR Type. The "middling" trend observed longitudinally in another quantitative study, in which students with higher levels of SR decreased over time, and those with lower SR increased, was observed to some extent in these interviews (A. R. Bielefeldt and Canney 2015). Student ideas seemed to change subtly, so assigning a final type at the end of each year was not a simple task. Some students seemed to be in between two or more Types. Member checks with the students in the fourth year of interviews are planned in order to allow the students to directly comment on how they feel their ideas have changed after reading some of their key responses from the first three years.

Finally, nine of the students in this study who left engineering were still interviewed. In the first year, as Table 21 shows, seven of these nine students were classified as Type 1 based on their first interviews. Though their reasons for leaving engineering were varied, these were the students who desired to study engineering in order to improve the lives of those with far less privilege. This is concerning. While not discussed at length here, Chapter 6 describes their experiences in more detail that gives insight to the social responsibility-related reasons for their decision to leave the engineering field.

The next section of the results presents four students' evolution of ideas about how they saw themselves as socially responsible engineers in the future, and how they planned to act on their understandings of social responsibility in the future. These deeper explorations of students ideas serve to show the changes in the students' own words to get a feeling for how they were discussing these ideas and some of the nuance within their statements.

Student 1: Tucker, Type 4 to Type 2, CE, LPU

Tucker was one of only three Type 4 students with respect to engineering SR attitudes at the end of the first year of college. Tucker was majoring in Civil Engineering and remained in this major attending Large Public University over three years of college. Tucker had the least developed definition of SR among all of the students who were interviewed in the first year. He said, after a little prodding that it's "just like, not be fraudulent and keep to your word and stuff, and having good ethics I guess." It seemed that he had not been asked to consider the concept before. He certainly did not articulate any SR goals for his own engineering career. As such, he was categorized as Type 4 with respect to his SR aspirations in engineering. He described some influences such as an engineering ethics module of his introduction to civil engineering course and witnessing cheating in his college courses. Tucker was not involved with any volunteering or even extracurricular activities during his first year of college.

Tucker did become more involved during his second year, but not through activities that would, on the surface, develop social responsibility. When asked about any ethics instruction, he replied, "My only real instruction on that was intro to civil engineering last year." He attended seminars put on by the Association of General Contractors and participated on the concrete canoe team where he gained some responsibility when he recognized that he had skills of value due to his experience with construction and formwork. He defined social responsibility as being "responsible for your own actions every day and following societal rules," but this did not seem to strongly transfer too much to his ideas about the profession. He did describe how communication is part of his social responsibility, on teams and in his future in construction. His experiences with a lack of communication on the concrete canoe team lead to its incorporation in his definition of SR. Also, when asked about the most important component of any future job, he responded, "If they don't have ethical practices, I'm obviously not going to take the job." It seemed that this should not be conflated completely with the social responsibility of engineers, but carried significance to look forward to in the third year of interviews after he had a summer internship. At the end of his sophomore year, Tucker's engineering SR was still characterized as Type 4.

Tucker's year since the second interview was dramatic, and partially traumatic. He had an injury during his internship between sophomore and junior year while he was doing a construction rotation; this caused him to spend the rest of the summer recovering in the hospital. He described that it gave him time to think – he even considered leaving engineering and pursuing medical school. In terms of social responsibility, though, he still believed that an engineer needs to "do everything right," but then said, "and to realize the impacts of whatever we do." Immediately, Tucker showed that he was thinking about the broader context of engineering than he had before. By saying "we," he showed his personal identification with the engineering profession. Later in the interview, when asked what engineers should be doing to impact society, he said, “We’re using our in-depth understanding of structures or something specific to come up with these buildings or dams or whatever that society needs.” As part of the profession, he feels that engineers are inherently benefitting society, but he had a hard time thinking about how engineering would play a role in social issues. It seems that Tucker is comfortable being part of the engineering profession that values honesty and safe products. He has advanced his understanding of how he, as an engineer, can impact society through quality and even sustainable buildings. This matches his own, somewhat limited, understanding of social responsibility that has grown through some of his own experiences while in college, but not primarily due to his classes.

Interestingly, Tucker describes the exact issue Moriarty (1995) discussed – that engineers are too separated from those impacted in order to grow the ethic of care. He said, “engineering is sort of not necessarily like, an instant feedback….You sort of know that what you have done is good.” He sees a stronger connection to people through medicine, like he received when he was recovering from his injury. Overall, though, Tucker seems happy with the responsibility taken by the engineering industry. At the end of the third interview, he said, “We’re doing things to improve what we do now…. I think if I were to become an engineer, I would do a good job of that.” At the end of his junior year, Tucker’s engineering social responsibility was characterized as Type 2. He saw the responsibility engineers have to society at large.

STUDENT 2: MADISON, TYPE 3, NO CHANGE, ME, TECHU

Madison, who remained a mechanical engineering major at TechU over three years of college, was classified as a Type 3 in the first year because she discussed a desire to volunteer and help others generally, but not through her work as an engineer. From the beginning of college, it seemed Madison knew that she wanted to work in the manufacturing industry, which she found fascinating through her father’s partnerships with engineers in the manufacturing industry. She already had an internship lined up for the summer after her first year of college. Interestingly, influenced by her engineering ethics instruction, she strongly believed that “engineers need to create or design things to better society as a whole." Then she went on to say, "It obviously depends on what they are focused in, like making the environment cleaner and safer or helping with humans, like medical wise, they just need to help society develop." She did not mention her own sector that she was planning to join. Additionally, while she was aware of EWB and efforts to assist the disadvantaged (especially with clean water projects), she did not discuss an interest in participating. At the end of the interview, again shifting the responsibility away from herself and her chosen profession, she expressed, "I think it's important that people are trying to put their social beliefs into effect and helping people, because there are people that need the help. I think that's really important and a good thing that people are doing that."

Madison's second year of college seemed to be spent looking forward to another summer at the same internship, as she found her classes uninteresting. She learned much more about the manufacturing industry the previous summer, and about what her role would be as a professional in the future. She understood her responsibility as an engineer rather specifically, saying "Everything you do in trying to engineer a plant like this is to try to make it easier on the employee working at the station." She elaborated using the word "care" when describing how she enjoyed the culture of the plant before describing that improving efficiency was also a top priority. Personally, she did not volunteer, but helped others in classes. She tried to help at a soup kitchen, but all the volunteer spots were booked for months. As in the previous year, she showed an awareness that there are needs of others, but did not feel empowered to try to address any issues. She explained, "You need to be a world leader or a big CEO where you have all the money and you can go and feed all these people." At the end of her sophomore year, Madison was again characterized as Type 3 with regards to her engineering SR goals.

By the third interview, Madison seemed to become more confident in her ideas about the nature of social responsibility in the engineering profession and personal life. When asked about the responsibilities of an engineer, she expressed mostly safety and solving problems that need solving. She continued later in the interview that, "In engineering, you need to provide products for people whether they are in need of it or not just to promote a better lifestyle…." With this statement, she began to explain her strong belief that personal and professional social responsibilities were separate. She said, "…in a professional area, you are, you sometimes have to forget about what your beliefs are and do what your company thinks. That is unless you think it is unsafe or something like that." Madison seemed to believe that this was an important component of an engineering job, to be part of the company. While she did believe that "a lot of the engineering companies, their goal is to make products that people will buy so they can make money," she saw local responsibilities as the way she would affect society through her engineering work by providing jobs to the community and making sure the plant was not harming the environment. She finished the interview in response to a question about pro bono work by saying, "As an engineer, my pro bono work is separate from my engineering work." She did not see this work as a responsibility of her company, but rather of herself as an individual with valuable skills to offer the disadvantaged sector of society. At the end of her junior year of college majoring in mechanical engineering, Madison remained characterized as Type 3 in her engineering SR attitudes, though she had developed some Type 2 characteristics.

Madison did not change her ideas very much over her first three years of college, but learned how she might be able to act on her personal social responsibility in the future. She seemed comfortable with her engineering job's contribution to the economy and the company without a large impact on society. From the beginning, Madison was motivated by her interest in the technical, problem-solving aspects of engineering, and she had no need to weave helping others into her professional ambitions.

Student 3: Rachael, Type 3 to Type 2, CompSci, PrU

Rachael, a student attending PrU, started with a double major in computer science and mechanical engineering, which she believed would lead her into the robotics profession. This double major ended up being too many classes, so she chose Computer Science. She started in engineering because she "always wanted to work on robots" and she "found them fascinating." She was raised with "engineers in the house" and had significant exposure to interesting technology, which she wanted to help create. At the same time, she volunteered often with her high school, which was "really big on, like, volunteer work and helping the community and all of that." She learned about the value of engineering and service independently, but they seemed to be balanced. She found a good match at PrU with its strong engineering program and culture of service. During her first year of college, however, she did not participate in any co-curricular activities, and focused intensely on her studies. Rachael did feel education was a very important social issue, and she was aware of some engineering service activities such as EWB. When asked if social responsibility moved her towards engineering, however, she replied, “I have always kind of kept them separate before. …my engineering career complements my social responsibility where it fits into it.” In the first year, she could think through the ways engineering could improve society in specific and general ways, but still kept her personal social responsibilities separate from those she found in her education. At the end of her first year of college as a Computer Science major, Rachael was characterized as Type 3 with respect to her engineering SR attitudes.

In the second year, Rachael was in a transition from being a Type 3 to a Type 2 individual. Over the summer between her first and second years, she taught middle school students programming. This contributed to her goals around addressing education gaps, and she started to see how her engineering experience was important both in teaching important skills and as a role model. Again, she discussed an awareness of how engineers can help address social issues, using the same examples as in the first year. She brought up a new personal interest early on – “making robots that will explore space.” Then, later in the interview, she described how working towards being prepared for life on another world is part of her social responsibility as an engineer:

> I guess in the sense of if technology is moving forward, then the overall lifestyle is moving up and if the overall lifestyle is moving up, then like those people that have poorer lifestyles, it will get better even if not much. And then the other thing I guess is that, specifically with exploring space and the finding other spaces to move out to, that it will provide new opportunities again in the same way that um, America was kind of used as a place to start again for immigrants and things like that.

Through this quote, Rachael showed how engineering inherently improves society. As such, any engineering she does would be socially responsible. Her goals, however, would push beyond engineers’ current social responsibility into the new frontier of space, and that is exciting to her. At the end of the interview, she states that engineering “happens to overlap” with her sense of social responsibility, but her “passion for engineering” motivated her to continue in the field. She seemed to fit more into Type 2 by the end of the second year interview.

Rachael’s third year of college was very interesting. As she finished her computer science classes, she became involved with drone research. She described that she was trying to design an unmanned aerial vehicle that would “fly and take pictures and record the radiation at those areas and take their GPS coordinates and come back with that data.” This research along with a project-based class gave her more concrete ideas about how she could use her education to make technological improvements that would help first responders be safer in disaster situations. She also recognized the controversy around drones through interaction with non-engineering students at PrU. Directly, she said that the “responsibilities of an engineer are…creating for society and keeping stable for progress and technology.” She went on to say about computer science in particular that “you have to create for society rather than for yourself…, which is sometime hard to keep in mind as an engineer.” She was aware that she enjoyed engineering for the sake of engineering, but has learned how her original interests in robotics can help society in dramatic ways. Even though she did not enter engineering to help society, her education and other opportunities such as research opened her eyes to her ability to have a societal impact. Thus, at the end of her junior year of college as a computer science major, Rachael was characterized as a “strong” Type 2 with respect to her SR aspiration in engineering.

Student 4: Jolene, Type 1 to Type 2, CE, TechU→MPU2

Jolene was a civil engineering student who spent her first year at TechU, which has strong connections to international development through engineering. She then transferred to a medium-sized, highly undergraduate public university (MPU2) near her hometown where she remained a civil engineering major (“The Carnegie Classification of Institutions of Higher Education” 2015). Jolene started off in college with a strong sense of social responsibility that she wanted to act upon through engineering. She was one of only three students characterized as Type 1 at the end of their first year of college who stayed in engineering; seven other Type 1 students left engineering majors. Early in the interview, and her engineering career, Jolene integrated her ideas about social responsibility with the education she would gain through engineering school:

> I believe that my social obligation is to use the resources that I have. Whether it's engineering or just my knowledge of anything or skills and use that to like, help other people to benefit communities as a whole and just do my part in making the world better. Any way I can.

In concert with her history of family volunteering internationally, organized religion, and her understanding of engineering through her parents' work, she was excited about an upcoming opportunity. She said, as part of missionary work, that "My dad and I are planning on going to Ethiopia and building a biogas digester." She continued to describe the project and her plan for her summer travel with her father. Similar to Sarah, Jolene originally wanted to get involved with EWB, and it seemed a good fit, but found school to be too much work. So, while she was motivated to continue in engineering due to her increased ability to help others, she did not participate in any service activities during her first year of college.

By the second interview at the end of sophomore year, Jolene had transferred to MPU2 in her hometown due to financial reasons and to be closer to her family and boyfriend. She also began working 20 hours per week at her father's wastewater treatment company. She learned about project management, and that type of work became her ideal career – being out in the field rather than in an office every day. Interestingly, Jolene discussed her social responsibility as an engineer in mostly microethical terms – honesty, safety, and not wasting money. She did not discuss her grand ideas from the year before about improving society through engineering. Finally, regarding her planned project in Ethiopia, she explained that she and her father "didn't get a chance to go ever because we haven't been able to get everything figured out, like, with the biodigesters." She was still interested in this type of work for her future, but did not see it integrated with her engineering job. Instead, she would "pretty much work here in order to get enough money to be able to go over there." Jolene had shifted the main thrust of her ideas about what she could do as an engineer to improve society from helping the marginalized and disadvantaged (such as those in Ethiopia) to an idea more aligned with the status quo of what engineers already do, which she was seeing in her internship within her home community. At the end of her sophomore year, Jolene's SR attitudes in regards to engineering would be characterized as Type 2, a decrease from her initial aspirations as a Type 1.

Jolene's ideas at the end of her third year were very similar to the end of her second year, and her ideas about how she planned to be a socially responsible engineer. She continued to work at her father's company through the summer and school year while taking a larger course load so she could finish in a total of four years. Her ideas about what she could do in the future as a civil engineer did not change, but were reinforced, and possibly aligned better with her personal ideas. She said that "to be an engineer is to contribute to society or is to help people," which seems to be a lifelong goal that she would prioritize highly. She explained, when discussing her potential engineering service-related future that "some people would rather go on a vacation, like on a cruise with their whole family, than use that money to go to a foreign country that they have never been to before and try to do something for someone else." She went on to describe her father's new project improving the wastewater treatment in one Caribbean nation with which she planned to be involved. While these are noble efforts, she still plans to volunteer at most one month per year, rather than devoting her engineering skills and time to the disadvantaged.

From the first year, Jolene's exposure to engineering service and social responsibility affected her interest in the profession. However, as she began to experience engineering in the 'real world' through her job, a more typical version of engineering emerged as the way she planned to spend most of her time. She recognized the value of civil engineering in her local community, and seemed content with contributing to these efforts in a friendly, comfortable company for her career. She was one of the most altruistic of the students interviewed, but still ended her third year as a Type 2.

SUMMARY

The SR aspirations of engineering students were found to be quite different for many students at the end of their junior year compared to the end of their first year. At the end of the first year, 34% of the students were Type 1, 28% Type 2, 28% Type 3 and 10% Type 4 (among 29 students). At the end of junior year, there were only 5% Type 1 (a decrease of 29%), 65% Type 2 (an increase of 37%), 20% Type

3, and 10% Type 4 (among 20 engineering students). The loss of those most motivated for socially responsible engineering to serve disadvantaged communities and people to non-engineering disciplines is possibly the most disappointing result of these interviews. It seemed they may have been drawn to engineering by messages from a "changing conversation" about engineering, but did not see these embodied within the culture of engineering. The engineering curriculum and environment should encourage students towards the higher 'SR Types' by showing the opportunities for a significant impact. Tucker's progression from Type 4 to Type 2 is encouraging as he came to realize how engineering has the power to impact society in positive ways. Todd's progression to Type 2, then regression to Type 4, however, is discouraging since he was influenced to believe that social impact would not be a major part of his future engineering career. The combination of his internship and what was valued in his classes made him believe that minimally including social responsibility in his engineering future was adequate.

In the first year, the students were almost equally split between the ways they planned to act on social responsibility in their futures. These numbers are encouraging. The engineering profession needs a diversity of interests in the field in order to fill the many varied engineering jobs that must be filled. These interviews showed that the students who would be pushing the engineering profession to be more caring, and take on more social responsibility, and not finding these ambitions supported or discussed in their engineering curriculum. The significant increase in students who were classified as Type 2 is important such that engineering students recognize their socially impactful roles as future professionals, and the fact that it integrates with their own SR desires indicates that they would be likely to stay in the engineering profession. To keep high ambitions for their future potential to impact society through engineering, these young professionals need to have experiences that encourage these ideas.

One emergent opportunity seems to be that mechanical engineering courses can teach students how their designs impact society, which could move some of the Type 3 students to Type 2 or even Type 1. The world is filled with mechanically engineered products, and it is possible that students would enjoy engaging with discussions around the repercussions of obsolete technology waste and the inherent value of a widget beyond its market value. Regarding gender, two main findings emerge: a disproportional number of women (7) left engineering, and six of them were Type 1; no women were ever classified as Type 4. This matches Canney and Bielefeldt's findings that women have higher SR than men in engineering.

Tucker's interview, especially in the third year, shows how educators do not fully control of student retention and ideas about social responsibility. Sometimes major personal experiences occur. Additionally, Tucker had a rare chance for reflection that most engineering students do not have. Many students seem very busy with overloaded course schedules and resume building through jobs and co-curricular activities; it is unclear that these students pause to critically reflect on society and their role in it. It shouldn't take a head trauma for students to have time to critically consider their educational decisions.

Madison's series of interviews shows that a student may just be committed to one thing they enjoyed. This may be well established due to their upbringing, and they enter college with these strong ideas. Even without knowing exactly why they are most interested in this, continuing to give more options is important. With Madison's deep interest in manufacturing reinforced by her positive experiences in her internship, she seemed not to consider any other career option. At the same time, she did not describe any courses in her second or third years that influenced her understanding of how engineers could or should affect society, particularly those without power in a capitalist society. Madison seemed to have high potential for thinking through ideas of how she might improve the lives of others through engineering, but was not given many concrete examples or opportunities.

In contrast to Madison, Rachael's experiences give a great example of some engineering students' varied interests and the different ways that students try to incorporate them with engineering or keep them separate in their minds and in practice. Rachael eventually found a promising path though humanitarian drone research that allowed her to act on her own desire to have a positive impact through engineering. While she would not be directly working towards her aforementioned desire to improve educational opportunities, she can continue to do that separately from her engineering work. If more students were presented with options such as those Rachael found, it is probable that their visions of their future engineering selves would include more social responsibility.

Finally, Jolene represents a growing subset of engineering students who choose the major because they want a way to use their education to improve the lives of others. It seemed, though, that in order to stay in engineering and be satisfied with her education, Jolene needed to temper her expectations of helping others directly and relegate this type of work to volunteering a small part of each year. While this is more closely aligned with what she would find in the current engineering workplace (Rulifson et al. 2015), more exposure to humanitarian engineering practices could have encouraged Jolene to be more optimistic about the impacts she could have in the future as an engineer. Like Madison, she did not describe courses that would have allowed her to consider these options.

These, and the other interviews, all contribute differing, but related concepts about the Ethic of Care in engineering. None of the students seemed against an engineering profession that was more caring, and some felt that engineering should be doing more to impact society in a positive way. They saw engineers as problem solvers and commented on issues such as climate change, hunger, shelter, and sanitation as examples of potential problems to be solved. With the intensity of engineering school and in some cases a lack of activism on campus, many of these students were not confronted by opportunities to engage and test out their learned engineering skills in a socially impactful way. With more opportunities, students can begin to act on their understandings of social responsibility and reach those higher levels theorized in Canney's PSRDM framework (2014).

Limitations and Validity

Of the 236 first year students with validated responses to the EPRA Survey, 75 checked a box that they would like to be interviewed. The incentive of $100 for completing the interview was not mentioned when the students would make this decision of whether or not they would like to participate in an interview. Perhaps, the students in this study were more interested in speaking about social responsibility than other engineering students. This may also account for why more students in the lowest quartile of EPRA scores did not participate in the interviews associated with this study. Possibly, some of the students were significantly influenced by the interview itself. Eight students mentioned that the interview brought up new ideas. For example, at the end of the first interview with Tucker, he said “I’ve never really, outside of these interviews really considered social responsibility.” Besides these issues, there is little reason to believe that the students are drastically different from the larger pool of engineering students overall. Relatedly, it is unclear if the students from the four participating institutions are representative of universities more broadly. Certainly there is significant overlap, but the four involved with this study are all doctorate granting institutions that offer social responsibility related programs within and outside of the engineering curriculum. Further, this study originally targeted only civil, environmental, and mechanical engineering majors. While mechanical and civil have the first and second highest number of bachelor’s degrees awarded, environmental is the 16^{th} highest and has a higher representation of women than is typical. In addition to other majors, this study did not deliberately include electrical, computer science, or chemical engineering – the third, fourth, and fifth largest engineering majors, respectively (Yoder 2014). Finally, this pool of students does not allow for comment on the effects of race, ethnicity, socio-economic status, first-generation, or a multitude of other demographic traits.

Students have only been interviewed through their first three years of college, and it is as yet unclear if all of them will continue to pursue engineering after graduation. Significant changes can happen in students’ final year of college as they participate in capstone design courses, interview with more companies and more seriously consider their priorities in a potential future career. Additionally, while every reasonable attempt was made to interview all students each year, some could not be reached or were too busy to participate. As there seems to be no trend of the types of students who chose not to continue participating, it is reasonable to assume that this pool of students is not further biased.

The interviewer (one of the co-authors) has been and continues to be involved with efforts to promote social justice through engineering. In particular, he has participated in many engineering projects in developing communities. While no significant influence of these experiences was noticed in the interviews, there is a possibility that the interviewer's own interests and bias about what the engineering profession should be accomplishing affected the trajectory of the interview. For example, the interviewer asked more follow-up questions about a student's interest in EWB than airplane design due to his own interest and personal experience.

As this is a qualitative study in which students were interviewed just once each year, the researchers had to make interpretations about the meaning and importance of some students' statements. For example, as there was not a section of questions about how much the students align their personalities with the engineering profession as they understand it, the researchers needed to infer from some of their language just how much they saw themselves as the socially responsible engineer they were describing. Further, the authors both have a background in civil and environmental engineering. While every attempt was made to be objective, this lens of societal impact likely affected the interpretations of students' ideas. Finally, there were occasions in the interviews when some students had difficulty expressing their ideas when the questions were too open-ended. Examples were given by the interviewer to stimulate thoughts, and these possibly affected students' responses throughout the interview.

To address some of the above issues, in addition to the analysis validity measures, the results presented herein were critically reviewed by the second author who is deeply engaged in engineering education and engineering education research. The results of the study have also been reviewed by multiple faculty with varying degrees of experience in engineering education, education research, and student advising. Their participation helped to ensure the results were presented without bias.

FUTURE WORK

The 20 engineering students presented in this study will be interviewed a fourth time as many will be preparing to enter the profession. At least one student, Nathan, plans to already be a practicing engineer since he will graduate early. Others will be taking longer to finish their degree (like Tanya) or will pursue a master's degree (like Denise and Kim), but all will continue to develop their anticipated integration of social responsibility and engineering in their future jobs as their plans become more concrete. At this crucial juncture in the students' personal and professional lives, the students will be asked more questions about how they specifically foresee themselves as future socially responsible engineers as well as how they compare their ideas now to their responses from previous years. This member check will wrap up the four years of interviews that collectively will map the students' changing ideas throughout college.

In addition, the authors are concurrently trying to answer other research questions revolving around engineering and social responsibility. One study focuses on how students understand socially responsible engineering as an entity outside of their own personal ambitions, and how these ideas are shaped by varying influences before and through their time in college (Chapter 4). A second study presented in Chapter 6 focuses on students who left engineering, and how their decision was influenced by a desire to have a positive social impact through their careers.

CONCLUSIONS

Students conceptualized very different versions of engineering through their family, class, media, and especially internship experiences. Further, they each had their own unique idea of social responsibility, and they integrated this with engineering to varying degrees. It seems that engineering students should be exposed to many different versions of engineering through their pre-engineering experiences, college courses, and career fairs in order to continue expanding their ideas about what their futures as socially responsible engineers could be. This responsibility falls on faculty and administration to further improve middle and high school outreach in addition to thinking more creatively about the examples they use in courses and the companies or organizations they invite to campus. The overview of the students shows the middling of student ideas, where it seems that students feel they need to conform to the examples of engineering they see. If these examples speak strongly to their sense of social responsibility, it stands to reason that they will not only stay in engineering through college, but continue after graduation. These students who do become professional engineers then need to experience support for the ways they want to integrate their own sense of social responsibility into their work. This responsibility falls on engineering companies, and they should be happy to accept it – they will be able to retain more employees that are hard-working, dedicated, and passionate about their profession which exemplifies the Ethic of Care. These are the professionals who will help to perpetuate the cycle to make engineering more caring, which in turn will make it a more impactful, accessible, and desirable career path for current and future generations.

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CHAPTER VI: ARE THE MOST SOCIALLY MOTIVATED STUDENTS LEAVING ENGINEERING?

ABSTRACT

Engineering programs and policymakers have made many attempts to retain more students who originally choose the major. Some efforts have been successful, but the 70% overall retention rate leaves room for improvement and calls for more understanding of why students leave engineering for other majors. One hypothesis may be that some students, especially women, do not find enough social relevance in their engineering courses and interactions with the profession. Understanding more about the reasons some students leave in relation to their desires to act on their ideas about social responsibility through their careers can shed light on this gap in the literature. This study analyzes three rounds of hour-long interviews with students who left engineering. Questions revolved around students' reasons for leaving engineering, how their own sense of social responsibility came into their decision, and what opportunities for social impact they envisioned in their new potential career path. All nine students' answers to these questions and others are presented, with a final elongated, narrative analysis section for three of the students who saw the opportunity to have a larger impact through a different major. For some students, prosocial motivations did push and pull them to another major along with other variables such as an unsupportive environment, dry technical courses, and difficulty with the curricular content. These results can provide some direction for those trying to improve engineering retention, especially of those students who want to have a large social impact through their profession.

Keywords: social responsibility; retention; persistence; women; qualitative research;

INTRODUCTION AND BACKGROUND

The engineering profession in the United States does not have enough diversity of gender or race and is often believed to be a homogenous unit. Understandably does not inspire many new people to choose the engineering profession as they begin thinking about what career would best suit their interests. The National Academy of Engineering (NAE) recognized this issue, and developed publications such as *Changing the Conversation* and *Rising Above the Gathering Storm* to rally more support for increasing diversity in engineering schools, who would graduate into the profession (National Academy of Engineering 2008; National Academy of Engineering 2005). The authors of *Changing the Conversation* wrote that, "The new messages cast engineering as inherently creative and concerned with human welfare, as well as an emotionally satisfying calling" (National Academy of Engineering 2008). Since these publications were released, some universities have found success in recruiting and retaining a more diverse engineering student population. Still, those who do start to study engineering in college may leave, about 41% of both men and women do, and this number has stayed consistent since 2005 (Cosentino de Cohen and Deterding 2009; Susan M. Lord et al. 2009, 20; Yoder 2014). Some universities and some engineering majors have been able to keep their more diverse students, but others have been losing a larger proportion (Yoder 2014). While the percentage of women receiving engineering bachelor's degrees has risen every year from 2009 to 2014, the total is still only 19.9% (Yoder 2014). Further exacerbating the problem, women only represent about 10% of the engineering profession (Bureau of Labor Statistics 2014). Issues abound at every level: recruitment, retention, and persistence.

Over the last twenty years, research has shown numerous reasons for the dearth of women in engineering. *Talking About Leaving* explored qualitatively why students choose to leave engineering. Largely, a 'chilly climate' of engineering culture, which is not supportive of those who struggle, and a lack of altruism in engineering school were found to be much more important factors for women than preparation, performance, or effort (Seymour and Hewitt 1997). These have been confirmed in more recent studies as well (Tsui 2010; Lichtenstein et al. 2014). A lack of self-efficacy and misalignment with the dominant discourses of engineering can also lead women to leave engineering (Amelink and Meszaros 2011; Hughes 2012). Women who do stay in engineering identify with the profession to a lesser degree as some may need to deny parts of their personality to fit in (Ong 2005; Tonso 2006). Others who stay in engineering often receive support from role models, mentors, and other networks, which combat the dominant culture (Lichtenstein et al. 2014, Johnson 2012, Ureksoy 2011).

In the same year of *Changing the Conversation*'s publication, the NAE published about the *Engineer of 2020*, and the skills future engineers would need to be able to address the many global issues on the rise and still to come (National Academy of Engineering 2004). "These aspirations describe engineers who are broadly educated, see themselves as global citizens, can lead in business and public service, as well as in research, development and design, are ethical and inclusive of all segments of society." Showing that the engineering profession is that described in the *Engineer of 2020*, can change the conversation to bring in and keep a more diverse population. For example, a study of girls in elementary, middle, and high school found that they are not interested in engineering due to their perception that engineering is not caring (Capobianco and Yu 2014).

Women in engineering are more motivated by helping others, and engineering education needs to provide examples of engineering and helping (Pierrakos et al. 2009). Learning Through Service (LTS) activities improve perceptions of engineering (A. Bielefeldt 2006; Carberry 2010; Tsui 2010), so there are examples of success to follow. In general, a culture of social responsibility (SR) tends to align better with women's values (Schreuders, Mannon, and Rutherford 2009; Eccles 2007; Miller et al. 2000), and this is an opportunity that should not be missed in engineering. It seems, however, that these efforts are not yet the norm or valued by most engineering faculty (Strobel et al. 2013). The lack of empathy, political and social relevance in the culture of engineering is still perpetuated in most engineering education (Cech 2014; Baillie and Levine 2013). Engineering students' perceived importance of the social impacts of engineering (such as "professional/ethical responsibilities" and the "consequences of technology") were found to decrease from the first to fourth years indicating a "culture of disengagement" in engineering education (Cech 2014). Further, women in engineering were found to have higher levels of social responsibility on average than men (N. E. Canney 2013), but these levels decreased for 23.6% of the women after one year in engineering school (A. R. Bielefeldt and Canney 2015).

Building on previous research, this study asks two related research questions: (i) Are students motivated by social impact leaving engineering to find more caring or impactful majors, and (ii) what narratives do leavers tell about their decision to leave as it relates to social responsibility-related ambitions?

METHODS

As the goals of this study were to understand the experiences and motivations of students who left engineering, a qualitative approach was chosen. Interviews were conducted in spring 2013 with 34 first-year students who originally chose engineering majors. By this first interview, three students were already leaving engineering for other majors. In the second longitudinal interview near the end of sophomore year, four additional students had left or were in the process of leaving engineering. By their third interview at the end of junior year, two additional students who continued to be part of the study had left engineering. A summary of the demographic characteristics of the nine students who left engineering majors is provided in

Table *27* below. The longitudinal nature of this study with an interview each year allowed the researchers to explore students' decisions to leave as they were happening, and identify potential recent influences that led to discontent within the engineering program. In addition, students were asked to complete an online survey in each year, which collected primarily quantitative data.

The original 34 engineering students who participated in the interviews were selected using criterion-based selection (Miles, Huberman, and Saldaña 2013). The students represented a wide variety of attitudes towards social responsibility (SR), four universities (Table 26), primarily three engineering majors (plus some undeclared engineering majors from the Private University (PrU) and a high over-sampling of women (62% of the 34 students). To assess SR attitudes, students completed the Engineering Professional Responsibility Assessment (EPRA) in their first month of college, resulting in an average SR "score" that could range from 1 to 7 based on the average Likert-item response (N.E. Canney 2013); the actual average SR scores of first year students ranged from 3.51 to 6.98 (median 5.88). Of the 236 first-year engineering student responses from five institutions, 75 students indicated a willingness to participate in an interview (SR scores ranged from 4.00 to 6.80). Every attempt was made to have an interview pool which achieved a diversity of SR scores, gender, majors, and institutions, but 12 of the students invited to participate in the interviews did not respond. Their average SR scores ranged from 4.23 to 6.40 (median 5.31). The initial SR scores of the 34 students who ultimately participated in the year 1 interviews ranged from 4.00 to 6.80 (median 5.88). The 34 students initially were majoring in mechanical (ME; n=11), civil (CE; n=9), and environmental (EnvE; n=9) engineering, with 5 additional students from PrU who did not declare a particular discipline until the end of their first year. These students had settled on a major by the time of the first interview. They also were originally attending one of four universities (summarized in *Table 26*): a large public research-intensive university (LPU; n=11), a medium-sized technically-focused public university (TechU; n=9), a medium-sized public university (MPU; n=6), and a private research-intensive university (PrU; n=8). The demographic categorization of these universities (Table 26) are based on the Carnegie Classifications (Carnegie 2015). These universities also differed in regional location (West, Midwest, East) and retention rates in engineering (Table 26).

Table 26: University Demographics

Institution	**Enrollment**	**Carnegie Basic & UG classifications**	**Public/Private**	**Typical Eng Retention, Y0-Y3**	
				Women (%)	**Men (%)**
LPU	> 15K	RU/VH, A&S+Prof/HGC	Public	69%[a]	74%[a]
TechU	5K – 15K	RU/H; Prof-F/HGC	Public	81.4%[b]	74.9%[b]
MPU	5K – 15K	RU/H; A&S+Prof/HGC	Public	63.8%[c]	63.8%-c
PrU	5K – 15K	RU/VH; A&S+Prof/HGC	Private	~90%[d]	~90%[d]

[a]Official data from recruitment and retention data manager at LPU
[b]Official data available through university website
[c]Official data, though not separated by gender, includes 'mathematical sciences' and engineering
[d]Personal communication from Associate Dean of Engineering

A summary of all the initial demographics for the students who left engineering and transferred to non-engineering majors are shown below in

Table *27*. Notice that none of the students are from TechU, but otherwise are well-distributed by university and major. Further, seven of the nine leavers were women (33% of the full female interview pool) compared with two men (15% of the full interview pool). It is somewhat surprising to have this disparity since the retention rates are fairly similar by gender as shown above and according to national statistics (Cosentino de Cohen and Deterding 2009; Susan M. Lord et al. 2009; Ohland et al. 2008). All of the nine students who left engineering were non-Hispanic whites and matriculated into college directly after high school; only Kaitlin was a first generation college student (one of the three first-generation students among the initial cohort of 34 students). Among the full group of 34 students, two students took time-off from college and one student left LPU and did not respond to contact attempts (so his continued pursuit of engineering or another major is not known); the remaining 23 students continued to pursue engineering degrees through junior year.

Table 27: Demographics on the Pre-Survey of the Nine "Leaver" Students

Pseudonym	Gender	Initial Major	Institution	Initial SR Avg Score
Thomas	M	ME	LPU	4.00
Nelson	M	EnvE	MPU	4.82
Alicia	F	ME	LPU	5.64
Miranda	F	Other - ChE	PrU	5.98
Lindsey	F	Other - BiomE	PrU	6.00
Maggie	F	CE	MPU	6.02
Kaitlin	F	EnvE	MPU	6.08
Katie	F	CE	LPU	6.58
Jocelyn	F	ME	LPU	6.80

ChE – Chemical Engineering; BiomE – Biomedical Engineering

All of the research was conducted according to methods and protocols approved by the University of Colorado Institutional Review Board for Human Subjects Research, Protocol 11-0414, and included informed consent before each interview and online survey.

INTERVIEWS

Interview questions were developed each year to best elicit the students' ideas about social responsibility as it relates to engineering and then in future years, their chosen major or profession. See some of the most relevant leaver questions in *Table 28* below. In the first year, questions were generally about the student's reasons for entering engineering, their social issue awareness and involvement, and finally how they connected engineering and social issues. In the first year, there were no questions developed specifically for students who had chosen to leave engineering, so these interviews ended up being less structured. The students who had chosen to leave engineering by the first year were asked to describe their reasons for leaving and why they chose their new major. For more details regarding the interview questions and methods for the first year, see the earlier conference publication from the authors (G. A. Rulifson, Bielefeldt, and Thomas 2014).

The second round of interview questions built upon the first round, but led students to discuss more about their expected future careers. Questions were developed specifically for the students who left engineering. These questions were balanced between their experiences over the past year within and outside their major (and engineering if applicable), potential and ideal careers in the future, and connections between these two broad areas in relation to social responsibility. As in the first year, if students had decided to leave engineering between the first and second interviews, they were asked to expand on their reasons for leaving engineering, and what drew them to their new major. More details about the methods for the second round can be found in a recent conference paper (G. Rulifson and Bielefeldt 2015).

The third round of interview questions scaffolded upon the exploratory first and second round questions and findings, and were more direct than previous interviews as the research objectives became more focused on student narratives about leaving engineering. The questions were more open-ended to allow the students to identify themselves what experiences were most impactful in their decision. Then, students continued in their narrative to describe experiences within their major and considerations about their future careers as they relate to SR. These questions were developed by the authors initially, then were critiqued by a professor in the school of education and a scholar in science and technology studies who were familiar with the research.

Table 28: Leaver Specific Interview Questions

Year	Question
2, 3	Why did you change majors? / What do you think were the most significant motivations for you to switch from engineering to your new major?
2	What are the main differences you have found between your major and engineering?
2	What is your ideal career now? Why?
2	Do you expect social responsibility will be part of your future career? How strongly? In what ways?
2, 3	Are you better able to address your social responsibility related goals with your current major than with engineering? In what ways specifically?
2	Does your sense of social responsibility move you towards, away, or neither from a career in your field? In what ways? Has this changed significantly since last year?
3	Tell me about your experience from freshman year until now in your new major. Tell me any significant events or activities that affected this experience. - I'm interested in how you decided on engineering, came to the decision that engineering was not the best fit for you, and then chose your new major.
3	In what ways does your major allow you to impact society? - How important is that to you?
3	Do you think you would have considered stayed in engineering if… - socially responsible engineering had been more prominent in your classes? - discussion of ethical issues had been more prominent in your classes? - you could have connected engineering with your own personal experiences?
3	How do you think your engineering education could be more socially engaged/relevant?

Semi-structured, audio recorded interviews up to 90 minutes in length were conducted by the same male doctoral researcher from February-May 2013, March-April 2014, and March-April 2015, respectively. An incentive of $100 was offered for each completed interview. Staying on script through a structured interview may have limited students' deeper expression, so the conversation was allowed to flow naturally and return to the interview questions when appropriate (Saldaña 2012; M. A. Eisenhart et al. 1998).

After the first interview, each interviewee was assigned a pseudonym using typical conventions (Ogden 2008). Interviews were transcribed verbatim into Microsoft Word using Dragon voice recognition software (*Microsoft Word* 2013; *Nuance Dragon Speak* 2013). Then, each interview was read and edited while listening to the interview to produce an accurate transcript. This transcript was then imported into Nvivo 10 for identifying and classifying the multiple themes and related influences (QSR International 2013).

Interview Analysis

As the first round of interviews was exploratory, inductive coding methods (Miles, Huberman, and Saldaña 2013) were used. Three researchers (PhD student, faculty advisor, and an engineering undergraduate) co-developed a code book based on a sub-set of 13 interviews (four per person plus one in common). Further details regarding first year analysis can be found in Rulifson et al. (2014).

After the first round of interviews, the researchers used the initial emergent coding to categorize the students based on how they described their intended integration of social responsibility and their engineering careers, or at least their engineering education. This resulted in four distinct groups or "Types" representing the spectrum of desired integration with students' understandings of SR; these were described in Rulifson et al. (2014) and will be presented in the results.

For the second round of interviews, the reliable code book developed from the first round was used while remaining open to codes emerging as students expressed new ideas. More codes were also developed to capture answers to the new interview questions regarding their professional intentions following graduation. A similar coding process was followed as in the first year, but between just two researchers (PhD student, faculty advisor). Finally, changes in SR understandings and connections to engineering between years one and two were found. For more details about the second year's analysis, see Rulifson and Bielefeldt (2015).

In the third year, analysis was similar to the first and second years in the preparation of the transcripts and use of the original code book while remaining open to more codes, as required for the new interview questions about general engineering responsibility and *pro bono* attitudes.

NARRATIVE ANALYSIS

As coding of the first two rounds of interviews continued, it became clear that the stories of these students who left engineering were the most important components, and a richer method of analysis was needed. Narrative analysis was a natural fit – "One of the ways - probably the primary way - human beings make sense of their experience is by casting it in narrative form" (Gee 1985 quoted in Riessman 1990). Students took those experiences and used them in major life decisions, and narrative analysis allows those deep stories to unfold as the student experienced them. The narrative is not an exact description of the actual event, but the interpretation as experienced by the narrator. This experience is most important to this study, because that is what affects their decision to leave engineering.

There is no one method for narrative analysis (Riessman 1993). For this study, Riessman's methods of identifying stanzas within the speech are followed. These interviews have been transcribed verbatim by listening closely to the narrative section, paying particular attention to the pauses and conjunctions used in the speech that set off the stanzas. Each stanza was said for a reason and carries a certain weight and meaning within the arc of the story. Portions of the interview were chosen for relevance to the research questions regarding the student's reasons for leaving engineering related to social responsibility. Additionally, a length of at least three minutes was desired such that a fuller, uninterrupted story could be analyzed. Student narratives were chosen to show how social responsibility relates to some students' decisions to leave engineering for another major. By reading the stanzas of the narrative independently, the students' stories were clarified and deepened for a better understanding of their experiences.

Finally, after all the analysis was finished, it seemed useful to classify each of the leavers by the importance of social responsibility as a motivator to leave engineering and choose their new major. Each author read through the interviews of each of the leavers again, and made a judgement about where on a four-point spectrum the student fell. If there was disagreement, each author would present evidence for their position and discuss until agreement was reached.

RESULTS AND DISCUSSION

This section is divided into three main parts. First, the general description of the SR Type determination will be presented along with the students who fit into these Types out of the full 34 student cohort. Next, the general experiences of the leavers, divided chronologically by the year in which they left engineering, will be explained with quotes directly from the students. Finally, a detailed description and narrative analysis of three of the nine leaver students will be presented, which will provide a deeper understanding of these students SR-related reasons for leaving engineering to another major.

STUDENTS WHO LEFT ENGINEERING IN THE CONTEXT OF THE FULL COHORT

The full cohort of 34 students initially majoring in engineering were grouped into "Types" representing different attitudes about the integration of social responsibility and engineering that they envisioned in their careers; the results are summarized in Table 29.

Table 29: Descriptions of "Types" - How Students in the Full Cohort Integrated Engineering with Social Responsibility

Type	Y1 Men	Y1 Women	Description
1	2	8	Students' reasons for choosing engineering as a major and future profession were strongly related to their own strong sense of social responsibility that involved an acknowledgement of the inequalities present in the world from which the marginalized and disadvantaged suffer. Typically, these students also had significant experience with volunteering and/or international travel that exposed them to issues, with which they believed engineering could help.
2	4	6	Students wanted to better society at large with engineering, and this environmental or social responsibility, which was often broad and vague, was a reason for choosing engineering. For example, some students wanted to conserve the natural environment for their future job, so they chose environmental engineering.
3	4	6	Students enjoyed volunteering and believed helping others was important, but did not associate this sense of social responsibility with their own engineering vision. Their job in the future was more to be stable and interesting, rather than helping society. Possibly through their employers or the salary they would make, they would be able to volunteer, but not necessarily as an engineer.
4	3	1	Students had thought little about social responsibility or the social context of engineering at the time of the interview, and possibly had not participated in much non-required volunteering. To these students, their responsibility in the future did not extend far beyond legality,

Type	Y1 Men	Y1 Women	Description
			safety, and microethical adherence. Many were focused strictly on their studies and taking care of only those closest to them.

These types provided a way to understand the students' ideas in the first year and possibly identify trends between majors, universities, gender, and a propensity for leaving. It also gave a comparison for the same student's evolution regarding the integration of engineering and social responsibility in their futures. Although the research team tried to sample across range of SR attitudes, individuals with less SR motivation seemed harder to recruit to participate, so this may not be a fully representative sample.

The vast majority of the students who left engineering (7 of 9 or 78%) were initially those most motivated to help disadvantaged people through their career (so-called Type 1). Only 30% of all of the students who were initially Type 1 remained in engineering, while 70% left. In contrast, only 10% of the Type 2 students, 0% of the Type 3 students, and 25% of the Type 4 students left engineering. Although this is a small sample, it appears that the students who came to engineering with the most motivation to help the marginalized and disadvantaged with engineering disproportionately left engineering for other majors. Further, 75% of the female Type 1 students left compared with 50% of the Type 1 men.

Table 30: Contrast of Retention Based on SR Type and Gender

SR Type at End of Year 1	# of women who stayed in engineering for 3 years	# of women who left engineering by the end of junior year	# of men who stayed in engineering for 3 years	# of men who left engineering by the end of junior year
1	2[1]	6[1]	1[1]	1
2	5	1	2[1]	2[a]
3	6[2]	0	4[1]	0
4	1	0	2[1]	1[1]
All Types	14	7	9	4

Superscript indicates the number who changed their SR Type by the third year
[a]one student left LPU to another university and switched his major, but was not interviewed; one student left engineering school and was unsure in the third year of his return, so not included in Table 31

The three years of interviews revealed a wide array of experiences that led to the student choices to leave engineering. These nine students eventually chose eight different majors, and three students were in a different major before settling on their third. Only one student, Miranda, left natural science altogether, but she still had a mathematical component to her degree in quantitative economics. Three students also transferred to other universities, and one chose to take some time away from college as he was not committed to any particular field of study. Finally, of the original seven Type 1 students, six continued to be a Type 1. They chose their field of study because it aligned well with their understanding of social responsibility, and wished to pursue a career that improved the wellbeing of the marginalized and disadvantaged. Table 31 below shows students' progressions between majors, institutions, and SR types over their first three years of college.

Table 31: Student Majors and Integration of SR Through Three Years

Pseudonym	**Majors**	**Institution**	**SR Type**
Nelson	EnvE^{0} / Environmental Studies$^{1-2}$ / No School^{3}	MPU$^{0-2}$ / None^{3}	1
Kaitlin	EnvE^{0} / Landscape Architecture^{1} / Sustainable Agriculture & Global Development^{3}	MPU$^{0-1}$ / LPU2$^{2-3}$	1
Maggie	CE^{0} / Animal Science^{1} / Community & International Development$^{2-3}$	MPU	1
Katie	CE$^{0-1}$ / Environmental Studies$^{2-3}$	LPU	1
Alicia	ME$^{0-1}$ / Integrative Physiology$^{2-3}$	LPU	1
Lindsey	BiomE$^{0-1}$ / Biochemistry$^{2-3}$	PrU	2
Miranda	ChE$^{0-1}$ / Chem^{2} / Quantitative Economics^{3}	PrU	1^{1} / 3$^{2-3}$
Thomas	ME$^{0-2}$ / Geoscience^{3}	LPU$^{0-2}$ / LPU3^{3}	4^{1} / 3$^{2-3}$
Jocelyn	ME$^{0-2}$ / Environmental Science & Policy^{3}	LPU$^{0-1}$ / LPU4$^{2-3}$	1 / 2$^{2-3}$

Superscripts represent the interview time for these majors, institutions, and types. During the interview students typically described a new major, but had not yet formally switched to the new major. More details will be provided in the subsequent section that describes each student.

Social responsibility seemed to act both as a force out of engineering and into another major for some students. The ability to act on their understanding of SR within their future careers seemed important to many, however, the choice to leave engineering was generally coupled with other motivations – wanted more flexibility in their course schedule, did not enjoy the engineering courses, or felt they were not receiving support from engineering faculty.

For the most part, students told stories of their reasons for changing their major out of engineering without much provocation. It is difficult to get accepted to many engineering programs, so changing one's major out of engineering as is a significant decision that no student took lightly. Thus, they had thought through the decision independently and with others through many hours. As *Talking About Leaving* exposed, along with other studies, students typically did not leave engineering because the major was too difficult (Seymour and Hewitt 1997). Rather, they left because they were not enjoying engineering and had found a major or career path that suited them better.

STUDENTS' REASONS FOR LEAVING ENGINEERING

Students left engineering majors at all points from the second semester through junior year; thoughts of leaving often preceded the decision points by months or even many semesters. This section is organized chronologically, to present the stories of the students who left engineering in the first year, then sophomore year, and finally junior year. The main reasons for switching to other majors are presented, including any elements that relate to social responsibility.

The three students (Nelson, Kaitlin, and Maggie) who had decided to leave engineering by the time of the first interview at the end of their first year of college were all characterized as Type 1, having goals to serve disadvantaged populations through their careers. All were attending MPU and majoring in environmental or civil engineering. At MPU, these two majors are offered from the same department and students take identical courses in the first year. Students' reasons for leaving included: the engineering major did not seem to have enough social responsibility content and goals, and some students were unprepared for the difficulty of the prerequisite math and science classes. Nelson stated that he did poorly in two requirements to be in engineering, his college math courses; he felt that his background in math and chemistry from high school had not prepared him for the rigors of those courses in college. He was also very disappointed with the content in his introduction to engineering courses where he felt that he didn't learn anything / not enough design focus, as well as disliking the very structured nature of the curriculum with limited ability to choose his courses. Similarly, Kaitlin "struggled with calculus and chemistry," which were "a little overwhelming." Maggie reflected that she just wasn't passionate enough to continue the difficult pursuit of an engineering degree. In addition to the above mentioned reasons,

Table 32 provides quotes from those students, which show how they all wanted to connect engineering with their desire to act on social responsibility through their future jobs.

Table 32: Example Quotes from Students Who Left Engineering by the First Interview

Student	**Representative SR-related quote**
Nelson	I thought it would be a curriculum designed to teach you how to design buildings, just systems, energy systems or transportation systems that were in harmony with natural systems. I thought it would teach ways to mimic natural systems, or if not mimic to integrate well into them. The romanticized engineer saving the world sort of thing has died in me, definitely.
Maggie	I was drawn to civil engineering because I really wanted something that was very, very strong in the math and the sciences, but also had a lot of real-world applications for helping people.
Kaitlin	When I majored in environmental engineering, I was picturing large-scale greenhouse operations, vertical agriculture, maglev technology for transportation, solar everything. We are still learning about the current systems that are not working. I guess. So I'm not so interested in learning how to repair or sustain the current system, but I guess I wanted a class that really taught you how to design, to put in new systems.

Notice that these students originally had high expectations of how they would be able to use their engineering education to lead to jobs that would help society progress in meaningful ways. Additionally, though, it seems the students had only developed an understanding of a small slice of all the potential career paths available with an engineering degree before they left the major. Nelson and Kaitlin had similar comments about a mismatch between what they expected to learn in their engineering education, and what the majority of their courses were teaching. Maggie's experience is presented in more detail in the Narrative Analysis section below.

By the second year's interview, four more students had decided to leave engineering. Their main motivations varied, but again a lack of social responsibility related material and social context remained a significant reason. Multiple students described the lack of 'real-word' education after their introductory course, and they lost interest in the engineering major. Further, an inflexible schedule drove some students out of engineering into other majors which allowed them to embrace the university environment, and explore new fields. The following are examples of what caused students to switch out of engineering after a full year or more in the major.

Table 33: Example Quotes from Students Who Left Engineering by the Second Interview

Student	Representative quote
Katie	I wasn't failing anything, and I was getting fairly good grades, but more and more I was realizing how completely uninterested and dispassionate about my choice of study I was. And it was making me really unhappy because I went to class every day and I just realized that I just didn't care about what I was learning. I think that in this particular engineering program there is very little emphasis on anything that is not technical, and there is very little, little to no emphasis on humanities or on any sort of global or international awareness or culture or policy… and had this program had more, this particular engineering program offered more along those lines, then I think I would have stayed in engineering.
Alicia	I like engineering and I think it's fun, but I wasn't doing so well on my exams and so my grades weren't as good as they should have been, and so that was one of the factors for switching, but also I wasn't as into some of the classes as I thought I would be, and some of the classes I'd be taking or that I would be taking in my junior and senior year, I wasn't sure I was as, like, interested in them, I guess. I don't feel like I'm giving up. I feel like I'm just pursuing something, another, I mean another major that I was interested in before coming to college.
Miranda	…after freshman spring just because I had so many lab sciences, and I was exhausted and so mentally and physically I feel that the professors weren't too excited to be teaching or weren't very receptive to helping those who are struggling, but wanted to learn. I'm a very people oriented person, so me, it was kind of a disappointing environment versus how I had idealized engineering before. …eventually I was stressing myself out to the point where I was giving myself headaches every single night.
Lindsey	…at the beginning of this semester I decided to switch to biochem just because I could end up in the same career path as I would with biomedical engineering but I could take a lot more the courses that I want. I was planning out courses for the next 2 years I realized that I didn't really have any choice in what I was taking. I didn't really want to spend four years, kind of like in high school where you have courses put in front of you and you don't really get any variety.

Katie and Lindsey both appeared to be doing well and did not note any concerns about the difficulty of engineering coursework; however, they just found the engineering curriculum to be confining. In Katie's case, she found it disconnected from society – she made the decision between "four years in college doing something that I didn't care about, but that could potentially open doors related to something that I was passionate about or…to have a meaningful college experience and to use my passion for what I was doing to launch me into a career and future possibilities." Lindsey just wanted more diversity in her courses, and saw a parallel career path to helping people with disease research through a biochemistry major. She described her potential path, "I think that disease research is kind of cool so working on cancer research or Alzheimer's research or like something with the CDC is something like that I think would be cool." Alicia, however, was struggling with some of the courses, and while she felt she could get through the degree, she wasn't "all-in." She realized that her core interests were in helping people in the same way that she was helped in the past, so she decided to pursue integrative physiology and be a physical therapist. She explained, "I was always interested in the people side of engineering, like prosthetics and stuff, so I considered majoring in it. After I finished engineering and I stayed in a, and yeah I think I want to pursue chiropractic work or be a physical therapist."

Miranda also struggled with her classes, and was even at risk of academic probation. To further exacerbate her issues learning the material, she described engineering professors that were unsupportive and unwilling to help her better understand the material. She said in her first year, that "I had some experience with professors flat-out calling me stupid." The final push was in her first semester of her second year when she was struggling with a recent concussion. She said the professors "weren't very receptive in helping me catch up." This component of her experience exemplifies the 'chilly climate' described through numerous publications in the past (Seymour and Hewitt 1997; Lichtenstein et al. 2014; Tsui 2010). Interestingly, although Katie, Lindsey, and Miranda all left engineering, they still remained involved with the co-curricular engineering service programs, Bridges to Prosperity and Engineers Without Borders (in contrast, all of the students in the study who remained in engineering stopped or never started participating).

By the third interview, two more students had left engineering, at the end of their second year; quotes related to their decisions to change majors are highlighted in

Table *34*. Interestingly, both of these students switched universities also – Jocelyn after her first year, and Thomas after his second year.

Table 34: Example Quotes from Students Who Left Engineering by the Third Interview

Student	Representative quote
Thomas	I have nothing against it, I think engineering is pretty awesome, but at the same time I don't know if I could do, I didn't want to get stuck behind a desk for the next 30 years. I know engineering is really flexible once you get the major and it's a very, I don't know, it's a great thing to use but I wanted to use school as, kind of like a stepping stone to learn something more interesting that I find more appealing. I would've been able to find a job that wouldn't have been very hands-on…. But at the same time I'm not sure if I was that interested in what I was learning. It was neat and everything that went with it, but I didn't really have a drive for it.
Jocelyn	…It's just an easier medium to have your voice heard. Our [lawyers] voices are heard and it should be the scientists, honestly we like we should be listening to the scientists but in science it's not always as easy. You are more high profile as a lawyer and maybe you're going to get some attention….

With a new university, Thomas also took the opportunity to switch majors from mechanical engineering to geoscience. He simply found that he was more interested in this field than engineering, and wanted to distance himself from his family of engineers while pursuing a respected degree in a prestigious program. Thomas seemed content working outside as he believed he would be able to do through geoscience, and discussed the ways that his new major and potential profession allow him to impact society by educating populations about the value inherent in their natural surroundings. He didn't believe that he was better able to act on his social responsibility through geoscience than engineering; he said, "Any major that you go into, there are so many majors that are for philanthropy and help people, so it's all about applying yourself." As a Type 4 student who had progressed to a Type 3 student by the end of sophomore year, Thomas' minimal considerations of SR are not surprising.

Conversely, Jocelyn was a Type 1 student, and initially highly motivated to help underserved populations through her career. The catalyst for Jocelyn to leave engineering was her summer internship, "I really hated it. …Not only did I not like my job, but I didn't like my boss's job or my supervisor's job, or anybody's job." She found a new major and career choice in environmental law. She felt that her new major and career path allow her to have a strong social impact. Her story is explored more deeply in the next section.

In the following section, three individual student narratives are presented to elaborate on three students who were most motivated to use engineering to improve the lives of others. The narrative analysis will more deeply explore the students' experiences leaving engineering. These longer narratives reveal the students' emotion and depth involved with changing out of their major, and fully embracing their new potential career paths.

NARRATIVES OF THREE STUDENTS WITH PROSOCIAL MOTIVATIONS FOR CHOOSING ENGINEERING

The following sections tell the stories of Maggie, Katie, and Jocelyn, in their own words. Their stories are told chronologically, by presenting key quotes from their interviews each year and then selecting a longer narrative portion of the interview for detailed analysis. This approach was taken to provide a full picture of the reasons that each student gave for leaving engineering. Maggie, Katie, and Jocelyn left engineering in their first, second, and third years, respectively. While they all had different specific reasons for choosing engineering, and varied experiences within the engineering major, they all originally wanted to use engineering skills they would learn through college to act on their strong understandings of social responsibility. As such, all three were initially classified as Type 1 students with respect to social responsibility and a desire to help the less fortunate through engineering.

NARRATIVE 1: MAGGIE

Maggie started at MPU majoring in civil engineering. By her second semester of college at the time of the first interview, she had already decided to leave engineering. She described this at the beginning of her first interview in response to the second question, as shown below. The 'I' indicates the interviewer question and the 'M' indicates Maggie's response:

> I: Will you just tell me your name, major and your year in school?
> M: I'm Maggie, and I am a freshman for civil engineering.

> I: And how are you liking it so far? You're little ways in here almost a full year right?
> M: I am actually in the process of switching out. I really found a lot of the subject matter interesting, but it became apparent that, about midway through the semester, it was not something that I'd be happy with doing for the rest of my life. And that was a really hard choice for me because like I said, I found all the courses I was taking really, really interesting, so it was a really fine line of determining between just something being interesting and then wanting to do something because you have a passion for it.

It is interesting that Maggie first identifies herself as a civil engineering major; some other students would state their new major right away. In some ways Maggie seemed atypical, in that she described herself as leaning toward liberal arts up to the midway point in high school, before choosing engineering. The reasons that Maggie described for choosing engineering seemed very driven by a desire to help others:

> I: So what was is it about engineering that you liked? You found the subjects interesting, so maybe some more specifics on that?
> M: Yeah it started, it really started in the second half of my senior year of high school. I had taken required math courses up until the second semester when, it was actually the first semester that I was going through that I didn't have a math course. Up until that point I was kind of leaning toward something more in the liberal arts spectrum. And then over that semester, which was a year ago now, I began to realize just how much I really loved math and science and how much fulfillment I got out of working in it classroom-wise and also being able to use applications of it. …I was drawn to civil engineering because I really wanted something that was very, very strong in the math and the sciences, but also had a lot of real-world applications for helping people and a lot of my motivation for that has come from through high school, I participated in weeklong mission trips every year. So I had a lot of opportunity to actually like to get out and work on construction projects, work with people who needed help, and the idea of doing something like that for a living was really engaging to me and I felt at the time that civil engineering was the best way to get towards that.

Later in the interview, she elaborates on this idea of wanting to help others through engineering:

> M: When I was trying to figure out what I wanted to do for a living. The first thing I thought of was, 'I'm really happy when I'm helping people in this sort of an environment.'
> I: So about that kind of service being happiness thing, you said that that was the main reason like in high school, associating these and that led you to think: 'How can I help people? That's what I want to be doing'. Originally that was pushing your towards engineering?
> M: Yeah. A lot of…well it was also a question of how I could best utilize my skills. And I realized from having early on in high school I was very strong in math and science, above my peers. And I really enjoyed English and poetry and stuff like that, which is why even though I was really good at math and science, I was still kind of leaning towards that liberal arts degree entering my second semester senior year [of high school]. But again, like reevaluation proved that I was good at math and science because I really liked math and science. And with service work, I… I was a bit worried at first because I wasn't entirely sure how I could work it in. … and I was very interested in Engineers Without Borders and just working on projects like that. Working on…I guess it would be working on infrastructure without real…without really worrying about the financial aspect of it, I guess. I was more concerned with making…helping create an environment where people could comfortably have a community with each other.

She later critiqued the teaching she experienced in engineering education as a poor fit for her learning style and interests:

> I: So you're switching out of engineering into animal science? So when did you make this decision?
> M: "I made this decision almost a month ago now and I made this decision largely based around a sort of… I guess disheartening amounts of, kind of, the classes that were required. …a lot of the classes that were required…were very, very much teaching facts. I'm not sure if that would be productive for me as an individual and I'm not sure that's very conducive to the way I learn. I found that I was kind of looking at the programs that were offered for engineers and it just kept on getting more and more technical. And that was something that was really worrying to me because a lot of what… A lot of the situations where I learn best comes from diversity. And, I don't doubt that if I stuck it out for the three years and got a degree in civil engineering I could find a job that I really enjoyed that involved working a lot with people. But at the end of the day, I really needed, I need a little bit of perspective….
> M: … it's probably the biggest thing that like, it's the little voice in the back of my head saying, 'but then after college, you'll get to work with people all the time' but I can't go through three years of incredibly expensive schooling not enjoying what I'm learning. That's not something I'm willing to do.

Maggie also stated: "I'm not entirely sure where I want my education to go. I think that whatever I decide to go for with education is going to be something that I am passionate about enough to make a living off of." Further, she was not able to get involved in Engineers Without Borders, which was part of what attracted her to engineering initially: "I really wish I had been but they met on the one night of the week that I had a lab … unfortunately it just didn't work out this semester." So it seemed that the combination of an inflexible schedule and lack of diversity within classes, were enough for her to leave engineering. First, Maggie tried animal sciences, but then came to settle by her second interview on Community and International Development (CID). She described the major as "a lot of what I was looking for in civil engineering before I really knew what the job description was in a lot of ways." With more time to reflect on her experiences in engineering, she described the differences in the majors in the following three minute narrative:

> The biggest difference is definitely the social implications
> Um, er, rather, the study of social implications of
> what I would be doing
> um, because in civil engineering we touched on it
> in certain classes,
> but we never really went in-depth into like,
> lasting systemic problems
> um, in different communities
> and how to address those without kind of stomping on feet.
> So I think that is really a huge thing for me.
> And it's also a huge thing for me because
> I personally really value the human aspect of it.
> Um, some of the other differences would be the,
> there's a lot less technical study but there still is
> some sort of technical aspect of the CID major because we're looking at,
> we're looking at a lot of economics and how to

basically maximize
a community's ability
to function.
So there is some technical stuff,
but a lot of it is still very closely linked
to the social aspect of it,
as opposed to
existing in something of a vacuum,
which is kind of what I felt in the civil engineering major.
And, um, and, let's see,
with the CID major I really feel like I can
apply what I'm learning directly into my life
rather than just sort of like,
holding it as background knowledge
for when I will one day be able to apply it in my life.
Um, I feel like it has,
the CID major has more to offer me as a person,
rather than just as job training
in a lot of ways.
Um, I think it has the potential to prepare me personally
for situations that would exist outside of employment sort of, situations
whereas the civil engineering major was very very focused into
what you needed to know in order to
uh, really be able to succeed
in employment in industry.

In lines 1-12, Maggie described one major difference between majors, that engineering coursework did not provide time or expertise in discussing systemic social issues, which she valued highly. Lines 13-25, she laid out the balance between technical and social that she was experiencing in CID, which was not in engineering. Finally, Maggie explained the importance of her coursework allowing for personal development in lines 26-41. This brief narrative exposed three important ideas that could have implications for how to improve engineering education in order to align better with the values of students like Maggie.

In her third year, Maggie was very happy with her Community and International Development major for many reasons not least of which was that all of her classes had "a focus on, 'how does this affect other people?'" She described how she felt that she was better able to address her commitment to SR through her new major and potential career path by saying that in contrast to engineering, "The career I am in now, if you're not thinking about these things [SR], then you are not doing it correctly and you are failing in a major way."

NARRATIVE 2: KATIE

Katie started college enrolled in civil engineering at LPU. Her father was a mechanical engineer and she grew up in the Philippines. She was originally motivated to study engineering in order to help others, particularly those living in extreme poverty around the world, stating in her first year interview:

> I saw a lot of poverty and struggles that people of countries or developing nations face especially when it comes to clean water. In the Philippines we weren't allowed to drink water out of the sink, it wasn't sanitary. So that's just something that stuck with me and a couple summers ago I also spent some time with a host family and volunteering and doing a lot of projects such as helping clean up communities and schools and so I've seen a lot of the help that poverty-stricken areas have and just getting access to water, or having a sustainable energy system or anything like that is something that really interested me.

Katie was a strong Type 1 in regards to her ideas of SR and engineering. When asked the question at the end of year 1, "What interests you most about engineering in general?" she responded, "I think it's more than anything, the fact that with engineering I have the opportunity to make a really positive difference in people's lives." She wanted to work in international development and use her engineering skills and degree to help developing communities. The majority of her description of her experiences in her first year of college were positive; "I like the classes. I think that they are challenging. They are a lot of work, but I find it pretty interesting and I like my professors." She mentions both non-engineering and engineering courses as enjoyable:

> I: What have been a couple of your favorite classes so far?
> K: Well let's see. Last semester, I was part of the global studies academic program and so I took classes for that. And it was an introduction to international affairs and globalization. So not necessarily to do with the technical part of engineering, but I would like to pursue the international engineering certificate that is with all majors and I really enjoyed that class. This semester I really enjoyed my calculus class and my geomatics class.

When prompted, she also shared less positive experiences:

> I: What are some things that you are maybe having some troubles with? Some dislikes about the engineering so far?
> K: Well I took physics one last semester and I really struggled with that. I thought that the material was really hard and I didn't think the recitations were helpful at all. So I had some difficulties with that last semester but this semester it's going pretty well. I'm taking engineering projects and we just completed our introductory project and I was unfortunate enough to get put with a group that didn't work particularly well together. So that was a challenge for me.

By the beginning of her second year, though, she began questioning her original, long-standing plan to pursue an engineering degree. She described this in her second year interview; the following narrative is her three minute description of her process broken into stanzas:

1 Okay, yeah. So this time last year,
2 I was finishing my freshman year,
3 and I was still at that point planning on staying in civil engineering.
4 In fact, I went home that summer to Boise, Idaho and I took 10 credits.
5 I took gen chem and physics 2 and
6 um, was still planning on staying with engineering all through the summer.
7 And then I started my fall semester here this year, and
8 I was taking much more civil specific courses,
9 so thermodynamics and analytical mechanics, things like that and,
10 I was doing okay in all of my courses:
11 I wasn't failing anything, I was getting fairly good grades,
12 but more and more I was realizing how completely uninterested and dispassionate about my choice of study I was.
13 And um, it was making me really unhappy because I went to class every day and
14 realized that I just didn't care about what I was learning.
15 I wasn't interested by it,
16 I wasn't excited or inspired by it.
17 And so I started really looking, considering the possibility of changing majors.
18 I kind of thought about it some my freshman year and over the summer,
19 but I hadn't really let myself consider it.
20 I guess there was the turning point:
21 I was sitting at home one evening trying to do my homework
22 and I had been at it already for probably five or six hours and realized that
23 I didn't know *how* to do my homework,
24 and even more than that,
25 I didn't *want* to know how to do my homework.
26 And that was the big turning point.
27 So I started to talk to different people.
28 I reached out to teachers and professors and advisors and family friends and professionals and
29 basically anybody who was willing to talk to me about what it meant to make a change like this,
30 and what it would mean for my future and whether all the things that I dreamed about doing were still possible with a different degree.
31 Um, after a couple months of conversation and consideration on my part and really thinking about what it meant to do different things, um,
32 I decided that I was gonna switch majors.
33 So I petitioned the college of engineering to allow me to take classes outside of the engineering school this semester and um,
34 the switch isn't official yet but it will be within the next couple weeks, and,
35 um, I'll be doing a major in environmental studies and a minor in computer science.
36 And I've been taking classes this semester that are all either environmental studies or computer science.
37 So, I did decide to finish my engineering math sequence and
38 I'm loving my new major.
39 So yeah, that's how I got to where I am now.

In lines 1-11, Katie describes how she was going through the motions of any good engineering student. Then, starting in line 12, she describes what factors added up to her eventual 'turning point' which starts on line 20: the particular moment that solidified her decision to leave engineering. For the rest of the narrative, she describes the resolution of the situation that led to her current major, which she 'loves.' She described that her passion for the content she was learning drove her to find the ways to best address her social responsibility goals. At the end of the interview, Katie says strongly that,

> This last year has been obviously huge for me. And basically taking a plan that I've had for so long and abandoning it and completely switching directions, but I haven't regretted my decision once. There has not been a single moment where I second-guessed myself or have doubted myself and that wasn't the case when I was making the decision. Those were two of the most indecisive months of my life, but once I made the decision it's been exactly the right thing to do.

Katie does not go on in this interview to discuss at length the 'hypothetical narrative' of her expected integration of SR and her career path since she has few experiences to ground her expectations (Riessman 1993). In the third year, however, she had experienced more courses and been exposed to more potential directions she could go with her environmental studies major. Overall, she was enjoying the major immensely, and has "not looked back once." While no longer in engineering, she believed that engineers can still have an impact, and engineering may have still been a good choice if the classes were differently structured. She explained, "If there had been more classes that I felt would let me do some critical thinking and less analytical thinking…maybe I would have considered staying." She wanted more diversity within her classes or at least the ability to take more classes outside of the engineering college.

NARRATIVE 3: JOCELYN

Jocelyn was initially a mechanical engineering major at LPU, although she was almost an environmental engineering major. In response to the question 'what interests you most about engineering?' in the first year interview, she responded:

> I'm really hands-on, so, I don't know, I like gears and moving parts and things like that. I was always good at math and science in school, and I want to go into renewable energy and I think what drew me into engineering was just like, sometimes there is more support or response for someone that has an engineering degree versus someone who's just like, **`I want to save the world,' which was me**, so I needed the background knowledge I think to get me…to kind of be able to actually do something like that. I really like

> wind power. I think it's really cool and so that's the goal of eventually. I actually was an environmental engineering major for a long time. I came in environmental and I changed to mechanical immediately. I went to a camp that let you try out different kinds of engineering to try to get a feel for it.

She elaborated based on a follow-up question:

> I live right on the coast and I'm obsessed with the environment because there is so much nature. I've been snorkeling my whole life and boating and hiking and, it's all just there and I become really obsessed with it. I was really happy to be able to grow up in that but…my mom works in geothermal power, so that's how I started to figure out about these different technologies and just living in that coastal area, it definitely gets talked about a lot. My teachers were all like, "Go green, go work in renewable energy."

She described her father as a nuclear engineer, her mother as having a degree in oceanography, and her sister as an environmental engineer working for an oil company. In high school she completed volunteer projects in Central America which she described as "probably the best feeling in the world and the best experience and I would love to go back." Jocelyn had the highest SR score at the beginning of college among all of the first-year students who were interviewed, and she wanted to help the disadvantaged globally and in her community through engineering in the future. Based on these attitudes, she was classified as a Type 1 student. In her first year of college she was heavily involved with the Society of Women Engineers (SWE) outreach program and with two Engineers Without Borders (EWB) teams. At the start of the first interview, she said, "I've joined a couple of engineering clubs that I'm obsessed with, and they're my whole life." In the first interview, she described her goals following college, which included the Peace Corps, a PhD in engineering, working in the renewable energy field, and raising four children who would be "intelligent thinkers." All of these related to her desire to be socially responsible at different levels. She did, however, describe some negative experiences in her first year of college at LPU. At the very beginning of the interview, in response to the second question 'so how is engineering going?' she responded:

> It's hard. It's harder than expected, it's harder than high school. But it's fine. I struggled with one class so far, my CAD class. I felt that my TA was a little judgmental because I was a girl that didn't know how to do CAD. That was very frustrating and I didn't realize it actually happens, but it does and that was frustrating.

She talked at various points in the interview about her feelings that people didn't think women could be successful engineers, and it seemed that she was trying to balance multiple facets of her identity. "The teacher says `you're not going to make it because you're in a sorority.'" Later she described being frustrated with some of her courses – "I think calculus is really boring and it's a really bad system of teaching. [It's] like 200 kids or something so I have very little motivation to do well in that class which is frustrating." Jocelyn also had negative comments about engineering having a mindset of being "smarter" and isolated. But overall she spoke with confidence and determination about getting an engineering degree.

In the second year, Jocelyn had switched to another large, high research activity, public university so she could be closer to her family. She began in the mechanical engineering program and again became involved with co-curricular programs like EWB, though less than at LPU. She described being less active in SWE due to increased time spent with her sorority activities and also working as a nanny. When asked about how SR motivated her to pursue engineering, she replied, "I want to help with that and be a part of the research, the changing technologies that are going to have to happen as the world changes, and always has. And so I think the engineers are at the forefront of that. And that's just where I would like to be." She was also enjoying her classes. She explained,

> I actually really like my classes. I find them extremely interesting and I am in dynamics and thermodynamics and diff EQ right now and I really like all of those things and I find them extremely interesting and I have one really great professor…. I really like my classes, like I said, like I like the science part of it. And I like working on the problems and I like the real world applications. It definitely interests me. I like that it's a challenge. Not always, but most of the time I really do like that. I have to work hard on my classes and I was at a boring high school I think and having, like, the challenge is something I like, and it gets me motivated to go to class. As far as mechanical engineering, I'm really excited because I think there is a ton of possibilities for what you can do with it.

But when asked about her future career goals, Peace Corps is no longer mentioned:

> I: Can you kind of layout for me your ideal engineering career that you see yourself doing sometime in the future?
> J: Yeah. So I would like to get a master's degree and potentially even a doctorate, but definitely a master's degree so I'm staying in school for a little bit longer and then I would like to work in renewable energy, preferably wind power because that's what interests me the most but some type of an engineering firm and then I guess become a professional engineer after a few years and then as long as I can stay in renewable energy, the better for me. So that's the goal at this point.

> J: I definitely have to be super passionate about something to be interested and I mean, this is just something that's really important to me and I spend my weekends on the water. Like I said, so it's important to me to protect the earth and the ocean and everything, I mean it means so much to me. So if I'm going to work my whole life I would love to be working towards something like this, like a good cause, something that I believe in. And I think there is a lot of room for improvement. I think we've just started to scratch the surface of renewable energy, and I would love to continue working with it since there is so much to be learned and it's very exciting for me, but mostly because it's so important. I think I'll be able to excel.

Jocelyn's focus seemed more local – she talked a lot about her family and specifically said she isn't interested in traveling too much. At the end of the Year 2 interview she was directly prompted to discuss EWB and her Peace Corps plans that she had described in Year 1:

> I: So, just two more questions about some things that you said last year and one of them is how much are you involved with Engineers Without Borders right now? You spoke a little bit about it, but you spoke more about it last time so I'm wondering how that fits in.
> J: So the chapter's not as big here, I do go to meetings, but I haven't become as involved yet because like I said the chapter isn't big and they don't have as much for me to do and they also have a pretty tight group and so I think there was more work to be done at the other chapter and I could just say I'll do it. And they don't need me as much. So I'm working on it. I go to meetings and we discuss things and I do it. I can it's just that there's not as much of a need right now. But hopefully they'll continue to grow and I will continue to be a part of it.
> I: Something you mentioned last time was Peace Corps after your master's and so I'm wondering if that was still the plan at all.
> J: Yeah, that's still the plan. I don't know exactly where in the timeline, but hopefully after college that all works out and I'll do a year or two and then on to an engineering career but definitely Peace Corps is still in the plan.

Jocelyn seemed to perhaps be transitioning from a Type 1 to a Type 2; she was strongly focused on helping the environment, but it is less clear that she was highly motivated to help disadvantaged people. She also still remained committed to earning a degree in engineering.

The summer following her second year of college, Jocelyn had an internship in which she was very unhappy. In combination with courses that were not stimulating, she came to realize that she did not, and would not, enjoy engineering, and that she did not fully understand what an engineering job would entail until she experienced her mechanical engineering internship. Thus, she decided to change her major to prepare her to be an environmental lawyer. She responded to the question, "What do you think are a couple of the most significant motivations for you to switch from engineering to environmental science and policy?" with the following three minute narrative:

1 Um, let's see,

2 number one I, I think I can make a bigger impact.
3 Um, I mean, after law school I plan to be a politician,
4 I mean, I think we've definitely talked about that before.
5 I think maybe I hinted that that was something that I was interested in,
6 Um, and I, I think I can make a way bigger impact, um, doing this.
7 Uh, and um, I, and, there is also, like, as far as,
8 like, law school and, like, being a lawyer goes,
9 you have a little more of the voice I think.
10 Um, you know, for like,
11 I want to be an environmental lawyer
12 and if I disagree with something
13 it's like okay, you know
14 let's do something about it, like,
15 and so, um, that's, that's a huge thing for me,
16 I just, I, especially in, you know, my job this summer
17 I kind of felt like I was just, you know,
18 kind of like a person behind a desk that was just there,
19 and it wasn't very, um, very interesting and not fun for me.
20 So, uh, that's been, that's definitely a huge thing, um,
21 also, I didn't like my professors at LPU4,
22 I think that, uh, I think that with different professors I maybe would've stuck it out
23 and just, and still gone to law school but just at least stuck it out, you know?
24 Because that was, I thought about that for a little bit,
25 like I'll stick it out and then I'll go to law school.
26 Um, but I didn't like my professors, and uh,
27 I thought that my classes were very male-dominated.
28 Um, I had an advisor make me cry at some point because
29 I said I didn't like a teacher.
30 I went to my advisor because I didn't have any other teachers or any other options
31 and he was like suck it up, you know?
32 Which was, which was terrible and really really hard for me because I,
33 well I went to my professors a lot at LPU
34 and I think also that if I still was at LPU,
35 I might have stayed in engineering and then still gone to law school
36 because I enjoyed my professors so much.
37 I was definitely disappointed in LPU4 and I voiced that,
38 I voiced it to a couple advisors, I wrote some reviews and evaluations and, uh,
39 hopefully, maybe things will change, I don't know.
40 Um, so that was definitely, that was definitely a huge thing for me, um,
41 because I could have stuck it out, you know,
42 I could have gotten through it if I,
43 but I didn't really like it.
44 Um, and so, so that was a big part,
45 and then definitely that internship,
46 I mean, kind of, I think that maybe,
47 when you come into engineering as a high school senior
48 someone should be like 'hey, this is what your job is going to be like when you graduate.'
49 I don't think that was ever made clear to me.
50 Like, I pictured like, an engineer as a little bit more of a creative mind,
51 a little bit more hands-on,
52 and um, you know, a little bit more team oriented
53 and I don't think that, at least for the company that I worked at, it was not like that.
54 Um, and so I wish my guidance counselor would've been like, 'hey,' you know,
55 'look at what an engineer actually does every day. Go and research it before you make this decision.'
56 And I might not have made the same decision.

57 Um, so I think I, like, I tell people that a lot actually,
58 ‘are you sure this is what you want to do?’ You know,
59 and ‘Have you thought about what your job will actually be?’
60 I didn’t, you know, I wish I had.
61 So that was definitely, that was definitely a huge part of it,
62 so I guess those are the reasons.

Through her brief narrative, Jocelyn talked about many different experiences and ideas she had. In lines 1-15, she described how environmental law would allow her to have a larger impact (which related to her SR goals), and in lines 16-20 contrasted this with her internship experience. In lines 21-32, she explained how another motivator out of engineering were her professors at her new university, which she contrasted with those at LPU. She describes the “male-dominated” environment, and perhaps she felt that she didn’t fit in (which she also mentioned at another point in the interview). Interestingly, at LPU there was a female faculty member in mechanical engineering who had a second degree in law; that individual might have been a role model for Jocelyn. Apparently, her experience in college was very important as well as her future ability to have an impact, which she continued to discuss until line 44. For the final section of the narrative, she described how her understanding of engineering before college did not match what she experienced in her internship, and she wanted future students to know more about the profession before committing. In other parts of the third year interview she described additional considerations, such as not liking all the time at a computer and not fitting in:

> Sitting at the computer 8 hours a day working on a tiny little detail and that’s frustrating for me because I didn’t really like what I was doing. …I didn’t like the manufacturing scene in general, it’s really dark and gray and I don’t see daylight for 8 hours which is kind of insane. The engineers just kind of didn’t care. They were like this is normal, this is fine. I was like what do you mean, you don’t have a window and they were cool with it because they like the computer stuff and I just felt like it wasn’t for me and **I didn’t fit in there**. … I asked what else is there and they said yeah there is, but everywhere you go you’re going to be working with the computer on Matlab or whatever it is or some design program, and **I can’t work in front of a computer all day or I will hate it**. Like I hate Solidworks so bad. Which I guess should’ve been the first indication and not take the job maybe because I knew was going to be Solidworks, but I don’t know.

Talking with others, she got the impression of computer and desk work reinforced:

> My dad didn’t tell me. He has a PhD in nuclear engineering and he worked for Florida power and light which is a big electric company down here, for like 20 years and I called him up and I said did you work behind a desk in a cold dark room all day? And he said yes of course I did. Why didn’t you tell me that?

So perhaps if Jocelyn had selected a different internship, the outcome might have been different. Or perhaps many of the career paths in engineering would have been disappointing. Jocelyn continued to be involved with other activities such as a community garden through which she could make an impact outside of her chosen profession. Through environmental law, she found a way to combine her love for the environment and disdain for those polluting it. She did not see the same opportunities through engineering as she went deeper into the profession.

DISCUSSION

These nine students show the wide variety of motivating factors for originally entering and then leaving engineering; social responsibility was an important component for most of these engineering students, and the most important factor for some.

Five important reasons for leaving resulted from the interviews with these students: (i) found a way to have a social impact through their major while enjoying their courses; (ii) the engineering course structure did not allow for a diversity of thought or learning, and was too formulaic; (iii) students were not well-informed about what engineering work would entail, and were frustrated by the mismatch of their preconceptions and their perceived reality as they learned more; (iv) engineering courses were too difficult without a strong enough drive to be an engineer, and (v) engineering faculty were unsupportive, or worse, somewhat misogynistic. Most students left engineering due to a combination of two or more of these motivators. Jocelyn’s reasons fell into (i), (iii), and (v), Miranda’s into (i), (iv), and (v) and Kaitlin’s into (i), (ii), and (iii). All of these can potentially be addressed with a revamping of the engineering education to include more than the technical content and better teaching of the complex technical material. Engineering faculty know why what they are teaching is important; passing this information on to the students during class would add valuable interest and context. This is not a new idea, but more work is needed to ensure widespread adoption of these ideas.

It was helpful to classify the role that SR-related issues played in the decisions of the students to leave engineering. Four categories were created, shown in Table 35. In only Jocelyn’s case did her primary motivation to leave engineering seem related to her SR-goals for her career; and that was only after feeling like a misfit in engineering and experiencing an internship where she was unhappy. Perhaps in the interview she put this “face” on her decision, in order to look at the positive side attracting her to her new major rather than the negatives in engineering that stimulated her to look outside engineering. For three of the students, concerns about meeting their SR goals through engineering seemed among key motivations to leave engineering, along with other factors of similar significance and importance. For another three students, the primary reasons for leaving engineering seemed unrelated to SR, but SR was also among the concerns. And finally, two students seemed to leave engineering for other majors due to reasons that were unconnected with their SR aspirations (or lack of SR motivations, in the case of Thomas). The two authors agreed on six of these independently, then needed to discuss to reach consensus on Jocelyn, Kaitlin, and Alicia who were somewhat in between Types.

Table 35: Leaver Student Types

Type	Students	Type Description
I	Jocelyn	SR is the primary concern and driver to leave engineering.
II	Maggie Katie Kaitlin	SR is among the top concerns and drivers to leave engineering.
III	Nelson Alicia Miranda	Reason to leave engineering partially related to SR concerns.
IV	Thomas Lindsey	Leaving engineering did not appear to be related to SR concerns.

To retain those Type 1 students who just did not find through their engineering education, engineering needs to change not only its image, but its practices to show the potential significant and positive impact on the world. Universities can certainly improve on the issues listed above such as improved teaching, more supportive advisors and professors, or more engaged basic courses in physics and mathematics. Learning Through Service in engineering is growing through service learning and co-curriculars such as EWB. However, a crucial component is for the engineering profession to follow through with a macroethical imperative that gives socially motivated students a reason to finish engineering school and persist to an engineering career. These students are critical thinkers who want their careers to align strongly with their own character and desires to help others with the privileges they have been given. The status quo of engineering is not enough. Engineering companies, and engineers, must be pro-active in promoting equality, peace, and justice.

Finally, at the nexus of engineering practice and education are the faculty and administration of universities. Students commented that they mostly were exposed to jobs that were secure, but mostly benefitted the advantaged, or did not contribute to a better environment physically and culturally. If more companies that were working towards social good were showcased, these Type 1 students may be able to identify and find more motivation to continue in the engineering field.

LIMITATIONS AND VALIDITY

As it is not possible to understand the students' complete ideas on any issues, interpretation of the students' words by the researchers was necessary. Both authors have backgrounds in civil and environmental engineering. It became clear through the interviews, but also through discussions about this study, that the authors have a particular lens through which they see student experiences, and the role of engineers and engineering educators. As described in the methods, the authors reached out to one professor in mechanical engineering, one undergraduate student, and another reviewer in the School of Education who has a wealth of experience with qualitative studies in science and engineering education.

The experiences of these few students can help improve engineering education broadly, but the results need to be transferred to particular contexts depending on majors, the university environment, and ongoing retention efforts, to name a few (M. Eisenhart 2008). This study only included certain engineering majors, mainly civil, environmental, and mechanical. The universities presented herein are all doctorate-granting institutions. While mechanical and civil have the first and second highest number of bachelor's degrees awarded, environmental is the 16^{th} highest and has a higher representation of women. In addition to other majors, this study did not deliberately include electrical, computer science, or chemical engineering – the third, fourth, and fifth largest engineering majors, respectively (Yoder 2014). Finally, this pool of students does not allow for comment on the effects of race, ethnicity, socio-economic status, first-generation, or a multitude of other demographic traits.

Of the 236 first year students with validated responses to the EPRA Survey, 75 checked a box that they would like to be interviewed. The incentive of $100 for completing the interview was not mentioned when the students would make this decision of whether or not they would like to participate in an interview. Perhaps, the students in this study were more interested in speaking about social responsibility than other engineering students. This may also account for why more students in the lowest quartile of EPRA scores did not elect to participate in the interviews associated with this study. Besides these issues, we have little reason to believe that the students are drastically different from the larger pool of engineering students overall. Also, the first year interviews with Jocelyn and Thomas were in person, in contrast to all of the other interviews that were conducted on the phone, but that did not seem to affect their responses to the questions.

Further validity and reliability measures are planned at the end of this study, which is still ongoing, and those are described in more detail in the 'Future Work' section below.

FUTURE WORK

The students in this study will be surveyed for open responses about their previous year experiences in their new major and their plans for the future. Based on future plans described at the end of their third year, some students will likely graduate after 4.5 or 5 years and some will pursue graduate degrees. Most will be interviewing and getting job offers. The specific survey questions have yet to be developed, but this will be a chance to find out students' thoughts about how specifically they are viewing social responsibility in their futures as they are on the precipice of their professions. Additionally, this will be an opportunity to perform a member check to get the interviewee's opinion and feedback about the research group's interpretation of their experiences.

The authors are concurrently continuing research into engineering students' ideas about SR. One study focuses on how engineering students envision themselves as socially responsible engineers in the future and how these ideas change through college; it involves students' discussions around how they balance and mesh their ideas around personal and professional responsibility over three years of interviews. A second related study attempts to understand how engineering students think about socially responsible engineering, and how this idea is influenced by many different actors in the students' lives throughout college. The students in both of these studies will be interviewed a fourth time as they are closer to understanding what their lives as engineers may look like in the future. Also, the quantitative data collected through the EPRA survey has not been fully exhausted, and comparisons between the leaver students' and engineering students' responses as they change over time could be very interesting.

CONCLUSIONS

Are the most socially motivated students leaving engineering? From this sample, it seems they are leaving at higher percentages than others. These individuals left engineering for multiple reasons, and SR seemed among those reasons. These Type 1 students, who wanted to use engineering to benefit the disadvantaged or marginalized of the world, are the best examples of engineers for middle or high schoolers would want to improve society. If engineering education could change to incorporate and uphold the values these students find important, recruitment, retention, and persistence of women in engineering would likely increase (Hewlett et al. 2008). Their entry into the engineering workforce would then, in time, create a culture in engineering that is more caring and beneficial to all those in the global society (Moriarty 1995). Without change, the engineering profession will continue to struggle with the diversity and impact needed to address the growing and coming challenges of the future.

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CHAPTER VII: IMPLICATIONS OF THIS STUDY AND FUTURE WORK

In recent years, and somewhat throughout history, debates about the social responsibility of engineers have been ongoing and evolving at high levels in professional societies and government. This study sought to understand engineers' social responsibility from the students' perspective. Some of this research confirms that which has been concluded from broad quantitative studies or the results from a single institution. It confirms some ideas about women in engineering and how well they feel their goals do or do not align with the goals presented to them of the engineering profession. It problematizes many ideas about what a 'typical' engineer is, and believes. It sheds light on the complexity of these students' lives and leaves open many questions that could further inform our understanding of student life and how this translates to their goals in the engineering profession.

Specifically, this research points to a number of practical steps that engineering educators, administrators, K-12 teachers and advisors, professionals, and hiring managers can take to improve social responsibility content in engineering and retain and recruit students with a strong motivation to act ob their social responsibility through their profession..Parents of bright young students who may be considering engineering as a major can also learn from the results of this study.

First, I will present how this study confirms some of the findings of previous studies. Then, I will give specific recommendations as a result of this study for each of the parties listed above. Next, I will give ideas of what could be potentially future work that builds from the results of this study. Finally, I will give a personal, critical conclusion bringing in my own experience and with these interviews.

1. From the first study of engineering students' changing influences on their ideas of socially responsible engineering, we learned that without the in-class exposure to how engineers impact society beyond their first year courses, students became less concerned with these responsibilities. As students moved closer to becoming practicing engineers, the ideals of loyalty to one's company, financial security, and microethical obligations seemed to dominate thinking about SR. For those students who did continue to value engineering's impact on society, it often became

more limited to the communities in which they worked for their internships. These were the most important exposures and understandings of real-life engineering practice these students would experience. It seemed that in the middle years, there was very little other influence that would counter their understanding of engineering. Therefore, it is not surprising that Cech (2014) found a "culture of disengagement" and Canney (2015) saw a decrease in social responsibility scores over time. A further valuable conclusion is that students' lives are complicated, and the engineering curriculum will not fully determine what students think about their professional goals. While important, family, health, and other personal conditions will impact their opinions in ways we cannot predict.

2. In general, engineering students did seem to become less engaged or concerned with society through their time in college. There were multiple reasons for this disengagement (that expand upon the findings of Cech 2014). First, engineering students' time was monopolized by their technical classes and they did not have the opportunity to stay involved with the more socially relevant courses, extracurriculars, and conversations that many others in college embrace and find most valuable. Second, students were heavily influenced by the engineering profession through career fairs, internships and co-ops – internships are framed as an accurate and intimate experience within the engineering profession for a period of three months. If a student gleaned the values of the engineering profession through this experience that did not include social responsibility or much beyond microethics, the student would come away with these values as well if they were to continue in engineering. Should their values not align, and their personal values would not mold to match those of the engineering profession, the student may leave engineering altogether. Third, engineering students desired, and quite possibly needed, more flexibility in their curriculum. This is a corollary to the second point, but it seemed that engineering students had much potential to learn about how engineering fit into the rest of society simply by taking classes in other departments around campus. Forbes' (2015) study about

flexibility researches the issue in more detail by quantifying and comparing programs (Forbes, Bielefeldt, and Sullivan 2015).

3. Overall, women in this study were more motivated than men by helping others whether or not they stayed in engineering. The many other documented reasons that women leave engineering were also present in this study. Some described the unsupportive, “chilly climate” of engineering culture (Seymour and Hewitt 1997; Lichtenstein et al. 2014; Tsui 2010). Others misunderstood what engineering work entailed, and some were just dissatisfied with their engineering curriculum. They did not find enough value in an engineering degree to be unhappy for their time in college and possibly into their engineering jobs. It is somewhat encouraging that none of the students left exclusively because their engineering courses were not addressing social responsibility at all, or that their projected future career would be working against their own social responsibility values.

Some of the findings from this study are nothing new for engineering educators. Ideas around the social responsibility of engineers need to be infused throughout the curriculum, not just in the first and fourth years. Just by being asked to consider the questions in this study, some students said they were first exposed to these ideas. Improving this component of the engineering curriculum seems to require more effort on the part of the engineering faculty, but also more impetus on the engineering administration to improve their teaching of these ideas. In order for engineers to be ready to deal with the social, economic, and political forces that steer the direction of their work, more emphasis must be placed on these factors within engineering courses. Some students appreciated their third year professional practice class at TechU, and others described a particular class that started with a real-world mechanics of materials issue at the beginning of each class. These make direct connections of the technical material they are learning and the society in which their buildings, devices, and ideas will be implemented. Possibly, pairing the technical engineering knowledge with the humanities or social science courses would be valuable. This would foster interdisciplinary collaboration and better teaching. Additionally, efforts such as those in Learning Through Service, social contextualization of engineering problems, and the Engineering, Social Justice and Peace community can be replicated at any institution. As Chapter V described, emphasizing care in engineering education could lead to a new generation of caring engineering professionals, which will start the cycle to making the profession as a whole more caring (Moriarty 1995). The world needs more engineers that deeply care about social issues of today, and have the skills to address them.

At the same time that engineering educators can try to make the college-level curriculum more socially engaged, the growing number of K-12 engineering programs should ensure that their curricula encourage this thinking as well. *Changing the Conversation* outlined well that the messaging about what makes a good engineer needs to change. Competence in mathematics and science are no longer enough (National Academy of Engineering 2008). A quality engineering professional also needs to have a drive to improve society. While this study did not focus specifically on K-12, the first year engineering students did describe their reasons for pursuing engineering, and 15 of 34 said it was at least partially due to their aptitude in math and science. Eleven also said they had some sort of high school engineering experience that led them to the major. In general the students without previous experience in engineering who believed that they would have the greatest social impact through the major ended up leaving the major. This misunderstanding does not need to happen; K-12 engineering and college engineering can work together to provide an educational experience that is accurate and ambitious. At the same time, if students succeed through engineering school and do not find this kind of work in the profession, they will leave for other professions.

Engineering practice quite possibly has the largest changes to make in its messaging, structure, and purpose. Engineers have the potential to tip the scale more towards addressing inequalities and improving the environment when making decisions about which projects to take and how to execute them. Some companies have started to make volunteer opportunities easier or more enticing for their engineers by providing extra paid time off or supporting through meeting space within their office (see Rulifson and Bielefeldt 2015 for more details about engineers’ experiences with service). If the engineering companies want to keep more of the socially motivated engineers within their companies, though, more effort must be taken. Decline projects that are socially neutral, provide meetings that allow engineers to ask questions about the social implications of a project, or take on more *pro bono* work. Too many engineering companies have been operating at the bare minimum of social responsibility compared to the amount they have benefitted from the society which pays them. These efforts may require taking some risks, seeing what opportunities are in developing countries, and opening a company's procedures to criticism. A concerted effort, though, will not only keep the more socially responsible engineers, it will make the world a better place.

Future Work

This study brings up more questions about engineering students' social responsibility development. First, this study will have a fourth round of interviews with the engineering students in the Spring of 2016 as they are preparing to graduate and join the engineering profession. The leaver students will be asked to complete a survey with questions regarding the fulfillment they found in their new major and how that relates to their desires to act on their social responsibility. There are also components of the interviews which were not explored in this dissertation. For example, students were asked to list traits that characterized themselves and engineers. This exercise elicited interesting ideas from the students, but did not fit well into the longitudinal study presented here.

The data in this study can be parsed in many different ways, and studies can be performed to understand any of those components better. For instance, I am particularly interested in the specific ways that internships influence students (i) ideas about socially responsible engineering and (ii) their social responsibility-related identities as engineers. While this study explored these somewhat, I would like to be more intentional about the questions asked specifically regarding their internships. This possibly would involve some on-the-job observations as well. More comparisons can also be done with the quantitative data that has been collected from numerous universities through the last distribution of the EPRA survey. Some of the trends here, such as previous engineering courses in high school, a desire to help others, and continued family influences can be explored to see how common these influences are with the larger engineering student population. Further, the large dataset will allow for comparisons between major, university, and other demographics. In this study, it seemed that students at TechU were highly unlikely to leave engineering, and environmental engineers were the most likely to change majors within engineering or leave engineering altogether. Another interesting area of study would be to follow these students into the workplace to find how they are experiencing their own social responsibilities as practicing engineers, and if this matches their expectations. We have little understanding of the engineering workplace from a research standpoint. It would be fascinating to find out how social responsibility is prioritized in actual decision making or how decisions are justified as socially responsible. Any project can do more, so how is the line drawn? Also, more information would be very interesting about the differences between sector (industry, government, consulting), engineering discipline, location, the status of the person making the decisions, and how these all vary through time with different responsibilities acquired through different roles within the company. Finally, since students develop their ideas of what engineering has the potential to do in terms of impacting society, it would be valuable to study high school pre-engineering students and try to understand what they are thinking about social responsibility and how they would achieve it through engineering.

Finally, I would like to comment about the value of this research, the process, and what I see for the future. Before beginning this research, I was a consulting structural engineer in the San Francisco Bay Area. The previous chapters have shown that this is largely qualitative education research in which I had no experience. This research has shown me the value of qualitative research in engineering education. The students' experiences are so rich and full of emotion that is difficult to translate into words. They are stressed, busy, excited, and nervous about classes, friends, sports, and jobs. Hearing from the students themselves about how they prioritize activities such as volunteering or part-time jobs was incredibly valuable. While I remember my own engineering education and the efforts in which I was involved, I am a number of years out of those experiences. When students were given a chance to elaborate on what they were feeling, their ideas formed in nuanced dialogue. Responses to a survey can be very valuable on the aggregate, but I feel that to really start making changes in engineering education, the same numbers being presented are not the most effective. This type of research gives a human character and an opportunity for the students to get something back from the growing engineering education research in which they are constantly being asked to be involved. Further qualitative and mixed methods research in engineering education will unearth more depth and ideas for improvement from the students themselves, those who are actually impacted by the interventions we make in the classroom and at the college level. The rigor of this type of research is no different than those with which engineering educators are comfortable, and it can lead to exciting advances in our knowledge and improvements in engineering education for the future.

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APPENDICES

APPENDIX A: Y0, FALL 2012 EPRA SURVEY (CANNEY 2013) AND UPDATED QUESTIONS

THE ENGINEERING PROFESSIONAL RESPONSIBILITY ASSESSMENT (EPRA) TOOL

Engineering Professional Responsibility Assessment

Definitions:
Community Service is voluntary work intended to help people in a particular community.
Social Responsibility is 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.
Social Justice relates to the distribution of the advantages and disadvantages in society, including the way in which they are allocated.

pro bono - Work done without compensation (pay) for the public good

Please rate how important the following skills are for a professional engineer using the following scale:

1	2	3	4	5	6	7
Very Unimportant	Unimportant	Slightly Unimportant	Neutral	Slightly Important	Important	Very Important

Fundamental Skills ***(i.e. Math & Science)***	1	2	3	4	5	6	7
Technical Skills ***(i.e. Conducting Experiments, Data Analysis, Design, Engineering Tools, & Problem Solving)***	1	2	3	4	5	6	7
Business Skills ***(i.e. Business Knowledge, Management Skills & Professionalism)***	1	2	3	4	5	6	7
Professional Skills ***(i.e. Communication, Contemporary Issues, Creativity, Leadership, Life-Long Learning, & Teamwork)***	1	2	3	4	5	6	7
Cultural Awareness/Understanding ***(i.e. of your culture, and those of others)***	1	2	3	4	5	6	7
Ethics ***(i.e. ensuring all of your work follows professional codes of conduct)***	1	2	3	4	5	6	7
Societal Context ***(i.e. how your work connects to society and vice versa)***	1	2	3	4	5	6	7
Volunteerism ***(for professional and personal reasons)***	1	2	3	4	5	6	7

Future Job Qualities: Below there are 8 bins with different job qualities on them. You have 10 stones to distribute among the bins to mark which qualities are important to you when thinking of your future engineering job. You may place multiple stones in any bin, but you must place exactly 10 stones in total and no fractional stone distributions are allowed. Write your number of stones in the square on each bin.

Clipart courtesy FCIT

Rate the level to which you agree/disagree with the following statements using the following scale:

1	2	3	4	5	6	7
Strongly Disagree	Disagree	Slightly Disagree	Neutral	Slightly Agree	Agree	Strongly Agree

Engineers have contributed greatly to fixing problems in the world	1	2	3	4	5	6	7
I would *not* change my engineering design because it conflicted with community feedback	1	2	3	4	5	6	7
Volunteer experience(s) have changed the way I think about spending money	1	2	3	4	5	6	7
It is important to me personally to have a career that involves helping people	1	2	3	4	5	6	7
Engineering skills are *not* useful in making the community a better place	1	2	3	4	5	6	7
It is important for engineers to consider the potential broader impacts of technical solutions to problems	1	2	3	4	5	6	7
Service should *not* be an expected part of the engineering profession	1	2	3	4	5	6	7
I would be willing to have a career that earns less money if I were serving society	1	2	3	4	5	6	7
I will use engineering to help others	1	2	3	4	5	6	7
I view engineering and community service work as unconnected	1	2	3	4	5	6	7
I feel called to serve others through engineering	1	2	3	4	5	6	7
The needs of society have no affect on my choice to pursue engineering as a career	1	2	3	4	5	6	7
It is important to incorporate societal constraints into engineering decisions	1	2	3	4	5	6	7
Technology does *not* play an important role in solving society's problems	1	2	3	4	5	6	7
My engineering skills are strengthened through participation in engineering service opportunities	1	2	3	4	5	6	7
I feel called by the needs of society to pursue a career in engineering	1	2	3	4	5	6	7
Engineering firms should take on some *pro bono* work	1	2	3	4	5	6	7
I doubt that volunteer work will ever have much affect on my career	1	2	3	4	5	6	7
I think it is important to use my engineering to serve others	1	2	3	4	5	6	7
Engineers can have a positive impact on society	1	2	3	4	5	6	7
Engineers should use their skills to solve social problems	1	2	3	4	5	6	7
It is important to use my engineering abilities to provide a useful service to the community	1	2	3	4	5	6	7
I believe that I will be involved in social justice issues for the rest of my life	1	2	3	4	5	6	7

Rate the level to which you agree/disagree with the following statements using the following scale:

1	2	3	4	5	6	7
Strongly Disagree	Disagree	Slightly Disagree	Neutral	Slightly Agree	Agree	Strongly Agree

I do *not* think it is important to use engineering to serve the greater community	1	2	3	4	5	6	7
I believe my life will be positively affected by the volunteering that I do	1	2	3	4	5	6	7
I think people who are more fortunate in life should help less fortunate people with their needs and problems	1	2	3	4	5	6	7
I believe that extra time spent on community service is worthwhile	1	2	3	4	5	6	7
It is *not* my responsibility to do something about improving society	1	2	3	4	5	6	7
I believe it takes more than time, money, and community efforts to change social problems: we also need to work for change at a national or global level	1	2	3	4	5	6	7
Community groups need our help	1	2	3	4	5	6	7
There are *not* people in the community who need help	1	2	3	4	5	6	7
I can have an impact on solving problems that face my local community	1	2	3	4	5	6	7
It is important to me to have a sense of contribution and helpfulness through participating in community service	1	2	3	4	5	6	7
Please mark "3" if you are reading this question	1	2	3	4	5	6	7
It is my responsibility to take some real measures to help others in need	1	2	3	4	5	6	7
I feel an obligation to contribute to society	1	2	3	4	5	6	7
There are people who have needs which are not being met	1	2	3	4	5	6	7
My contribution to society will make a real difference	1	2	3	4	5	6	7
I think I should help people who are less fortunate with their needs and problems	1	2	3	4	5	6	7
I *cannot* have an impact on solving problems that face underserved communities internationally	1	2	3	4	5	6	7
There are needs in the community	1	2	3	4	5	6	7

Rate the frequency that you have engaged in any of the following community service activities <u>since the beginning of this school year</u>, using the following rating scale:

0	1	2	3	4	5
Have not Participated	Once	Twice	More than Twice but not routinely	Monthly	Weekly

Habitat for Humanity Build	0	1	2	3	4	5
Tutoring elementary or secondary children	0	1	2	3	4	5
Tutoring college students (unpaid)	0	1	2	3	4	5
Donated Blood	0	1	2	3	4	5
In Class Service Learning Project (i.e. service oriented capstone project)	0	1	2	3	4	5
Engineers without Borders (EWB), Engineers for a Sustainable World (ESW), or Bridges 2 Prosperity Project	0	1	2	3	4	5
Short term on-site service project (i.e. Spring Break Service trip, EWB/ESW in-country work)	0	1	2	3		
Disaster Relief Volunteer	0	1	2	3		
International Humanitarian Volunteer: (Specify)________________________	0	1	2	3		
Food Bank Volunteer	0	1	2	3	4	5
Meals on Wheels Volunteer	0	1	2	3	4	5
Nursing Home Volunteer	0	1	2	3	4	5
Political Campaign Volunteer	0	1	2	3	4	5
Big Brother/Big Sister, Boys & Girls Club, Boy/Girl Scouts	0	1	2	3	4	5
Soup Kitchen Volunteer	0	1	2	3	4	5
Sports Camp, Coaching, etc. (unpaid)	0	1	2	3	4	5
Professional Society (ASCE, ASME, AAEE, etc.)	0	1	2	3	4	5
Other:___________________________	0	1	2	3	4	5

If you were to volunteer, or have volunteered with an organization since coming to college, please specify why you would/did (check all that apply):

- ☐ Required for class
- ☐ To gain new skills
- ☐ I went with a friend
- ☐ To meet new people
- ☐ Because of my religious beliefs
- ☐ To build my resume
- ☐ Makes me feel good
- ☐ For an international experience (to travel)
- ☐ To help others
- ☐ Other:______________________________
- ☐ With my Fraternity/Sorority

Are there factors that currently or have previously limited/inhibited your participation in volunteer activities (check all that apply):

- ☐ Lack of time due to course work
- ☐ Not interested in volunteering
- ☐ Lack of time due to extracurricular activities
- ☐ My friends do not participate in volunteer activities
- ☐ Lack of time due to work obligations
- ☐ Previous negative experience(s) with volunteering
- ☐ Family obligations
- ☐ Financial limitations
- ☐ Health restrictions
- ☐ None
- ☐ Don't know where to volunteer/how to be connected with a volunteer opportunity
- ☐ Other:______________________________

Briefly describe any events that have influenced your views of community service and social responsibility.

Demographic Information

Name:					
Email:					
Gender	Male			Female	
Age:	<18	18-20	21-23	24-28	>28
Major:	Civil	Environmental Open		Mechanical	
	Other:________________________________				
College rank:	Freshman	Sophomore	Junior	Senior	Graduate
Cumulative GPA:	<2.5	2.5-3.0	3.0-3.5	3.5-4.0	
Race:	African American		Asian	Hispanic	
	Native American		Multiracial	Non-Hispanic White	
	Other:________________________________				
Previous Engineering Work Experience:	None	Summer or Part Time Internship/Co-term	Full Time Employment: For _______ year(s)		
Are you in the first generation of your family to attend college?	Yes		No		
How would you describe your religious preference?	Religious, affiliated with an organized religion (i.e. Christian, Muslim, Jewish, Hindu, Buddhist, etc.)	Spiritual but not affiliated with an organized religion (i.e. Humanist, Agnostic, etc.)	Atheist	Indifferent or not religious	
If religious, how active do you consider yourself in the practice of your religious preference?	Very active	Somewhat active	Not very active	Not active	Does not apply/Prefer not to say

<u>Questions added to the Tier 3 distribution (Spring 2015):</u>

Are there any college classes that you have found influential to your views of social responsibility?

- **Yes**
- **No**

If yes, what courses and in what ways?

Briefly describe any other events that have influenced your views of community service and social responsibility.

Appendix B: Full Demographics of Interviewed Students

Table 36: Demographics of All Interviewed Students, Y0 Total Score and YI Interview

Pseudonym	Initial Total SR Score	Gender	First Gen	Race / Ethnicity	Major (Y0)	Institution	Y1 Interview		Year 1 SR Type
							Medium	Length (min)	
Thomas	35 – 39.5 (< -1.5σ)	M		White	ME	LRU	In Person	56	4
Travis		M		Hispanic	EnvE	SRU	Phone	56	2
Todd	39.8 – 44.1 (-1.5σ to -0.5σ)	M		White	ME	TU	Phone	55	4
Quinn		M		Asian	CE	LRU	Skype	58	3
Jason		M		White	ME	TU	Phone	49	3
Jackie		F		White	ME	LRU	Phone	45	3
Madison		F		White	ME	TU	Phone	42	3
Nelson		M		White	EnvE	SRU	Phone	76	1
Tucker	44.1 – 48.5 (-0.5σ to .5σ)	M		White	CE	LRU	In Person	29	4
Macy		F		Multi	Other	MPU	Phone	32*	4
Trevor*		M		White	EnvE	SRU	Phone	54*	3
Ashley		F		White	Other	MPU	Phone	60	3
Kim		F		White	EnvE	LRU	In Person	50	2
Jamie		F		White	ME	TU	Phone	56	2
Denise		F	Yes	Hispanic	Other	MPU	Phone	76	2
Wynne		F		White	CE	LRU	Skype	40	2
Alicia		F		White	ME	LRU	In Person	54	1
Miranda		F		White	Other	MPU	Phone	73	1
Kaitlin		F	Yes	White	EnvE	SRU	Phone	63	1
Derek	48.7 – 52.1 (.5σ to 1.5σ)	M		White	Other	MPU	Phone	86	3
Julie		F		White	Other	MPU	Phone	54	3
Katherine		F		White	EnvE	SRU	Phone	57	3
Rachael		F		White	Other	MPU	Phone	58	3
Shawn		M		White	EnvE	LRU	Phone	56	2
Sarah		F	Yes	White	CE	TU	Phone	56	2
Tanya		F	Yes	Afr-Am	EnvE	TU	Phone	54	2
Brandon		M		White	EnvE	TU	Phone	65	2
Tim		M		White	ME	LRU	In Person	67	2
Nathan		M		White	CE	TU	Phone	51	1
Lindsey		F		White	Other	MPU	Phone	51	2
Maggie		F		White	CE	SRU	Phone	88	1
Jolene	52.2 – 54.2	F		White	CE	TU	Phone	53	1

Pseudonym	Initial Total SR Score	Gender	First Gen	Race / Ethnicity	Major (Y0)	Institution	Y1 Interview		Year 1 SR Type
							Medium	Length (min)	
Jocelyn	(> 1.5σ)	F		White	ME	LRU	In Person	56	1
Katie		F		White	CE	LRU	Phone	57	1
	Total (1st Year)	Men: 13 Women: 21	4	Asian: 1 Hisp: 2 Afr-Am: 1 Multirace: 1	ME: 12 CE: 7 EnvE: 7 Other Eng: 5	LRU: 11 SRU: 6 TU: 9 MPU: 8			Type 1: 9 Type 2: 11 Type 3: 10 Type 4: 4

*switched major within engineering; **left engineering;

+ ME – Mechanical; EnvE – Environmental; CE – Civil; CompSci – Computer Science; Env Stu – Environmental Studies; ChE – Chemical Engineering; BiomE – Biomedical Engineering; ArchE – Architectural Engineering; Int Phys – Integrated Physiology; Econ – Economics; LandArch – Landscape Architecture; BioChem – Biochemistry; AnimSci – Animal Science; IntlDev – Community and International Development

Table 37: Demographics of Interviewed Students, Y2 and Y3 Interviews and EPRA Trends

Pseudonym	**Major (Y0/Y1/Y2/Y3)**	**Institution**	**SR Type (Y1/Y2/Y3)**	**Y2 Interview Length (min)**	**SR score trend (Y1-Y2)**
Thomas**	ME/ME/ME/Geoscience	LRU / LRU3	4	61	Increase
Travis	EnvE/EnvE/EnvE/Unsure	SRU / No School	2	57	Increase
Todd	ME/ME/ME/ME	TU	4 / 3 / 4	54	No change
Quinn	CE/CompSci/No int/CompSci	LRU	3	No interview	---
Jason	ME/ME/ME/ME	TU	2 / 4 / 2	57	No change
Jackie	ME/ME/ME/ME	LRU	3	64	No change
Madison	ME/ME/ME/ME	TU	3	56	No change
Nelson**	EnvE/Env Stu/Env Stu/No School	MPU/No School	1	80	---
Tucker	CE/CE/CE/CE	LRU	4 / 4 / 2	51	No change
Macy	Other/ChE/ChE/No int	PrU	4	61	No change
Trevor	EnvE/CE/CE/CE	SRU	3 / 2 / 4	65	No change
Ashley	Other/ChE/ChE/ChE	MPU	3 / 3 /2	60	---
Kim	EnvE/EnvE/EnvE/CE	LRU	2	57	No change
Jamie	ME/ME/ME/ME	TU	2	57	No change
Denise	Other/ME/ME/ME	PrU	2	69	Decrease
Wynne	CE/ArchE/ArchE/ArchE	LRU	2	69	No change
Alicia**	ME/ME/Int Phys/Int Phys	LRU	1	66	No change
Miranda**	Other/ChE/Economics/Econ	PrU	1	69	Decrease
Kaitlin**	EnvE/LandArch/Undec/Intl Dev’t	MPU/LPU2	1	71	Decrease
Derek	Other/ME/ME/ME	PrU	3	74	No change
Julie	Other/ME/ME/ME	PrU	3	60	Decrease
Katherine	EnvE/EnvE/EnvE/CE	MPU	3	68	---
Rachael	Other/CompSci/CS/CS	PrU	3 / 2 / 2	62	Variable
Shawn	EnvE/EnvE/ChE/ChE	LRU	2	63	Decrease
Sarah	CE/CE/CE/CE	TU	2	58	Decrease
Tanya	EnvE/EnvE/EnvE/EnvE	TU	2	59	Variable
Brandon	EnvE/EnvE/CE/CE	TU	2	60	No change
Tim	ME/ME/No Interview/No Int	LRU	2	No interview	---
Nathan	CE/CE/CE/CE	TU	1 / 1 / 2	57	No change
Lindsey**	Other/BiomE/Biochem/Biochem	PrU	2	59	No change
Maggie**	CE/AnimSci/Intl Dev’t/Intl Dev’t	MPU	1	61	No change
Jolene	CE/CE/CE/CE	TU/MPU2	1 / 2 / 2	64	Decrease
Jocelyn**	ME/ME/ME/Environ Science	LRU/LPU4	1 / 2 / 2	62	Decrease
Katie**	CE/CE/Environ Studies/EnvStu	LRU	1	76	Increase
Y3 Totals	ME: 8	LRU: 9	Type 1: 9		Increase: 2

Pseudonym	**Major (Y0/Y1/Y2/Y3)**	**Institution**	**SR Type (Y1/Y2/Y3)**	**Y2 Interview Length (min)**	**SR score trend (Y1-Y2)**
	CE: 6 EnvE: 1 Other Eng: 5 Non Engrg: 9 Left Study: 3	MPU: TU: 9 PrU: 8	Type 2: 11 Type 3: 10 Type 4: 4		No change: 22 Decrease: 6

APPENDIX C: YEAR 1 INTERVIEWS CODE BOOK

1) Definition of SR (as implied throughout the interview)

Code	**Definition**	**Example Quote**
personal obligation	I have to	Jamie: "So the way I see it, society has invested a heck of a lot of money and time in me. So therefore, it is my responsibility to give them a back payment of that investment at some point in my life. "
personal desire	I want to, it makes me feel good	Maggie: "A lot of the time the work that we were doing was incredibly fulfilling because you did get to see like these projects could go up overnight and you got to see people's lives changed because of little things that you wouldn't really think of.... so like, when I was trying to figure out what I wanted to do for a living the first thing I thought of was I'm really happy when I'm helping people in this sort of an environment."
everyone's obligation	we all have to help each other, have to help the world	Nathan: "I think people need to come together and try to help each other out, in the time of need."
everyone's desire	it's great that people want to help, or a weak "should help others"	Jason: "I don't necessarily believe that everyone has to go volunteer; I know some people just can't, but if anyone has a good opportunity to do that they should do it or whatever."
charity	the act of giving money, but be cognizant of the reason and who	Lindsey: "I mean like if you have a lot of cookies and you see someone who has no cookies you need to give them some cookies. So it kind of develops as you grow older, not just cookies but money, or clothes, or donating to charity and stuff like that."
helping individuals	those close to you, or a couple particular people, peers (HW)	Tucker: "I've helped buddies and stuff. Just with like homework help if they have questions."
helping community	local, with volunteering	Jackie: "I feel like it means, the responsibility that you have as a member of the human race to go out and create a part of change in the world. Whether or not that is just in your local city in your local community working at a soup kitchen."

helping better society	at large	Tim: "I feel I need to help people because I'm very passionate about a couple social issues, and really passionate about improving the world as a whole whether through civil rights or hunger or any of the social issues we talked about."
inherent with engineering	without being prompted to relate SR to engineering, understand engineering to be serving all of society	Tucker: Q:"Yeah. So on a larger scale of what engineering can do for society, how do you see those two connecting?" T: "I think it's essential to society. We do most of the work that's necessary for normal life like water in engineering and mediating safety and the water. We need people to sanitize that and engineer a way to get it around the world and stuff. Buildings again, that kind of thing."
personal character	having good character, treating people with respect	Todd: "I just in general try to be a good person, you know? A good friend, supportive when I need to be, good son and brother…"
professional ethics	seem to relate to a job and what one should do	Tucker: "Just like not be fraudulent and keep to your word and stuff and having good ethics I guess."
safety		Ashley: "making sure that like what you are doing isn't harming people or like that what you are doing is like, just make sure the pros outweigh the cons and making sure you are being responsible with what you doing I guess."
equity	Recognition that they have more and others don't, or that big social issue is inequality	Nathan: "I guess I just feel like everyone deserves a chance, and a lot of these people who are impoverished, a lot of them spend their whole lives trying to get out of the hole that they're in and they don't get a lot of the chances that we get."
selflessness	putting other people before yourself	Sarah: "Like, you can't just think about yourself. It's, you have to think about everybody else with that and how it's your responsibility to help everybody, and you can't be selfish with, you know, your family or your company. It's your responsibility to better communities or states and countries."
environmentalism	concerned with protection of the environment for the sake of the environment, not resources	Tanya: "I actually thought about material science for a little bit but, naw, I really like the environment and actually being one with the environment."

conservation	environmental resources need to be preserved and used wisely	Maggie: "How to better utilize our resources and also support a growing population"
society and environment over money	need to think about the first two before money in making decisions	Miranda: "Because I know that some of the environmental solutions that people have developed thus far don’t make sense moneywise. It’s more expensive, sometimes a lot more expensive to develop something an environmentally friendly way versus the old traditional way"
helping the disadvantaged/marginalized /impoverished	more of an objective determination that these people need help, not relative to the interviewee's status	Madison: "I do think that engineers need to help impoverished countries like get safer water, cleaner water and help them to be able to afford stuff like that."

2) How is social responsibility learned and formulated throughout the students' freshman year of college and prior to coming to college?

<u>Pre-college</u>	**Definition**	**Example Quote**
travel abroad	experiences other cultures and underserved communities	Katie: “I also spent some time with a host family and volunteering and doing a lot of projects such as helping clean up communities and schools and so I’ve seen a lot of the help that poverty-stricken areas have and just getting access to water…”
Environmentalism	engages in or is exposed to how the environment needs to be preserved	Trevor: "I took an ecology class and we went up and down the Merrimack River, which is one of the biggest rivers in New Hampshire and we did water quality testing"
HS classes	the course they took was influential	Travis: "My teachers, my environmental science class made me realize that it is my responsibility to keep water clean and not waste certain things and to continue to recycle and reuse things that aren't going to last forever like aluminum, like cans and stuff, plastic containers just try to recycle more."
HS extracurricular	potentially this is local community service as well	Tanya: "I came to my definition I would say, in high school, that's where it came from the most because I was in the marching band and a dancer and we always did community things like the AIDS walk or breast cancer walk."

College	Definition	Example Quote
engineering ethics	generally talked about as learned through a class, but could be another medium	Miranda: “Like even our professors are talking about, how they brought up ethics a lot and how it is something that they always struggle with.”
EWB	involvement in EWB	Lindsey: “I was working with the water quality group who are doing a bunch of research to find a way to make the water more potable and more clean and healthy for them to drink"
volunteer groups	involvement in group that acts upon social responsibility	Nathan: “I’m in an organization called EWB, Engineers Without Borders, and I’m really trying to be involved with that, because not only is that a good engineering experience and I like it because we’re going out and we’re doing something for a community and were actually helping them.”
individual community service	doing community service not as part of a group	Tanya: "Currently, I have a friend in a nursing home that I visit. And I just became friends with him recently, like a few weeks ago. And for a while, he would interact with my elders in the nursing home and give them gifts and stuff."
engineering class	causes them to think about SR and/or shapes their understanding of it, for themselves personally or engineers	Madison: "Probably our engineering fundamentals class. It really instilled this, umm, bettering society and improvements and all that."
non-engineering class	things such as sustainability, history, even a development course	Katie: “Whether it’s politics or developing countries’ problems with capitalism. Those are just a range of issues that we talked about in the class, but it really opened my eyes to a lot more problems that are out there that I’d like to have a chance to address at least.”
personal observation	somewhat related to travel, but includes local communities too	Kim: “Probably education because, like, I don’t know it’s kind of, like, what I’m doing now and it affects me if they change anything obviously.”

news	learns of other communities, issues, inequities through news or conversations about the news	Jocelyn: “Industrial things that are pouring waste into our ocean so there’s definitely that environmental engineer that says, “Hey we need to clean this up,” like in the news and stuff like that.”
extracurricular activities	not typically considered "volunteering" but influential	Nelson: "Well I just started working in some undergraduate research here and they've really turned me on to a lot of the plights of the poor people of the world, specifically in areas like Bangladesh and coastal Africa."
discussion with others		Maggie: "I'm actually part of a club that meets on campus that meets twice a week and just talks about what our thoughts are and it gets into social justice conversations, and all sorts of things like that... And I've come to a lot of my conclusions through a lot of discussion with people whose opinion I respect."

3) How do students relate Engineering to SR?

	SR Type	**Definition**	**Example Quote**
EWB	1	good way to act on their understanding of SR,	Wynne: “I’m in an organization called EWB, Engineers Without Borders, and I’m really trying to be involved with that, because not only is that a good engineering experience and I like it because we’re going out and we’re doing something for a community and were actually helping them.
ethics	4	how engineers need to be socially responsible	Jason: "Well, even going back to that bridge collapse, that engineering failure and a bunch of people died. So that is kind of an engineering social responsibility right there."
role model	1	as an engineer doing service, they are a role model for others that see them/outreach-related	Julie: “So I wanted to sort of give back in that regard of like well now I could be an inspiration or a teacher to another child who like could someday become interested in engineering.”

have technical skills of value	1, 2	they believe that engineers have technical skills (structural design, water chemistry, product design) that are useful for acting on SR	Lindsey: “So like if you become a biomedical engineer, then you are gaining skills you can use to help with research or if you’re a civil engineer, you can find ways to use your skills to build structures and make roads and stuff like that in city planning. And so like you can kind of see where that can fit in with like solving the homelessness problem and stuff like that so I guess just because it’s a clear correlation.”
have professional skills of value	1	communication, teamwork, etc. that maybe are learned through engineering classes, but not necessarily	Katherine: "So yeah, I think that the utilization of resources and collaboration is like a huge thing that I’m seeing in engineering school that I also see as being a really crucial part of, sort of just being a global citizen."
problem-solvers	1, 2	world has problems, engineers can solve them	Jolene: "So, just to solve problems and make the world, make life easier. That's what engineers do."
engineering benefits society overall	2	inherently through what engineers do (though maybe not everyone equally)	Madison: "I know engineers need to create or design things to better society as a whole."
environmentalism	2	Bettering environment, but not with the motivation that humans can use it	Jocelyn: I definitely see a lot of engineering in the pollution area, you know air pollution and water quality. That was a lot of what I did when I went to Missouri S&T. There is a lot of that in Florida because there is this big industry. Industrial things that are pouring waste into our ocean so there’s definitely that environmental engineer that says, “Hey we need to clean this up,” like in the news and stuff like that.
conservation	2	renewable energy, initial ideas of EnvE, keep water clean, save the earth	Brandon: “Well, for environmental engineering, you know, water I guess. And being able to handle water and conserve water and use water in different ways and stuff. It's kind of an important thing.”

4) Does your sense of social responsibility move you towards or away from engineering?

	SR Type	**Definition**	**Example Quote**
SR not the reason for engineering, but an acknowledged benefit	3	SR not primary motivation for engineering	Jason: "I think right now I'd say it would be a bonus more than really important."
SR very important, w/ or w/o engineering	1, 3	Desire or need to help is very strong and will be involved no matter if engineering is part of their participation	Katie: "I think it's more than anything, the fact that with engineering I have the opportunity to make a really positive difference in people's lives. I thought a lot about going into some sort of public service major instead and going into policy, but I decided that I would rather do engineering. Because I had the chance to make a physical difference rather than just a policy difference that would take a long time to implement. With engineering I can go ahead and make people's lives better immediately."
Sees their version of SR in their engrg future	1,2		Quinn: "Right now as a university student I'm trying to learn my best to become a better person in order to help other people. I think helping other people is a very important part of life."
Their version of SR not related to their engrg future	3,4		Todd: "I know there are a lot of paths I can go down with engineering that could potentially improve the social atmosphere, but I don't know about me doing them as of right now."

APPENDIX D: CU BOULDER INSTITUTIONAL REVIEW BOARD APPROVAL

University of Colorado Boulder

Institutional Review Board
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Boulder, CO 80309
Phone: 303.735.3702
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APPROVAL

17-Nov-2014

Dear Gregory Rulifson,

On **17-Nov-2014** the IRB reviewed the following protocol:

Type of Submission:	Continuing Review
Review Category:	Expedited - Category 7
Title:	Assessing Engineering Students' Understanding of Social Responsibility from Undergraduate and Graduate Education into Professional Life
Investigator:	Rulifson, Gregory
Protocol #:	11-0414
Funding:	Federal
Documents Reviewed:	Canney CITI completion report; ASEE 2014 - Survey SR Responses; 2014 ASEE - Longitudinal Freshmen; HRP-212: FORM - Continuing Review; Canney - Framework for SR Development IJEE;

The IRB approved the protocol from **17-Nov-2014** to **16-Nov-2015** inclusive.

Before **17-Oct-2015**, you are to submit a completed FORM: Continuing Review (HRP-212) and required attachments to request continuing approval or closure. This protocol will expire if continuing review approval is not granted before **16-Nov-2015**.

Click the link to find the approved documents for this protocol: Approved Documents. Use copies of these documents to conduct your research. Among the approved documents is a completed IRB Authorization Agreement (IAA). The IAA should be presented to the collaborating institution(s) along with this IRB approval letter.

In conducting this protocol you must follow the requirements listed in the INVESTIGATOR MANUAL (HRP-103).

Sincerely,
Douglas Grafel
IRB Admin Review Coordinator
Institutional Review Board

Appendix E: Chapter IV, Additional Weidman I-E-O Models

Figure 13: Ashley (ChE, PrU) Weidman I-E-O Model

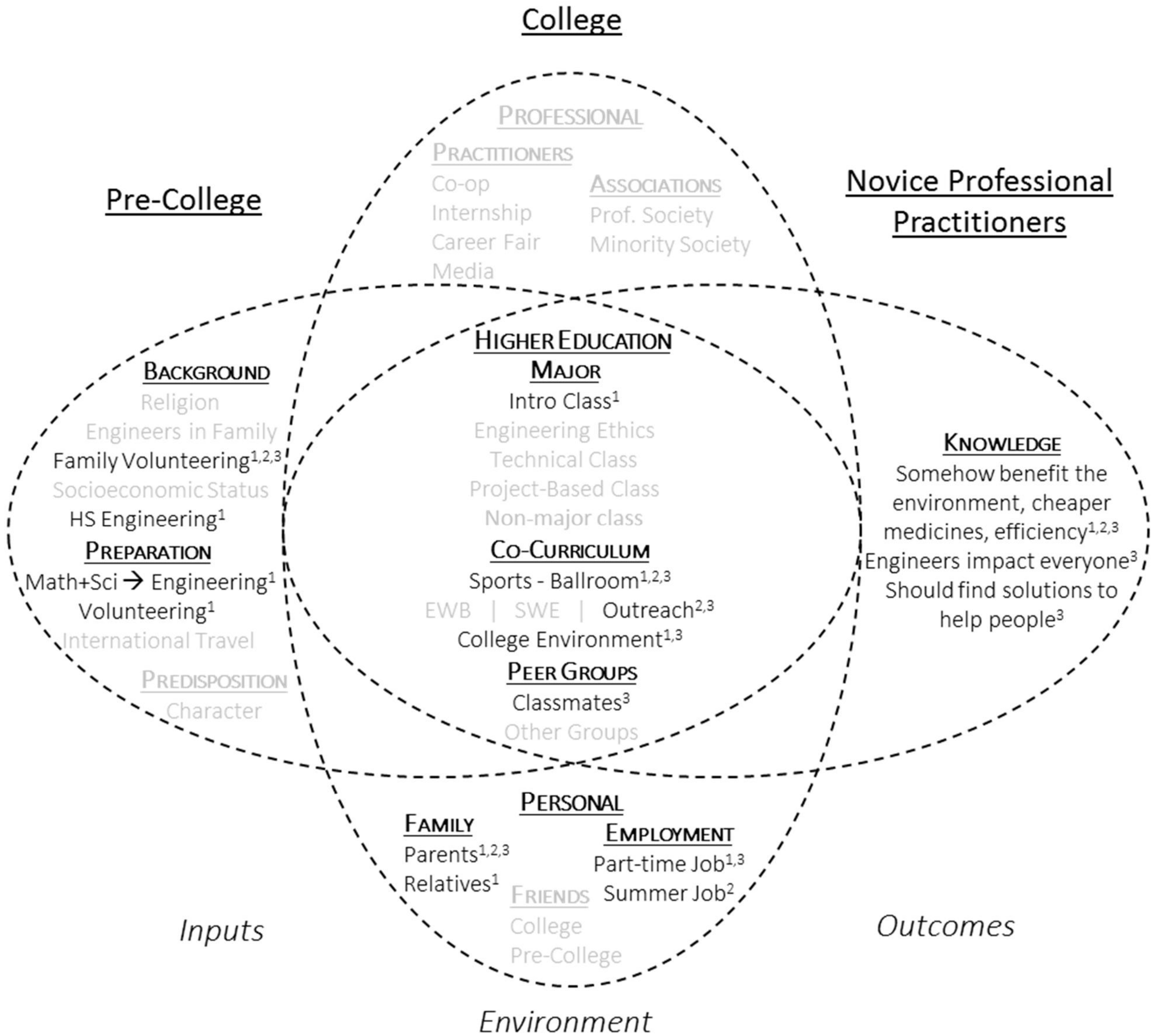


Figure 14: Brandon (EnvE --> CE, TechU) Weidman I-E-O Model

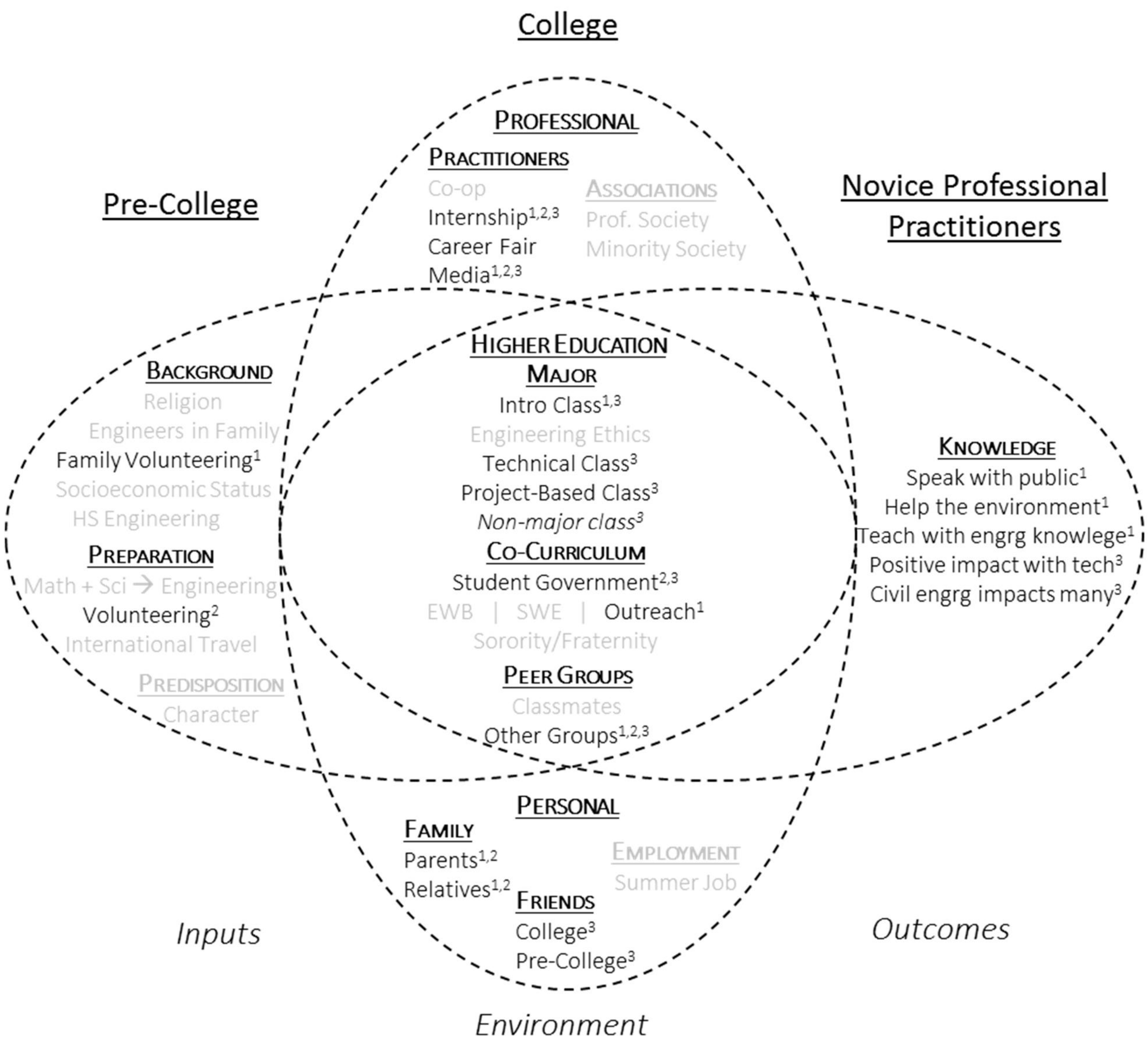


Figure 15: Denise (ME, PrU) Weidman I-E-O Model

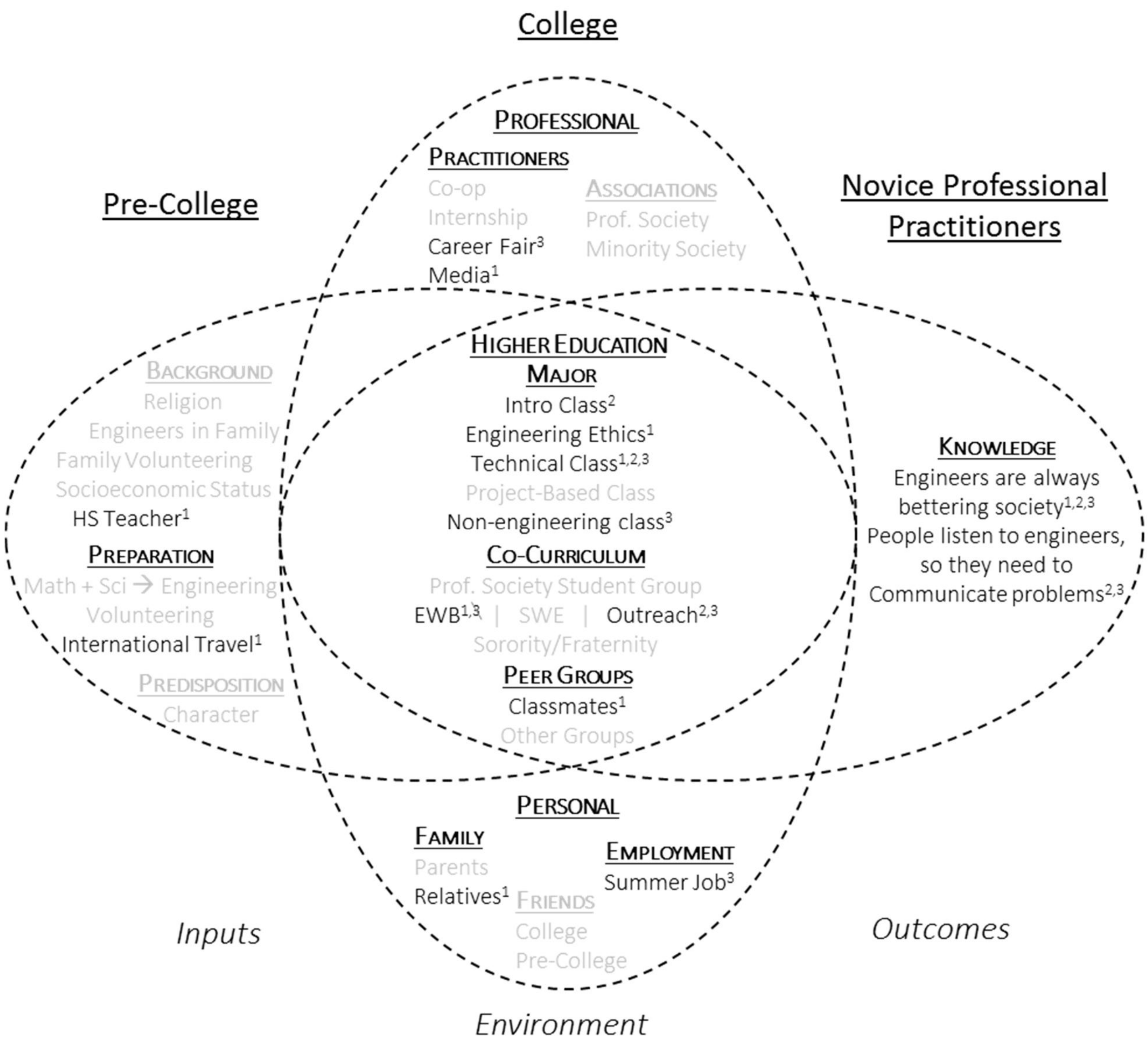


Figure 16: Derek (ME, PrU) Weidman I-E-O Model

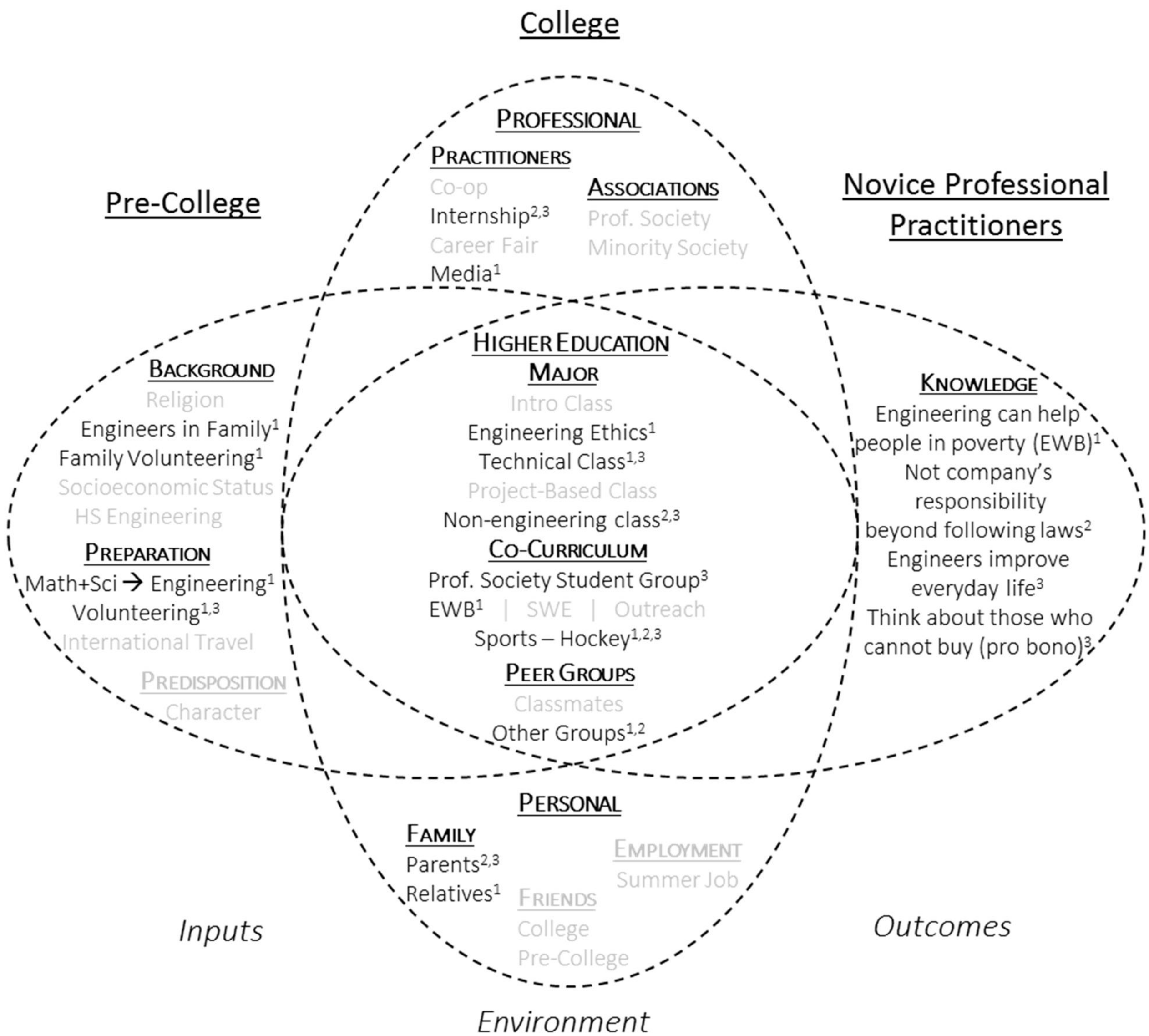


Figure 17: Jamie (ME, TechU) Weidman I-E-O Model

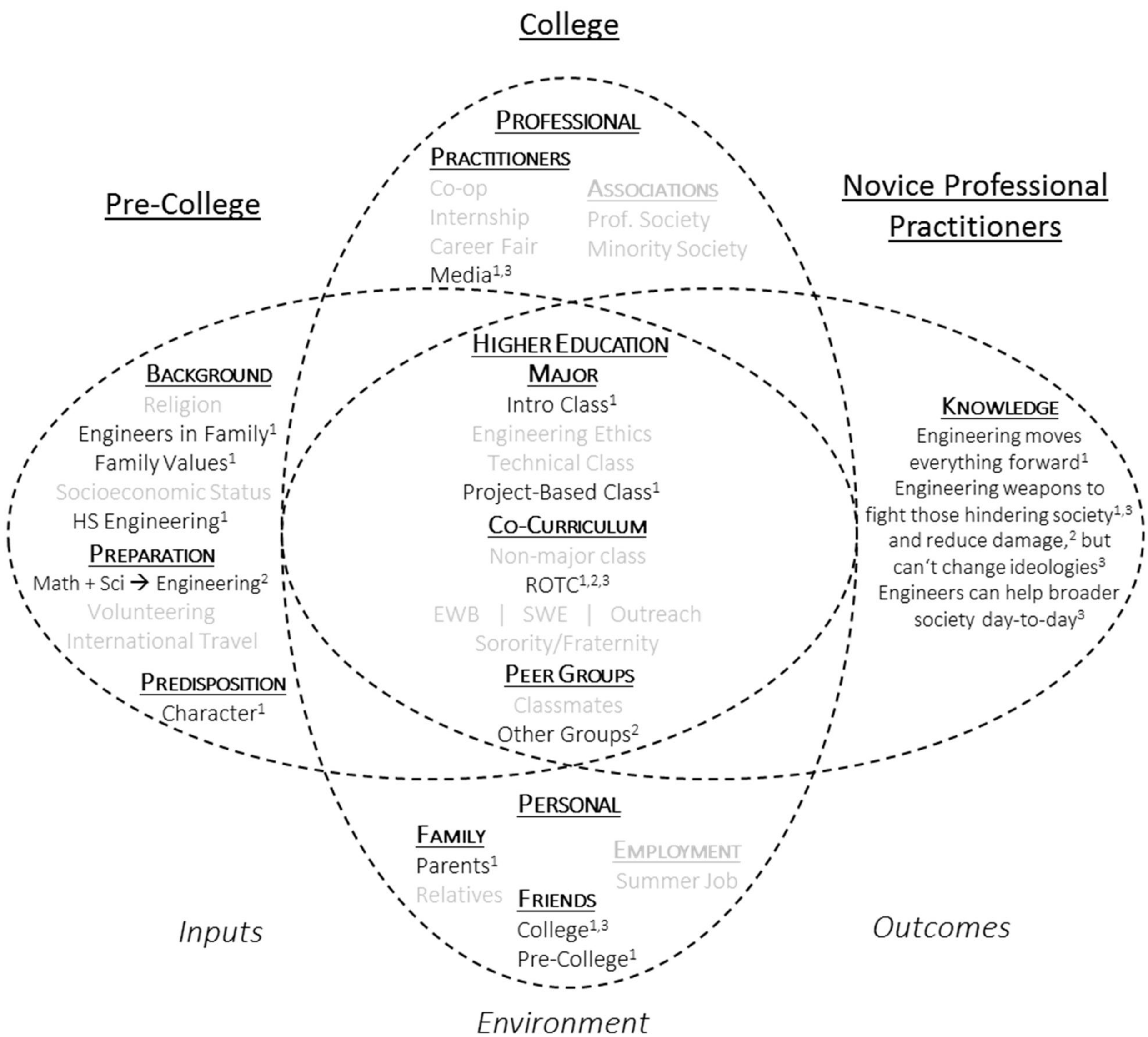


Figure 18: Jolene (CE, TechU → MPU2) Weidman I-E-O Model

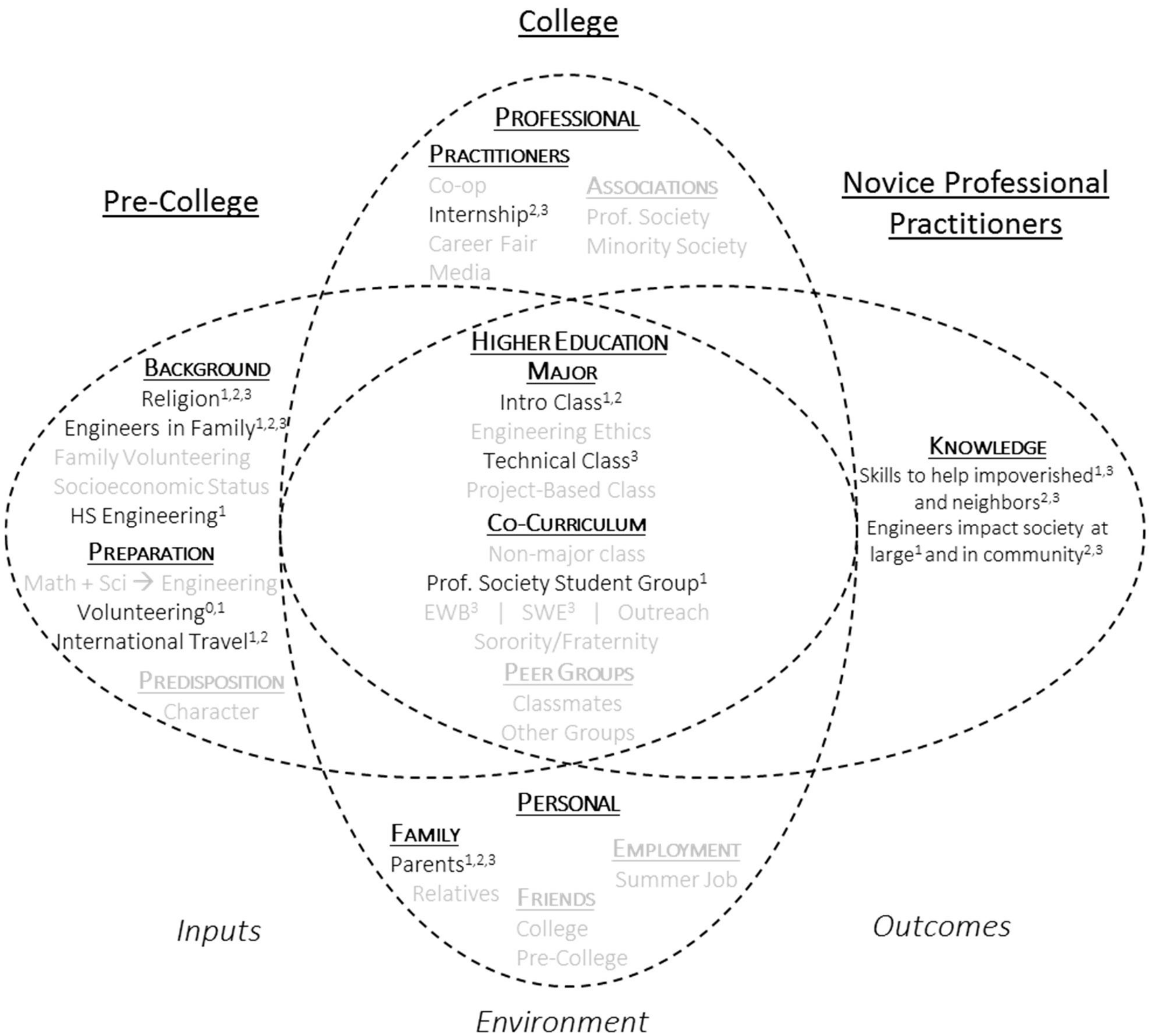


Figure 19: Katherine (CE, MPU) Weidman I-E-O Model

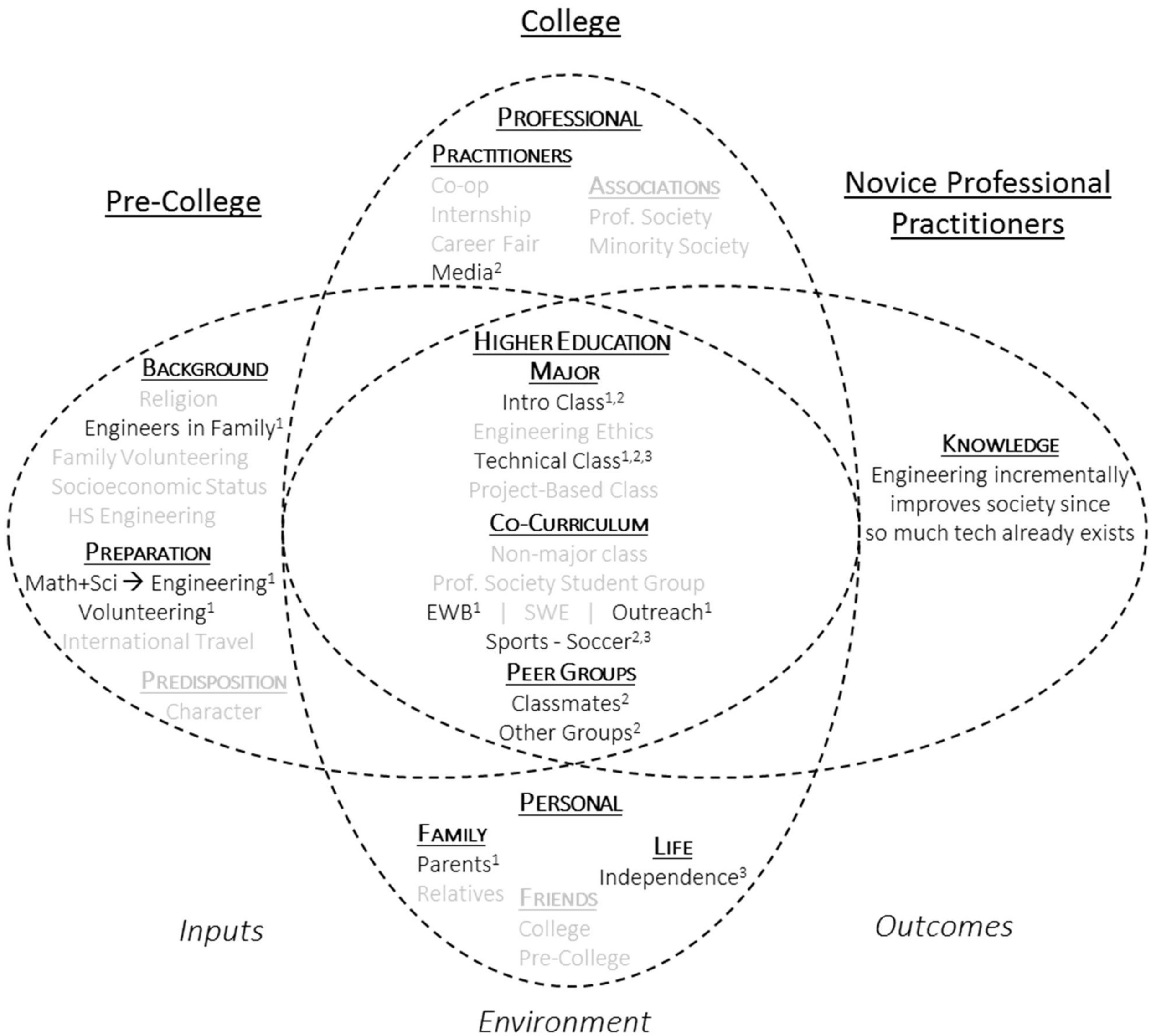


Figure 20: Madison (ME, TechU) Weidman I-E-O Model

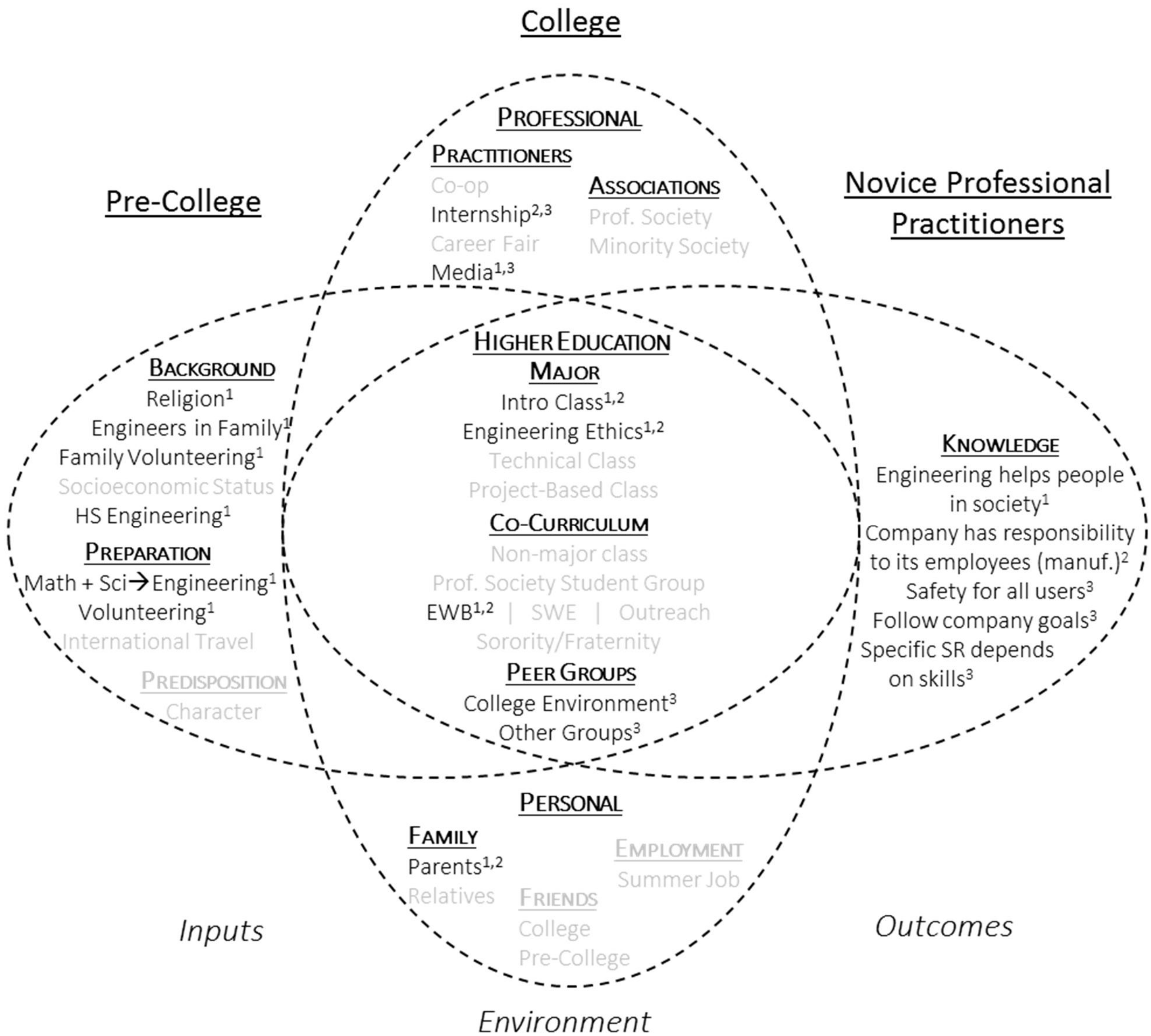


Figure 21: Rachael (ME, PrU) Weidman I-E-O Model

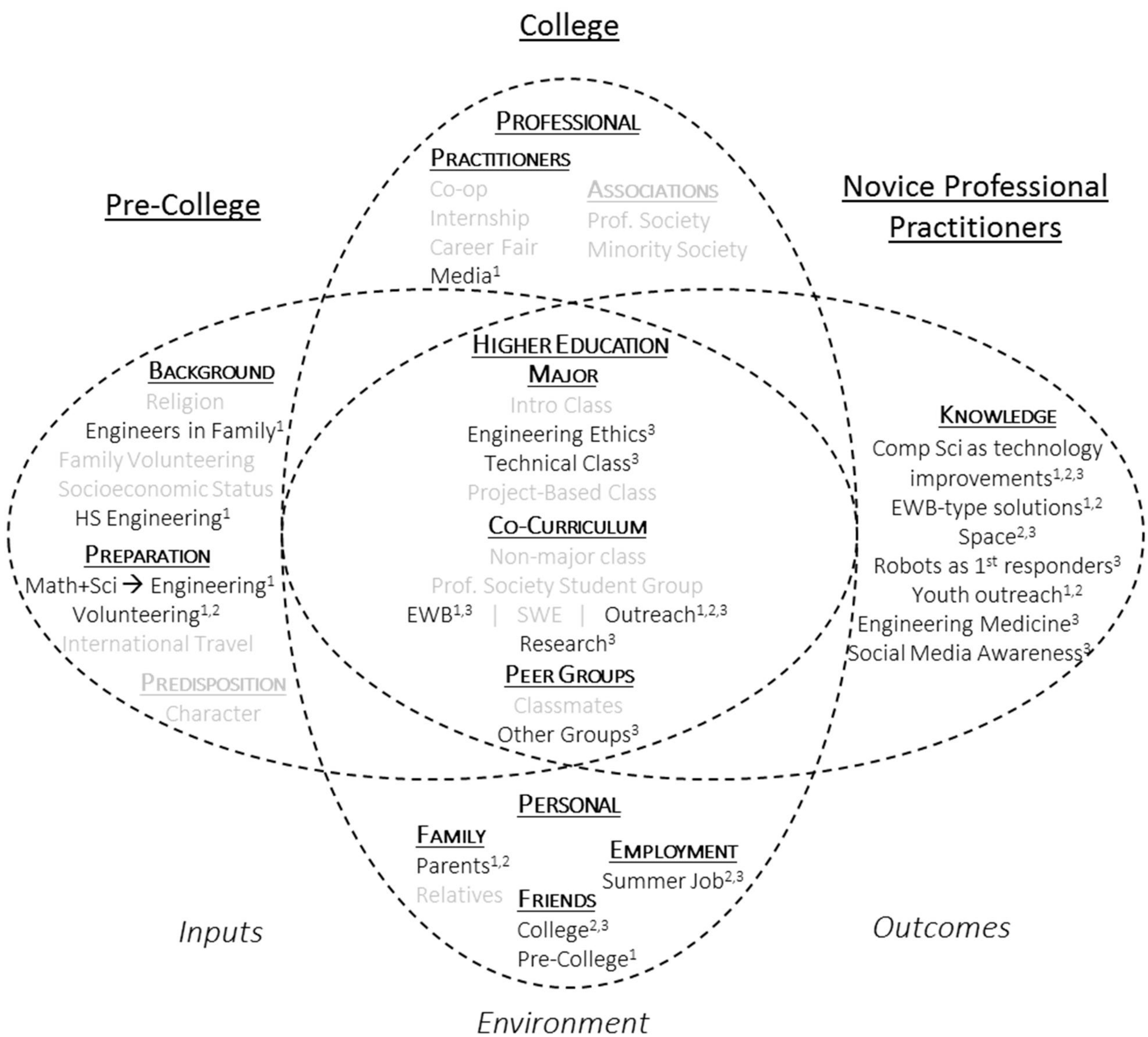


Figure 22: Sarah (CE, TechU) Weidman I-E-O Model

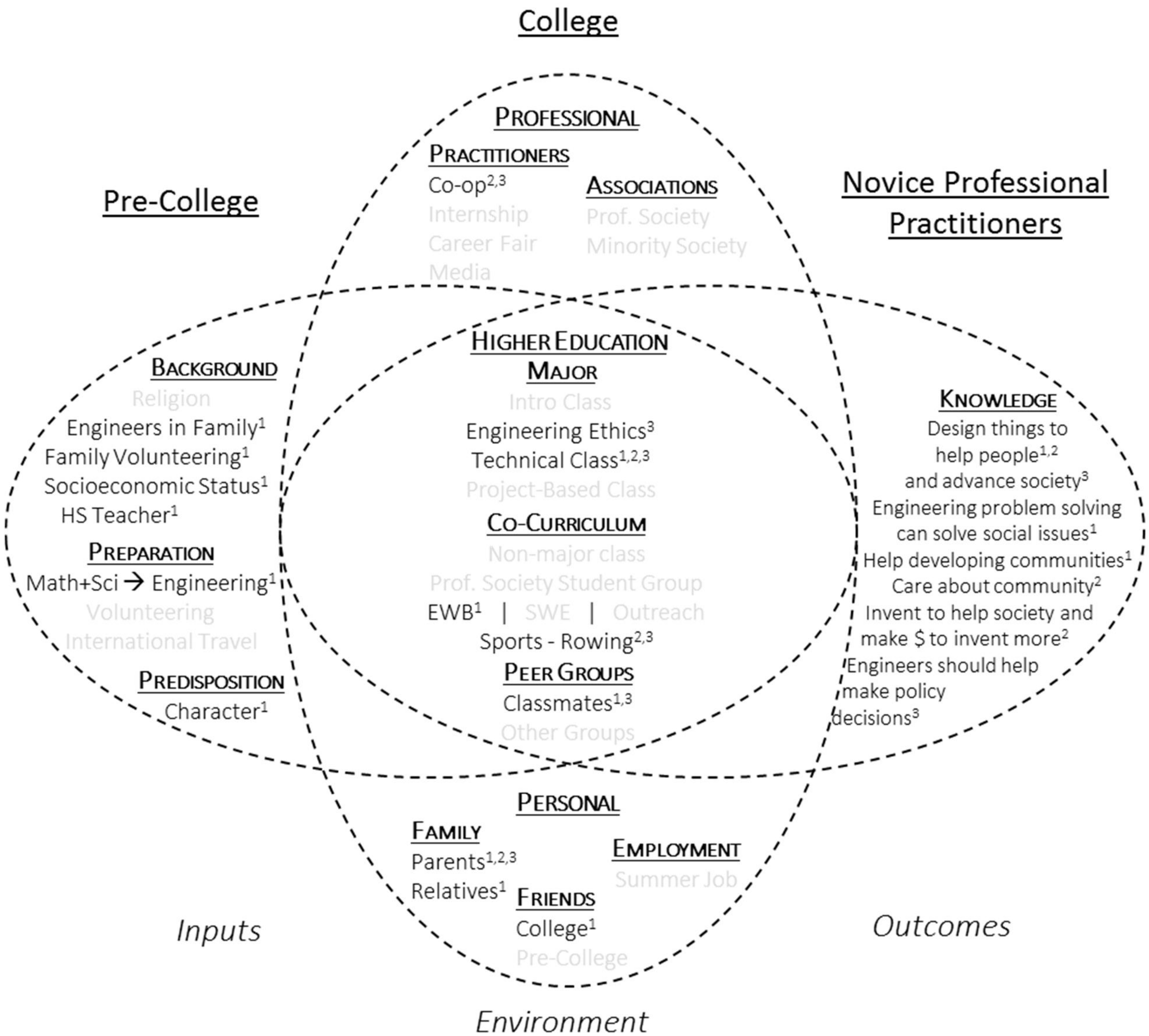


Figure 23: Shawn (EnvE → ChE, LPU) Weidman I-E-O Model

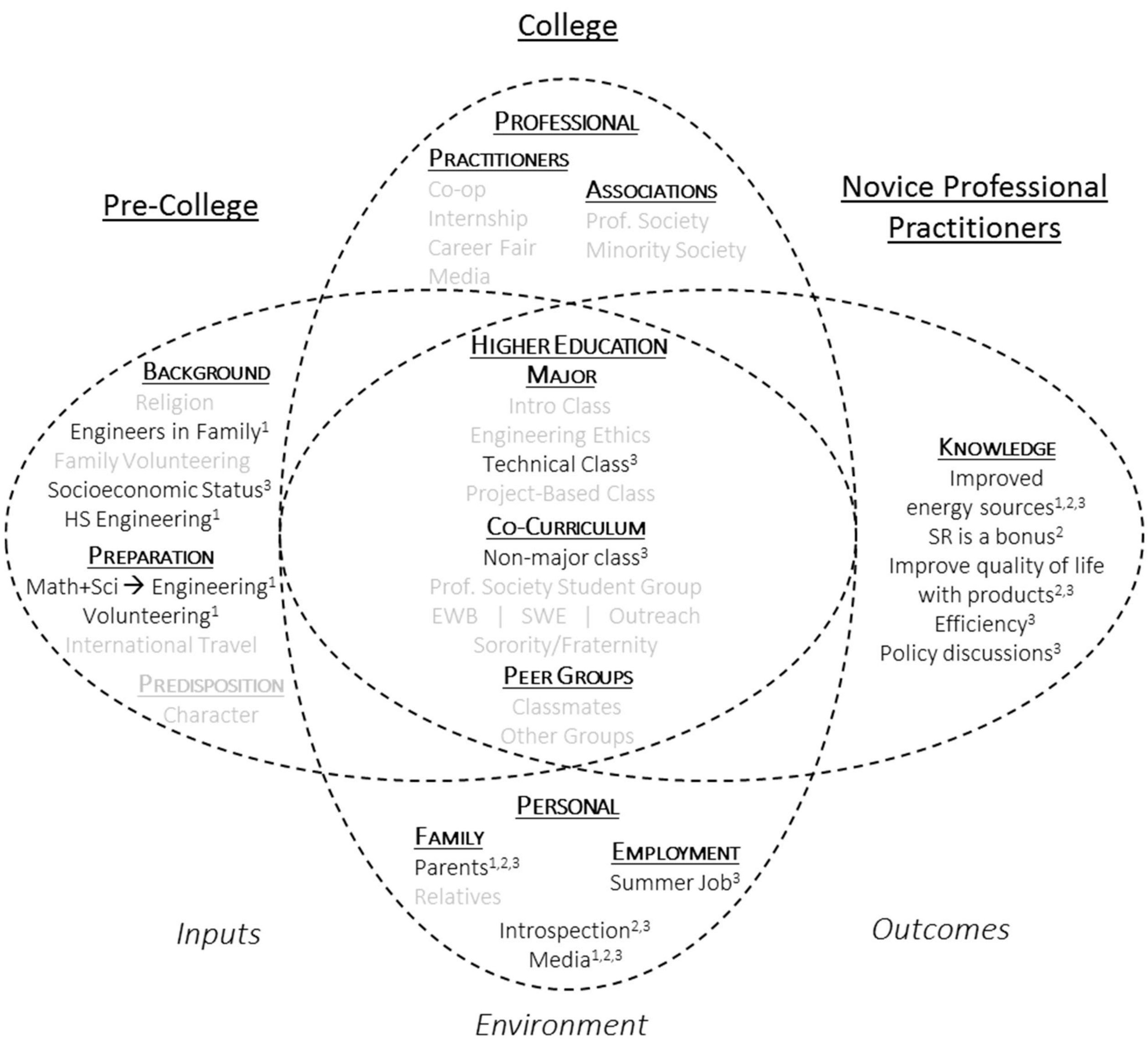


Figure 24: Tanya (EnvE, TechU) Weidman I-E-O Model

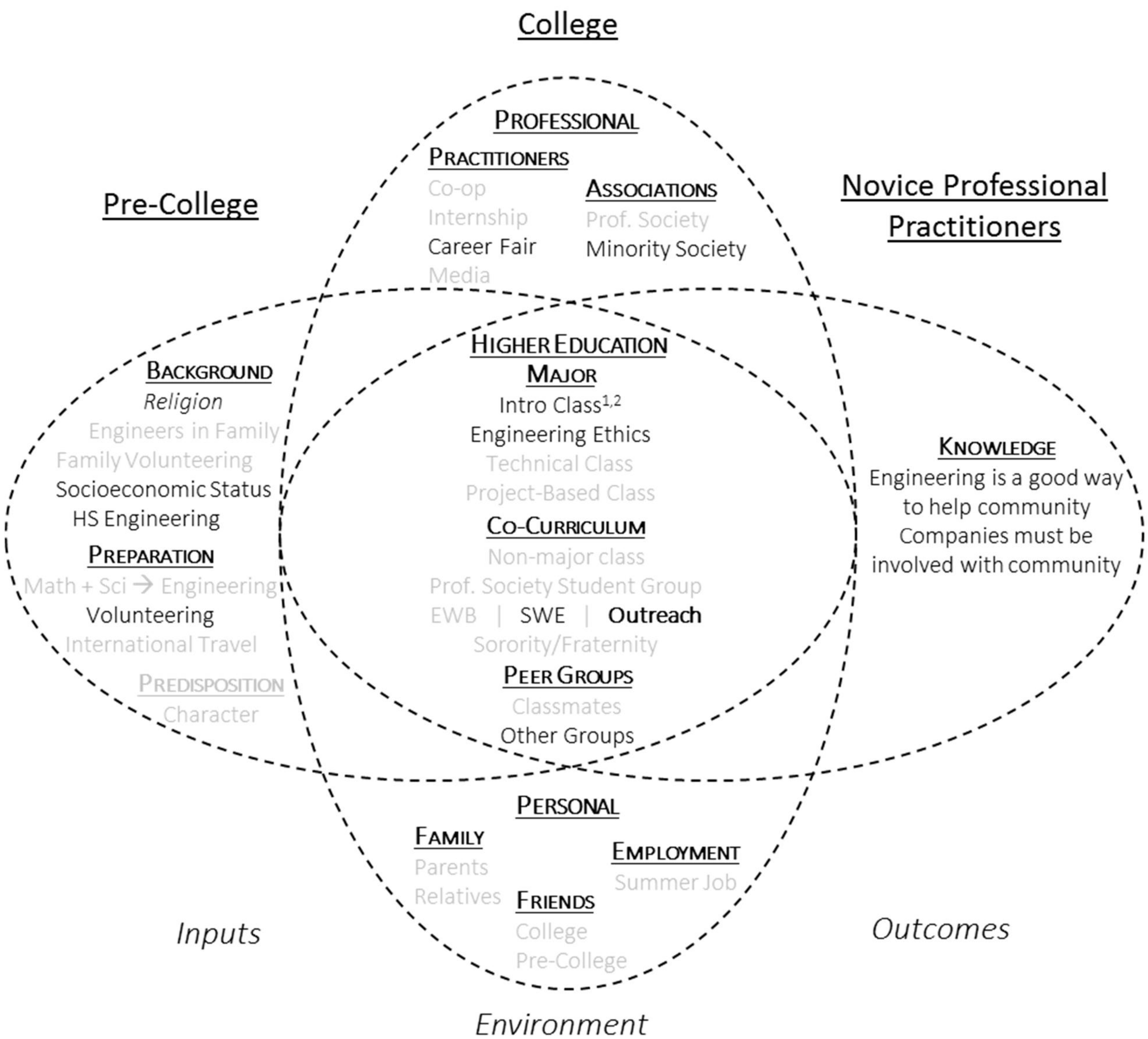


Figure 25: Todd (ME, TechU) Weidman I-E-O Model

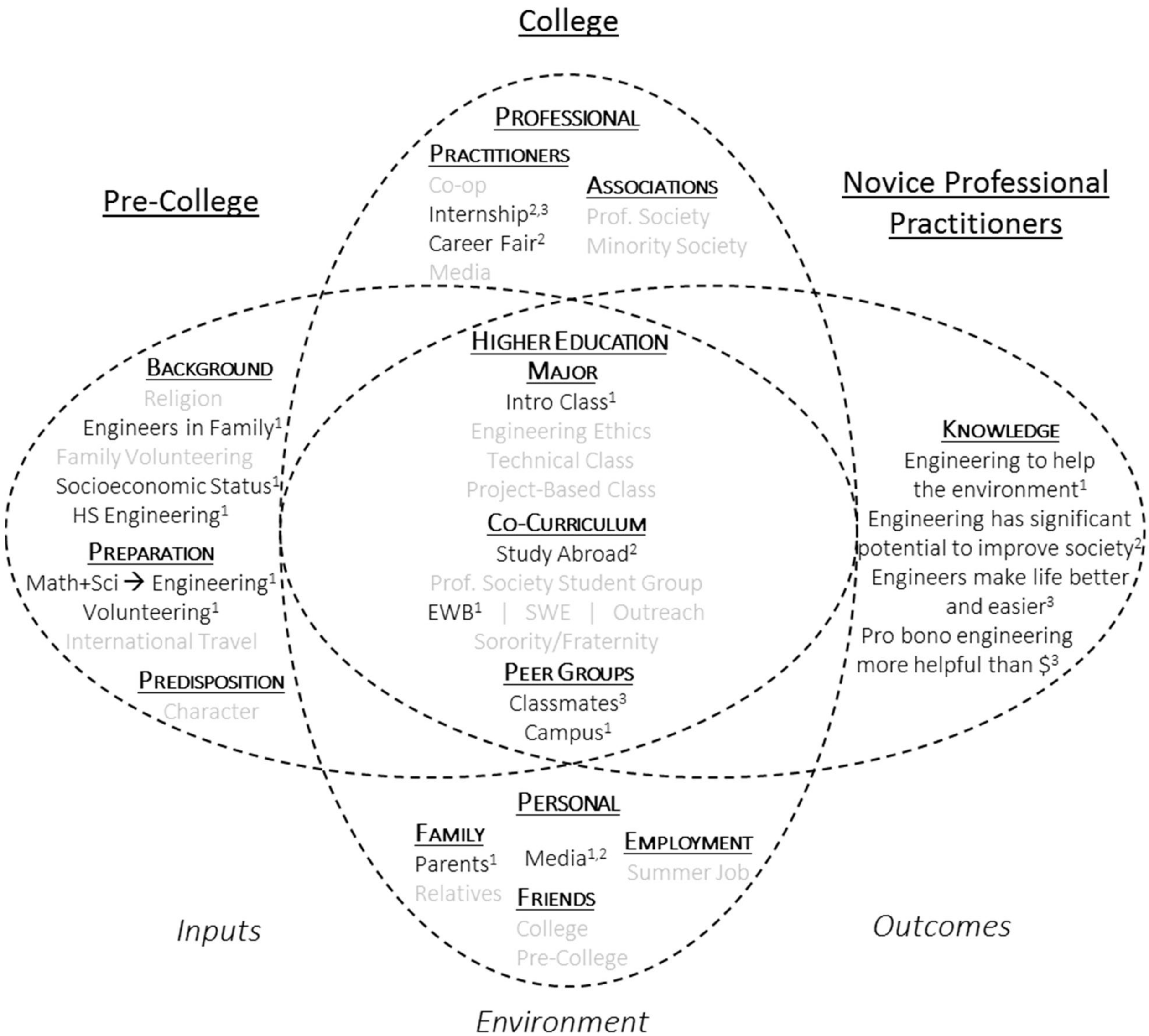


Figure 26: Trevor (CE, MPU) Weidman I-E-O Model

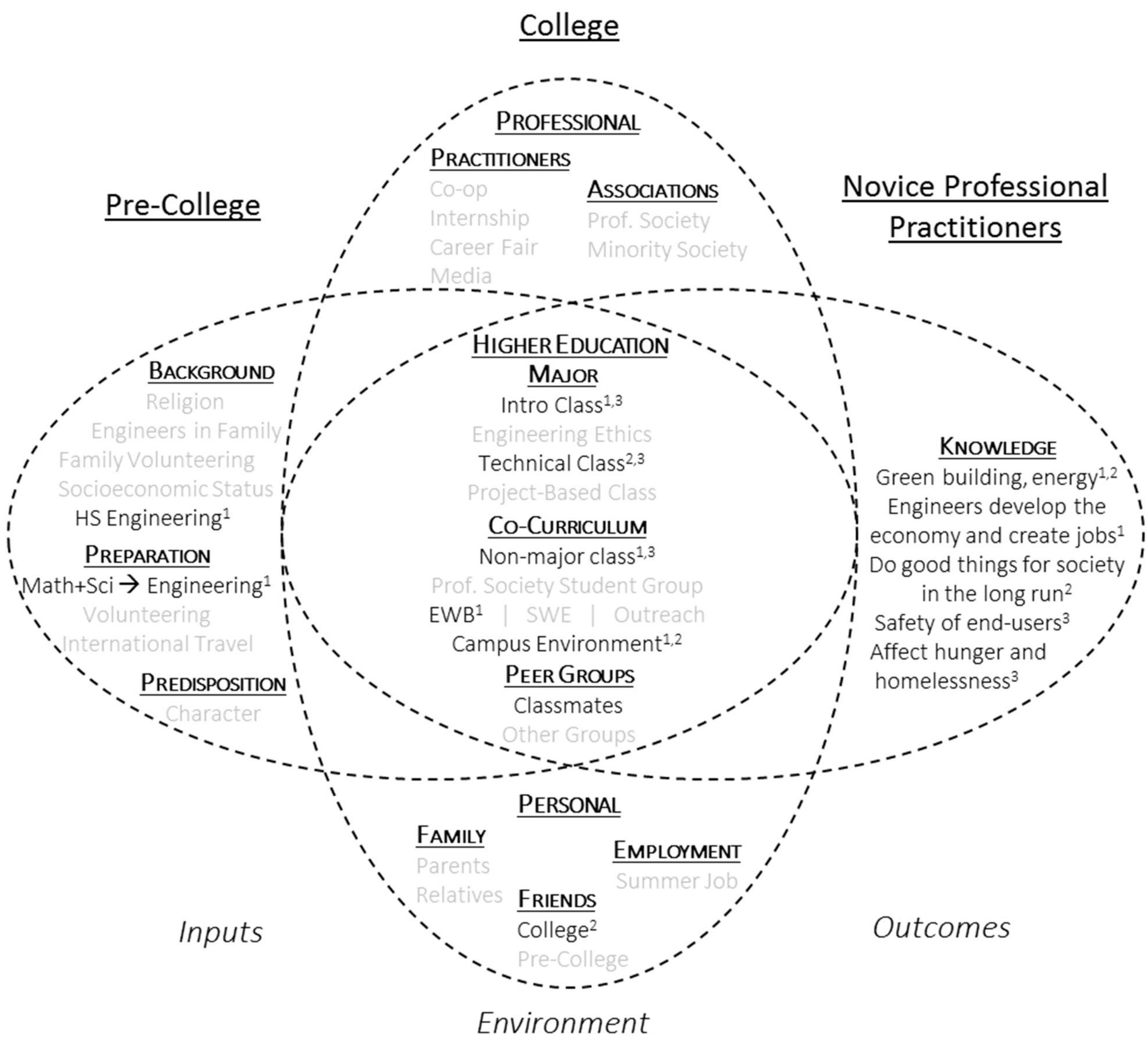


Figure 27: Tucker (CE, LPU) Weidman I-E-O Model

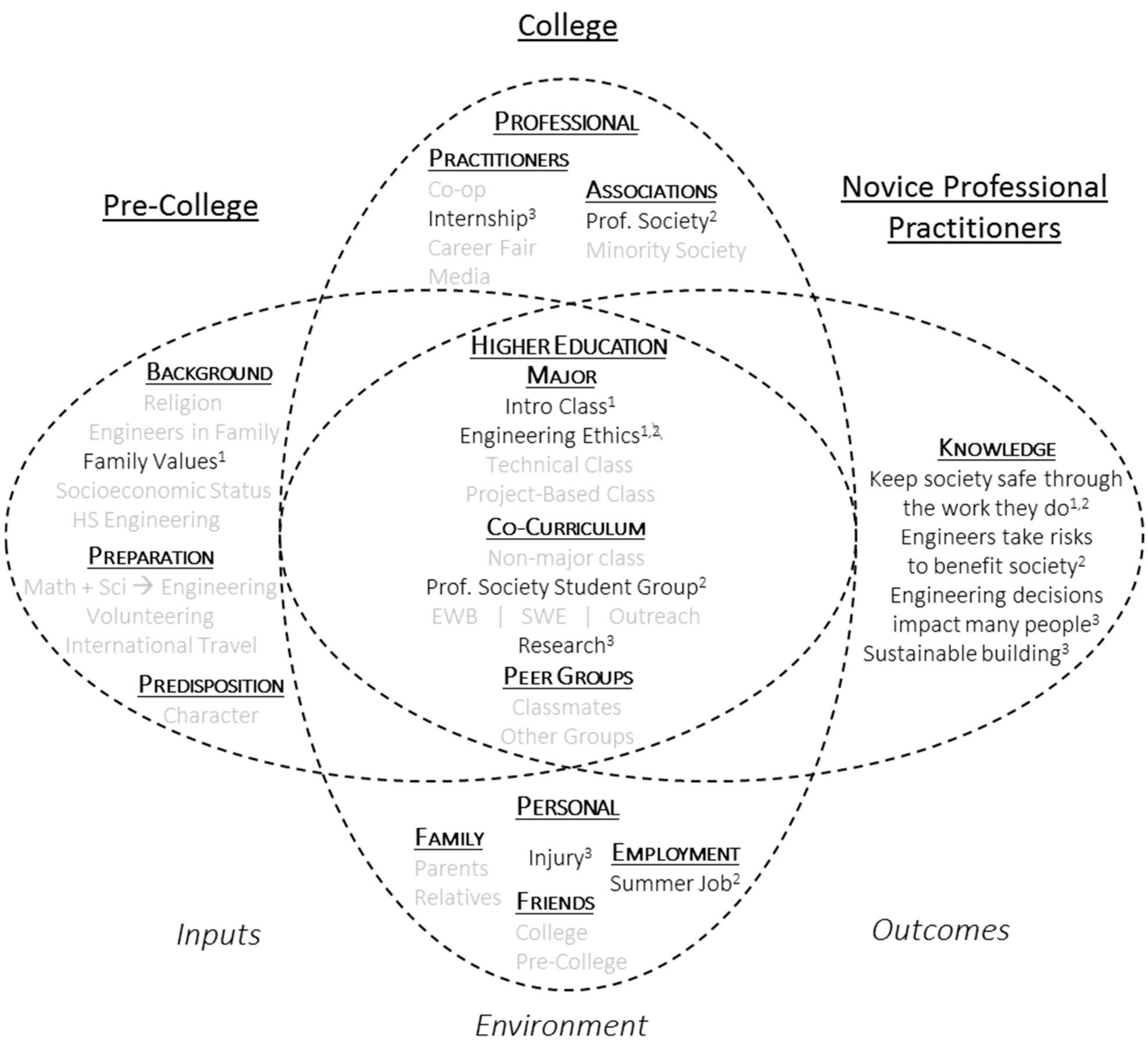
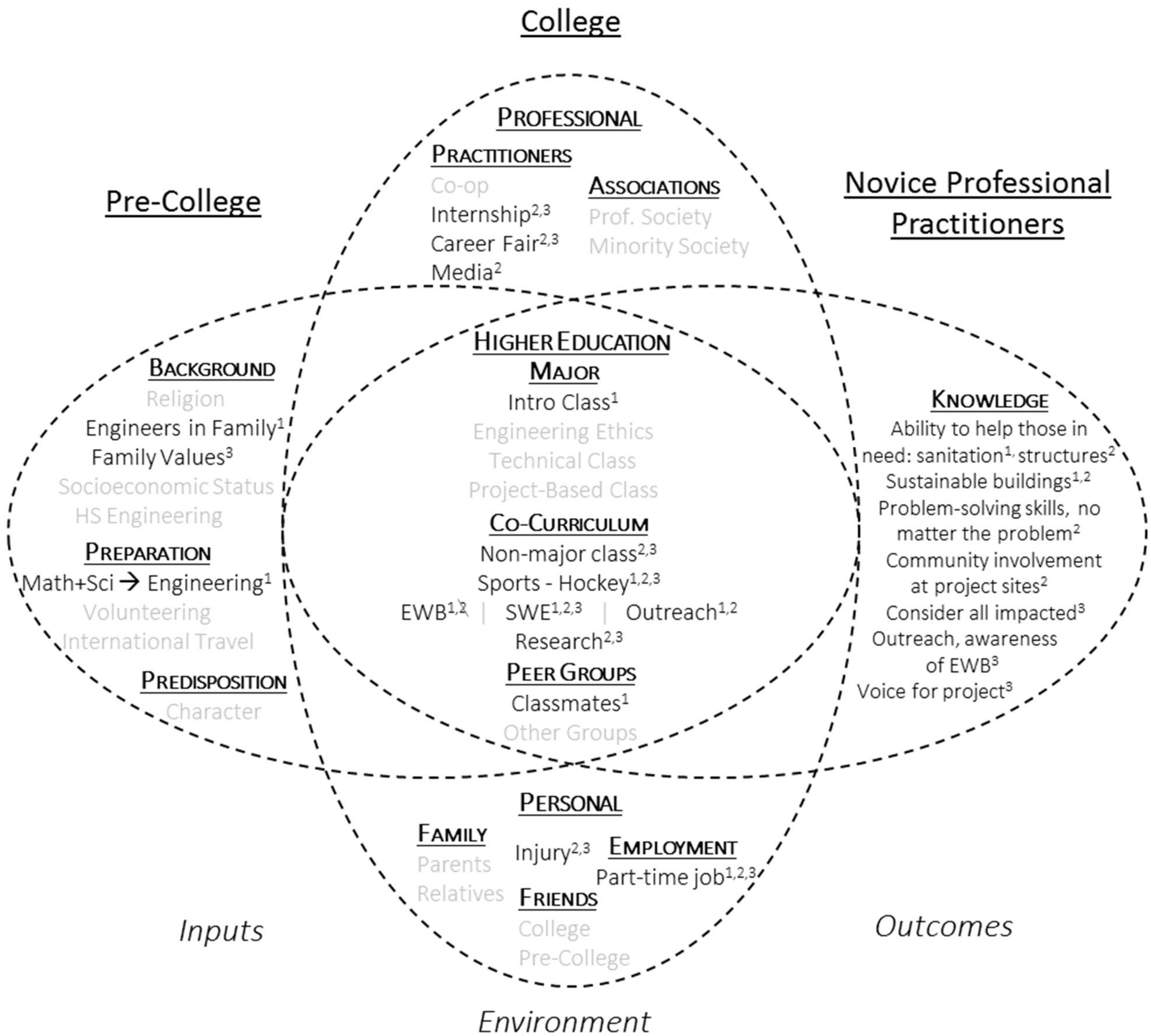


Figure 28: Wynne (CE → ArchE, LPU) Weidman I-E-O Model



Appendix F: Chapter 5, Additional Student, Sarah

Sarah, Type 2, no change, CE, TechU

Sarah, a civil engineering major at TechU, was classified as a type 2, since she had strong general ideas about how engineering helps society overall. She even briefly discussed that she would like to help people with engineering by saying, "So I really want to…go and help people in South America to like, better themselves. So I'm working on it, that's really my goal." This is similar to what the Type 1 students said, and Sarah even wanted to be involved in Engineers Without Borders and the Society of Women Engineers, but she did not elaborate on these ideas very much, and never became involved with the co-curricular groups. Sarah did passionately discuss her desire to become a water resource engineer, saying "water is very important to survival. It's, everything on the earth uses it, and everything on the Earth needs it to survive. And I think we are lazy in how we treat it." She already had a plan for her future engineering career, which would affect society overall in very positive ways. Further exemplifying her plans to act on the local social responsibilities she felt as a future engineer, Sarah explained, "wherever I live in the future I want to be part of the community council because I feel like they should have engineers on those panels." This foreshadowed her more locally-focused second-year interview.

Sarah's second interview focused mostly around her co-op experience, which was by far the most dominant influence in her understanding of what engineers do, and how she could act on her social responsibility through engineering. She took classes, had a part-time job, was on the crew team, and was not involved with any co-curricular activities in the first semester of her second year. In her second semester, rather than taking classes, she was employed by the municipality in her hometown. She thoroughly enjoyed the environment, the people, and the job itself. She summarized, "it's a really wonderful place to work." In terms of developing her ideas about how she would be a socially responsible engineer in the future, it was clear that the co-op was the most influential. She said, "Basically my whole job right now is based on social responsibility, like, to make roads that don't have giant potholes and so that cars don't break in them, and it doesn't fall apart." Sarah saw this job, which was very different from her goals to help people in South America from the first year, as socially responsible. Possibly, this deeper, local experience pushed her to believe that the engineering status quo is doing enough to impact society positively. It seemed her view of the potential she had with engineering to do social good had narrowed, but then she made a very strong statement towards the end of the interview when asked how social responsibility fits into her desire to be an engineer. She responded. "100%. I don't know of a better career that allows me to help more than engineering…. I guess that's kind of why I got into engineering, because I wanted to do something." She was still passionate about helping, and sees herself doing that through engineering, but the location, and people being helped, would be part of her community.

Sarah's third year interview was fairly similar to the second year. She described that her classes were more interesting since she could relate them to her co-op and the world around her. She made an observation based on some interactions with her classmates, saying "I think that I am a little bit more caring that you would assume an engineer would be." This notion was a departure from her second year in which she was fully identifying with the current civil engineering profession. She was seeing her peers as future engineers, and felt care would not be as highly valued by them. She did have high expectations for the responsibilities of engineers, and even more for herself. She said, "All engineers have to look at the world and what they have to do to improve it, …make it better for the people who live in it…. At least that's my goal with my engineering studies. I think that should be a goal for anybody with an engineering degree, not just to make money, but to do something." Later in the interview, she mostly described examples of how civil engineers were already 'making it better' through their engineering works (roads, water, sewers) besides the catastrophes she learned about in her third year professional practice course. At the end of the interview, Sarah came back to her responsibility as an engineer, with her engineering mind, of being involved with the school board in the future. This example further geographically localized her ideas around what she wants to do as a socially responsible engineer, but opened up different arenas that would be very valuable to her community.

Overall, Sarah seemed to have a fairly complex understanding of what SR could be for people in general, but it is vague. She speculated throughout the interviews about how engineers could be influential or helpful without having much experience with travel or volunteer work herself. The most significant change from the first year to the third year was the localization of what she expected to do as an engineer in the future. She still felt empowered to improve the world and people in the world, but now it seems she sees her own role as one that fits pretty well into the profession as it is. So far, rather than push her job or company to match what she wanted to do in her first year as an engineer, she was heavily influenced by her co-op that helped her create a vision of the civil engineering profession with which she could strongly identify and be satisfied. One major thread that was persistent, was the theme of 'action.' Being aware of an issue was not enough, one must attempt to address issues, using one's education, in order to be a socially responsible engineer.