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Learning Social Responsibility: Evolutions of Undergraduate Students' Predicted Engineering Futures*

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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 four 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 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, and 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; care; ethics

1. Introduction

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 the 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. It is important for engineering students to recognize that they will have this social responsibility through their profession, and to feel empowered by it. 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 [1]. 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 [2–4].

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 [5–7]. Further, perceptions of engineering as masculine and uncaring may contribute to the low representation of women in engineering [8]; women comprise about 20% of engineering Bachelor's graduates [9] and only about 10% of engineers in industry [10]. Possibly, if engineering education can be more socially relevant and caring, it will attract and retain more women, whom the profession needs [11–13].

This study uses a framework of the Ethic of Care to help understand how social responsibility fits into the practice and perception of engineering. In 1995, Moriarty described how the *ethos* of engineering, which is stronger and more ingrained than codes of ethics, could change to be about care [14]. 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. In 2013, Noddings explained that care relies on reciprocity,

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and with bureaucracy separating engineers from clients and communities, care has not penetrated in the same way as into medicine or law [15]. This could be seen through focus groups with practicing engineers and faculty as well: strict, technical engineering can be applied in a near vacuum [16, 17]. 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 [14].

This study builds on Canney's Professional Social Responsibility Development Model, developed in 2015, 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 [18]. 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 [18]. 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 [19, 20]. This cycle is shown in Fig. 1. For more sustainable and deeper integrations, care would permeate both one's personal life and profession [18, 21]. 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 [22]. Within this journal, a few examples that advocate for and integrate social responsibility ideas into design include Devon and Van De Poel, Terpenny et al., and Cobb et al. [23–25]. These types of efforts would help to "Change the Conversation" about what an engineer does and who an engineer is or can be [8]. If engineering students would learn and then 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.

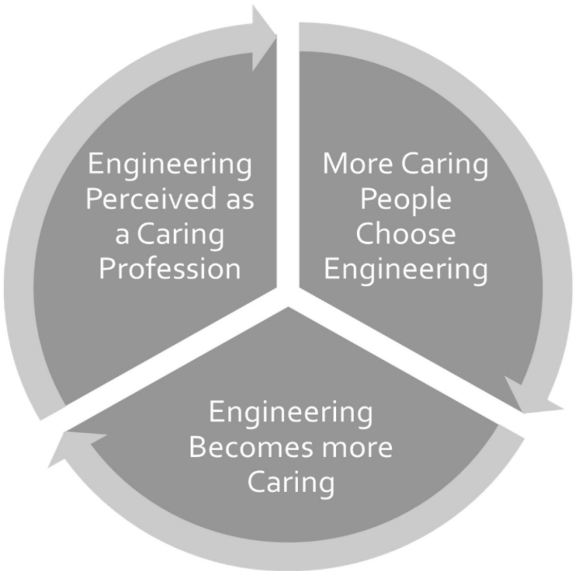

Fig. 1. Cycle towards a more caring engineering profession.

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 undergraduate engineering school.

2. 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 and are the focus of this paper. 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 three years in March to June of 2014, 2015, and 2016, at the end of their sophomore, junior, and senior years, respectively. It was important to understand how the students' developed as it was happening, rather than just the beginning and final year results [26].

Using criterion-based selection [27], the students in this study initially represented (i) a range of attitudes toward social responsibility (SR) as incoming college students, indicated by their average score on 50 Likert items on a survey (ii) a high oversampling of women in engineering (62% in this study vs. ~20% enrolled in engineering), (iii) four majors, and (iv) four universities. Students' attitudes about social responsibility were assessed quantitatively via an online survey, 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 [28]. The SR score has a potential range from 1 (low SR) to 7 (high SR); the actual range among the cohort interviewed was 4.00 to 6.80. The fifty items that map to SR are grouped into 8 dimensions, including professional

connectedness which is "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" [18].

A summary of the demographics of the students who participated in the interviews during three or four years are shown in Table 1, including 21 individuals who remained in engineering and nine who left engineering. Among the entire cohort of 34 students, their initial majors were primarily mechanical engineering (ME; n = 12), civil engineering (CE; n = 9), and environmental engineering (EnvE; n = 8); at one 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). The majority of the demographic information in Table 1 was supplied by the students via the online survey (see Canney 2013). In Table 1, 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, two stopped attending college and three did not participate in the interviews during at least three years; these individuals are therefore excluded from Table 1. Of the 29 students who participated longitudinally, 19 were female and 10 were male, three students were non-white, and four were first generation college students. All of these students entered college immediately following high school with the exception of Derek, who started college at age 21.

Semi-structured interviews up to 90 minutes in length were conducted by a male doctoral researcher and audio 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

Table 1. Initial Demographics of Interviewed Students

Pseudonym	Gender	Race/ Ethnicity	First Gen	Y0 Major	Institution	Y0 SR Avg Score	3 or 4 Interviews?
Sarah	F	White	Yes	CE	TechU	6.55	Yes
Jolene	F	White	No	CE	TechU	6.55	Yes
Tim	M	White	No	ME	LPU	6.50	No
Shawn	M	White	No	EnvE	LPU	6.46	Yes
Derek	M	White	No	ME	PrU	6.34	Yes
Katherine	F	White	No	CE	MPU	6.28	Yes
Nathan	M	White	No	CE	TechU	6.12	Yes
Tanya	F	Afr-Am	Yes	EnvE	TechU	6.10	Yes
Rachael	F	White	No	CompSci	PrU	6.10	Yes
Denise	F	Hispanic	Yes	ME	PrU	5.96	Yes
Wynne	F	White	No	CE	LPU	5.88	Yes
Julie	F	White	No	ME	PrU	5.88	Yes
Brandon	M	White	No	EnvE	TechU	5.82	Yes
Ashley	F	White	No	ChE	PrU	5.62	Yes
Jamie	F	White	No	ME	TechU	5.62	Yes
Kim	F	White	No	EnvE	LPU	5.54	Yes
Macy	F	Biracial	No	ChemE	PrU	5.54	No
Trevor	M	White	No	EnvE	MPU	5.52	Yes
Tucker	M	White	No	CE	LPU	5.48	Yes
Quinn	M	Asian	No	CE	LPU	5.33	Yes
Todd	M	White	No	ME	TechU	5.12	Yes
Madison	F	White	No	ME	TechU	4.86	Yes
Jackie	F	White	No	ME	LPU	4.86	No
Jason	M	White	No	ME	TechU	4.68	Yes
Travis	M	White	No	EnvE	MPU	4.50	No
Jocelyn***	F	White	No	ME	LPU	6.80	Yes
Katie**	F	White	No	CE	LPU	6.58	Yes
Kaitlin*	F	White	Yes	EnvE	MPU	6.08	Yes
Maggie*	F	White	No	CE	MPU	6.02	Yes
Lindsey**	F	White	No	BiomE	PrU	6.00	Yes
Miranda**	F	White	No	ChE	PrU	5.98	Yes
Alicia**	F	White	No	ME	LPU	5.64	Yes
Nelson*	M	White	No	EnvE	MPU	4.82	Yes
Thomas***	M	White	No	ME	LPU	4.00	Yes

* 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.

structured interview protocol might have limited students' development of ideas, so the interview was allowed to flow naturally and the interviewer asked the specific interview questions when appropriate [29, 30]. Each interviewee was assigned a pseudonym using standard naming conventions [31]. Interviews were transcribed verbatim into Microsoft Word using Dragon voice recognition software [32, 33]. 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 [34].

Each interview included about ten open-ended questions, which encouraged students to think and talk about: (i) engineering, (ii) helping others and social responsibility, and (iii) combining these two concepts, which may or may not have been connected for each student. Table 2 shows the interview questions from each year that are the most relevant for this study.

In the first year, a code book from the interviews was developed between three researchers that included specific codes under the themes 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 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.

3. Results

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 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 [35].

3.1 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 through fourth years built from the 'Types' defined using the first-year, exploratory interviews. More details about this analysis are available in Rulifson et al. [36]. In order from Type 1 to Type 4, students in each group have a more to less expansive idea of how they want to act on their social responsibility through engineering. With these ways of thinking about how

Table 2. Relevant Interview Questions from Years 1–4

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?
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?
4	What will be your responsibilities as an engineer? Think narrowly and broadly about the term 'responsibilities.' a. Who will you be responsible for as an engineer?
4	In what ways do you believe that you might be serving or helping people and/or society in some way during your career? a. To what extent is this helping aspect of the job important to you? b. How does the importance of helping compare with other factors such as salary, location, who you work with, etc.?

the students described themselves, the researchers were able to compare their responses in each year to this conceptualization. The SR type descriptions are shown in Table 3, along with the students who fit into these categories during the first year. The largest number of students (11) were Type 1, describing a motivation to serve the disadvantaged through engineering. Many of the students (9) were Type 2, acknowledging that engineering generally improved society and/or protected the environment. A number of students (10) also did not connect engineering with their ideas of social responsibility, designated Type 3 in this study. Only a small number of students (4) had little to no thoughts about social responsibility, labeled Type 4, near the end of their first year of college.

3.2 Changes in SR types for engineering students over four years

As students progressed through college, their ideas about socially responsible engineering evolved. Figure 2 summarizes the SR types of the students with respect to their engineering aspirations over time. Note that students who were not interviewed during any year were assumed to stay the same SR type. Largely, students who stayed in engineering converged on Type 2, conforming to the ideals of the engineering profession. The experiences during college that influenced these changes spanned academic, professional, and personal realms, and have been previously described by Rulifson and Bielefeldt [37].

First, 7 of the 11 engineering students classified as Type 1 at the end of their first year of college had left engineering before graduation. In fact, 7 of the 9 students who left engineering were Type 1 at the end of their first year. Among the entire cohort of 34 students, the 71% retention (29% "loss") of students in engineering majors is fairly typical [9, 38]. However, it appears that Type 1 students were more

Table 3. 'Type' Descriptions—How Students Personally Integrate Engineering and Social Responsibility

Type	Type Description and Example Quote	Year 1 Students
1	Students' reasons for choosing or staying in 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. Wynne, Y1—". . . we have so many communities abroad that are deficient and we have so many resources available to us . . . 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."	Katie** Jocelyn*** Nathan[2] Maggie* Jolene[2] Kaitlin* Miranda** Alicia** Tim Wynne Nelson*
2	Students wanted to better society at large with engineering, and this environmental or social responsibility, was often broad and vague. For example, some students wanted to conserve the natural environment in their future job. 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."	Sarah Shawn Denise Macy Jamie Lindsey** Brandon Kim Tanya
3	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. 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."	Derek Julie Rachael[2] Trevor[2,4] Jason[4,3] Madison Katherine Quinn Travis Ashley[2]
4	Students had thought little about social responsibility or the social context of engineering, 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, 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."	Tucker[2] Jackie Todd[2,4] Thomas***

* Student left engineering by the first interview; ** by the second interview; *** by the third interview; superscript indicates to which SR Type the student changed.

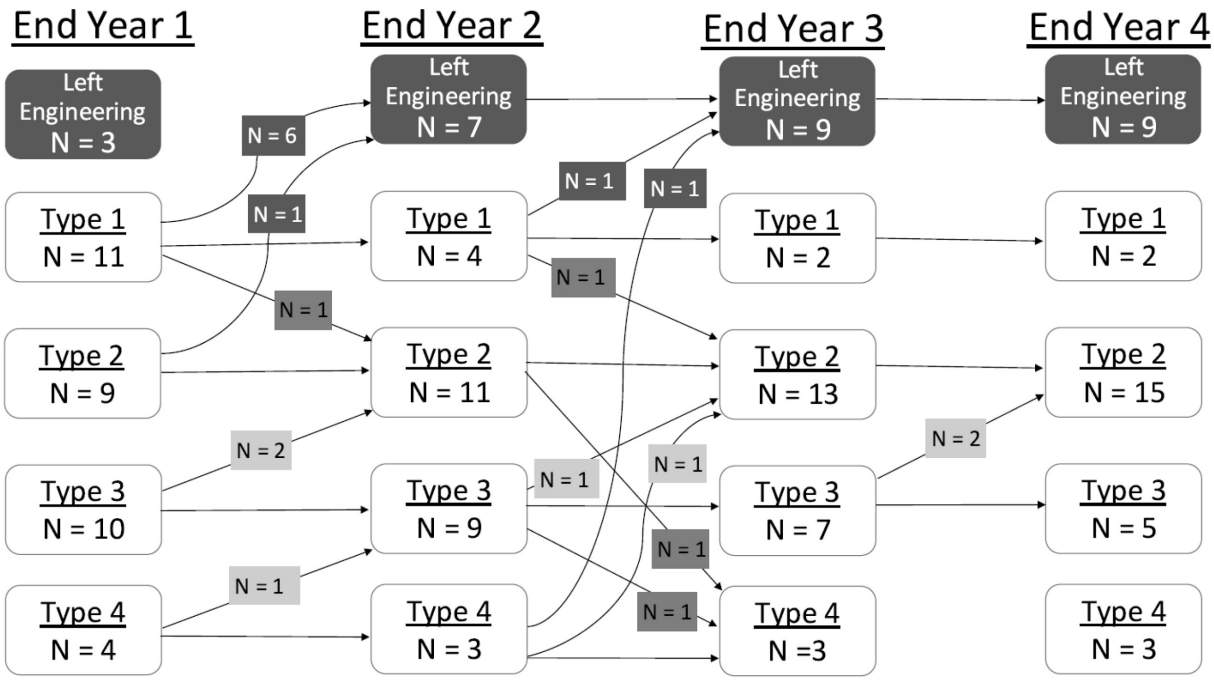

Fig. 2. SR Type Pathways over Four Years.

likely to leave engineering than those students whose vision of engineering was less driven by a strong sense of SR (see Rulifson and Bielefeldt [39] for more details about the stories of the leavers). Type 1 students had the strongest desire to care for others through engineering. Their loss is concerning, and a possible impediment to the cycle illustrated in Fig. 1 if the most caring students do not earn engineering degrees and have the opportunity to affect the engineering profession.

Among the 21 students who remained in engineering majors during the study, 13 stayed the same SR Type (one Type 1, seven Type 2, five Type 3), 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. The next section describes four students' evolution of ideas about how they saw themselves as future socially responsible engineers, and how they planned to act on their understandings of social responsibility as engineers. These deeper explorations of students' ideas show the changes in the students' own words to provide deeper context to the rough type classifications.

3.3 Tucker, Type 4 to Type 2, CE

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. 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. 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 more 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 [14]. 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 third year, Tucker's engineering social responsibility was characterized as Type 2. He saw the responsibility engineers have to society at large.

At the end of his time in college, though he was staying on for a masters, Tucker still saw engineering as having a generally good impact on society, and he was happy to be part of the profession. He hoped to do "meaningful work" like hospitals or affordable housing as a structural engineer, but really saw his responsibilities as safety, himself, the team of engineers, and the client. Not too much had changed in the year since the previous interview, but he certainly came to view his responsibilities more broadly than at the beginning of his time in college.

3.4 Madison, Type 3, ME

Madison, who remained a mechanical engineering major at TechU over four 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."

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. 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 time in 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.

3.5 Rachael, Type 3 to Type 2, CompSci

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 had to wrestle with the ethical implications of the drone research she was performing. She was still firmly a Type 2 with some new ideas about how to be a socially responsible engineer. In her fourth year, she described more professional influences that helped shape her understanding of her future socially responsible engineering self. She had an internship at a national lab and a co-op at NASA. These had different cultures, but both employers had significant consequences on society and national security. She said that she used to be interested in "science for science," but now sees the significant consequences on society and is excited to work towards these positive ends. She wanted to make sure that the technology she was producing would not "hurt the masses," and recognized that working towards the colonization of Mars would have major impacts on human life.

3.6 Jolene, Type 1 to Type 2, CE

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 [40]. 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. 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.

Jolene's ideas at the end of her third year were very similar to the end of her second year. In her fourth year, she planned to work full-time at her father's company, and was seriously considering taking over the engineering operations in the future. She also was planning her own wedding, and stated that her own community, rather than one abroad, was her top priority. She saw that she was helping society by treating their wastewater, and perhaps volunteering locally.

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 fourth year as a Type 2.

4. Limitations and validity

One could question whether the students who participated in the interviews are broadly representative of engineering students. Perhaps the students in this study were more interested in speaking about social responsibility than typical engineering students. This may account for why a number of students who had lower SR scores and were invited to participate in the interviews chose not to do so. It is unclear to what extent the findings would be representative of all engineering disciplines or universities more broadly, though two students did transfer to other universities. Finally, this pool of students does not allow for comment on demographic factors such as race or socio-economic status. Besides these issues, there is little reason to believe that the students are drastically different from the larger pool of engineering students overall.

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. 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 one student's interest in EWB than another student's interest in airplane design due to his own practice and personal experience. Possibly, some of the students were influenced by the interview itself. Eight students mentioned that the interview brought up new ideas. For example, at the end of the second interview with Tucker, he said "I've never really, outside of these interviews, really considered social responsibility."

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.

5. Discussion

The SR aspirations of engineering students were found to be quite different for many students at the end of their senior year compared to the end of their first year in college. Referring back to Fig. 2, at the end of the first year, similar percentages of the students initially enrolled in engineering were Types 1, 2, and 3, with a small number Type 4. At the end of the fourth year, the Type 2 was a strong majority (among 21 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, the inherent value of a widget beyond its market value, and adaptive technologies. 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 [41].

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, albeit due to a traumatic experience. 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 should not 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. Perhaps encouraging Madison to consider how many people are affected by the supply chain of car manufacturing, and engineers have the power to improve it, she would connect SR with engineering more strongly.

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 [42], 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 [18].

6. 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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