



## Environmental Considerations in Engineering: Students' Goals and Journeys

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# **Environmental Considerations in Engineering: Students' Goals and Journeys**

## **Abstract**

This qualitative study explored the journeys of students with environmental goals who started college majoring in engineering, including students' motivations to enter college majoring in engineering, their transitions through college, and how they viewed environmental issues as part of their future engineering careers and among the social responsibilities of engineers. Twelve engineering students with initially strong environmental interests were interviewed at the end of their first year of college; nine were initially majoring in environmental engineering (EnvE), two in civil engineering, and one in mechanical engineering. These students spanned three institutions and continued to participate in semi-structured interviews in subsequent years. In addition to interests in the environment, ten of the twelve students described family or friends as influential to choosing to major in engineering and seven discussed liking math/science in high school. Among the twelve students, one graduated with a degree in EnvE, five graduated from Civil Engineering, one graduated from Chemical Engineering, three transferred out of engineering to other majors, and two left college. Students who transferred out of EnvE to other engineering majors cited difficulty/disliking chemistry and broader career options among their reasons. Students who transferred out of engineering cited academic struggles, disliking the courses/curriculum in engineering, and disliking an internship experience. Another student was disappointed that engineering was not creative enough and lacked appropriate attention to broader issues. Among the students who left engineering, two transferred into environmental studies and one into environmental science, indicating their persistent commitment to environmental issues. The seven students who initially had environmental goals and persisted to earn engineering degrees discussed their career goals and responsibilities with respect to the environment in different ways. Five of the seven remained strong in their environmental convictions, and two seemed to lose their passion for helping the environment through engineering. The paper concludes with a discussion of how EnvE might better retain students with a broad range of interests and motivations.

## **Background**

Some students have a high level of interest in environmental issues and want to make this the focus of their academic studies and/or career. The disciplines with the most obvious focus on environmental issues are environmental studies (EnvS), environmental science (EnvSci), and environmental engineering (EnvE). An online search of programs in the U.S. that award Bachelor's degrees in these areas identified 183 EnvS, 500 EnvSci, and 70 EnvE degrees [1]. The number of Bachelor's degrees awarded in 2014-2015 in these majors were: 6015 EnvS, 5723 EnvSci, and 1414 EnvE [2]. (Note that the Integrated Postsecondary Education Data System (IPEDS) groups EnvE with Environmental Health Engineering under CIP code 14.1401.) What factors led students to select EnvE as their major entering college? And do the students who initially major in EnvE choose to remain and graduate in EnvE or change to other majors over time?

Previous studies have found that students majoring in engineering, computer science, and math had lower environmental interest scores than students in other majors [3, 4]. Thus, there is a chance that a student with a strong environmental interest might feel they don't "fit" with other engineering students, particularly in the first year of the curriculum that is primarily general courses with a range of engineering majors (e.g. calculus, physics, chemistry, engineering projects). Studies have also found that environmental concerns are higher among women [5-9] politically liberal individuals [9-11], and low income individuals [8]. These groups are generally under-represented in engineering compared to the overall undergraduate population and/or faculty [12-14], and therefore these factors may detract from students' feelings of belonging in engineering; this misfit of identity would be expected to lead to lower retention [15-17].

Within engineering, the most common reasons that environmental engineering students cited for choosing their major were: a desire to help the environment, ability to positively impact society, and enjoyment/aptitude for math and science; the prevalence of these reasons differed for civil and mechanical engineering students [18]. The reasons most commonly stated for choosing to major in engineering also differed between male and female students [19]; within EnvE, 41% of both genders cited helping the environment, but more female students cited having a positive impact on society and helping people. A more general study found 14 categories of students' motivations for choosing to study engineering; additional reasons commonly included problem solving, creativity/innovation, practicality, and a desire to build things [20]. This study also found gender and discipline differences among students' motivations; however, EnvE was not among the majors examined. Neither study explored if or how a students' motivations toward elements in engineering changed over time.

Students commonly change majors in college. Ohland et al. [21] found that 57% of the students who matriculated into engineering majors persisted in engineering to the 8<sup>th</sup> semester, the highest of all major groups (e.g. 51% social sciences, 41% other science/technology/math). The reasons that students leave engineering have been widely studied; a recent review clustered these into five factors [22]: classroom and academic climate; race and gender; grades and conceptual understanding; self-efficacy and self-confidence; interest and career goals. Few students transfer into engineering [21] and engineering admittance criteria are usually more stringent than other majors [23]. Thus, students with an environmental interest able to be admitted to engineering may choose that route, with the idea of leaving their options open in the future if they decide to change into EnvSci or EnvS. Changing majors within engineering has also been studied [24]; among six disciplines, industrial engineering majors were the most likely to stay in their major versus the lowest in computer engineering; EnvE was not among the disciplines examined.

Curricular factors are also being explored for links to persistence [25]. Previous research has found that EnvE BS degrees generally are heavily weighted to technical content, with a median of 78% coursework in math, science, and engineering, similar to other engineering disciplines [25, 26]. In addition, the EnvE Bachelor's degrees often offer little choice or flexibility; a median of no free electives and 44% courses with some level of choice. In comparison, it was found that the EnvS degree at one institution required fewer total credits to graduate (128 semester credit hours in EnvE vs. 120 in EnvS), 68% technical courses, 4% free electives, and 89% total choice [26]. Thus, curricular factors may influence the choice of major for students interested in environmental issues.

The majority of U.S. engineering Bachelor's degrees are accredited under ABET, which requires a minimum of 1 year (25%) of math and science and 1.5 years (37.5%) of engineering coursework [27]. ABET also requires that graduates meet a variety of learning outcomes including “understand the impact of engineering solutions in a global, economic, environmental, and societal context” and “design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, ... ethical, ... and sustainability” [27, p. 3]. Professional engineering codes of ethics mandate environmental protection and/or striving for sustainability [28-31]. Thus, engineering curricula include a variety of constraints, which include being taught about environmental issues.

Additional student concerns associated with selecting the major could include career factors [32]. For example, the average annual salaries among environmental scientists and specialists is about \$69,000 compared to EnvE at \$85,000 [33, 34]. Job security might also be an issue; the U.S. Bureau of Labor Statistics (BLS) reported environmental scientists and specialists had 89,500 jobs in 2016, with 10-year job outlook of 11% growth; this is better than EnvE at 53,800 jobs and 8% growth rate [33, 34]. However, there are many more degree programs and graduates in EnvSci, increasing competition for those jobs. As well, EnvE graduates can often take EnvSci jobs, should they choose to do so.

Thus, previous research points to a variety of factors that impact students decisions about which college majors they choose to enroll in, and factors that may impact their persistence. However, it is unclear the extent to which these factors are important to the pathways of students with initially strong interests in both environmental issues and engineering. In particular, there is a lack of strong information about persistence decisions for environmental engineering students. This study sought to provide more information on these elements, by gaining a rich understanding of the experiences of students using qualitative approaches less likely to bias student responses.

## **Research Questions**

Three topics were explored in this study:

- RQ1. Understand how students' motivations for environmental issues in combination with other factors led them to choose to enter college with an engineering major
- RQ2. Understand the reasons that engineering students change majors or persist in their major, among undergraduate students initially having strong environmental interests
- RQ3. Explore how students view environmental issues as part of their future engineering career pathways and among the social responsibilities of engineers.

## **Methods**

The research was conducted in accordance with methods approved by the institutional review board for human subject research in an expedited protocol. It was embedded within a larger study on engineering social responsibility that included both quantitative and qualitative elements. This study is a qualitative exploration of college students' thoughts and experiences, with a goal to improving our nuanced understanding of the research questions. These “how” and

“why” questions are best explored using rich methods rather than typical quantitative approaches with a large number of students.

The twelve research subjects with strong environmental interests entering college were initially majoring in engineering at three institutions. This included nine students initially majoring in EnvE, two in civil engineering, and one in mechanical engineering. In fall 2012, these 12 individuals were among 236 incoming first-year engineering students at five institutions who participated in an online survey to explore views of socially responsible engineering, and among the sub-set of 70 who indicated a willingness to participate in an interview. Criterion-based selection was used to choose students to participate in longitudinal interviews, with a goal to select students representing a diversity of social responsibility attitudes, genders (with intentional over-sampling of female students), majors, and institutions; in all, 34 first-year students participated in the interviews. The twelve students who voiced a strong interest in the environment during the first interview and are therefore the focus of this study are a subset of that larger interview group.

In spring 2013, spring 2014, spring 2015, and spring 2016 the cohort of students were contacted by email and asked to participate in a 30 to 60 minute interview. Not all students participated in the interviews in all of the years. Students were compensated with \$100 gift cards for each interview. With the exception of two in-person interviews in year one, the interviews were conducted over the phone. The interviews were semi-structured, with a series of intended questions, but amenable to letting the conversation flow. No interview questions were designed to address environmental issues in particular. This method therefore avoids bias in the student responses, since leading questions were not posed. The interview questions asked students what they had been doing the previous year in courses, outside of classes, and summer internships. The interviews also asked questions about students’ views of social responsibility and future career plans. The interviews were transcribed. Emergent themes related to the research questions around environmental issues were identified in the interview transcripts. The themes were discussed by the two authors to establish convergent opinions.

The relevant context of environmental opportunities at each of the three institutions initially attended by the environmentally-motivated students in this study are summarized below.

A medium-sized public university (MPU) located in the northeast had a strong focus on environmental issues. The catalog states, “One of the distinctive features of [MPU] is its focus on studying the environment and the problems the environment faces. Students interested in environmental issues have a rich array of academic choices.” The student union building was described as a “hub of campus activity. Striving to achieve its core values of social justice and environmental stewardship....” At MPU, the environmental engineering degree was offered from the same department with civil engineering. Both the civil and environmental engineering degrees were accredited by ABET. The civil and environmental engineering curricula included many common elements, such as a combined first-year, two-credit introductory course, a shared capstone design course, and numerous similar engineering science/engineering courses.

A large public university (LPU) in the West has a strong reputation for environmentalism and sustainability. For a number of years the largest undergraduate major on campus was EnvS,

which includes both a track in environmental science and a less technical track. Environmental engineering is offered as an interdisciplinary program, requiring courses from civil, mechanical and chemical engineering. The majority of incoming engineering students matriculate directly into specific engineering majors, so there is a one-credit introduction to environmental engineering course that is required in the first semester for all EnvE students, and separate introductory courses for other engineering majors. Engineering courses in the first two years are unique, but quite similar among related disciplines, so transferring between engineering majors is not difficult and generally will not extend the time until graduation.

At a technically-focused university in the Midwest (TU), environmental engineering degrees were offered from a Department of Civil and Environmental Engineering. The EnvE curriculum was comparatively very different from the civil engineering degree at TU. There was a separate introductory course in the first-year, and few of the courses other than the core math/science were the same. The closest non-engineering bachelor’s degree related to EnvE was Applied Ecology and Environmental Sciences.

**Results**

**RQ1. Decisions to enter engineering for students with strong environmental interests**

The characteristics of the 12 students with strong environmental interests who were initially majoring in engineering are summarized in Table 1. EnvE was the predominant major. The majority of the students were white; two students were racial/ethnic minorities and three were the first in their family to attend college (1<sup>st</sup> gen). Females were over-represented in the interview group (58%) compared to their representation in EnvE nationally earning 49.7% of the Bachelor’s degrees awarded; among all engineering disciplines, 19.9% of Bachelor’s degrees are awarded to women [12].

**TABLE 1. Students with strong environmental interests initially majoring in engineering**

Pseudonym	Institution	Gender	Other demographics	Pathway of college majors
Tanya	TU	F	Black, 1 <sup>st</sup> gen	EnvE, graduated in EnvE
Sarah	TU	F	1 <sup>st</sup> gen.	Civil E, graduated in Civil E
Kim	LPU	F		EnvE to Civile after year 2
Brandon	TU	M		EnvE to Civile during year 2
Trevor	MPU	M		EnvE to Civile after 1st semester
Katherine	MPU	F		EnvE to Civile within a few weeks
Shawn	LPU	M		EnvE to ChemicalE after year 1
Nelson	MPU	M		EnvE; after first semester transferred to EnvS; then left after 2 years in college
Katie	LPU	F		Civil E to EnvS
Jocelyn	LPU to LPU3	F		Mechanical E to EnvSci & Policy
Kaitlin	MPU to LPU2	F	1 <sup>st</sup> gen.	EnvE to landscape architecture to sustainable agriculture and global
Travis	MPU	M	Hispanic	EnvE; suspended from college yr3

The students described a number of reasons for choosing to major in engineering in general. These themes and students were:

- Had family members or friends who were engineers (n=10); six talked about knowing or meeting environmental engineers (e.g. Shawn's father); only Kim and Trevor did not know any engineers.
- Liked math and/or science in high school (n=7); Jocelyn, Katherine, Kim, Sarah, Shawn, Travis, Trevor.
- Hands-on building activities like Legos and/or computer-aided design (n=5); Brandon, Jocelyn, Nelson, Travis, Trevor.
- Helping people/society (n=5); Kaitlin, Katie, Katherine, Sarah, Shawn.
- Design (n=3); Nelson, Kaitlin, Sarah.
- Travel (n=2); Katherine and Katie.
- Engineers held in high esteem (n=1); Shawn.

The elements that motivated students to choose EnvE specifically included:

- Love of the outdoors (n=7); Brandon, Jocelyn, Kim, Shawn, Tanya, Travis, Trevor; such as spending time boating on the water for Trevor, outdoor hunting for Brandon.
- Sustainable/ renewable energy interests (n=4); Jocelyn, Kim, Travis, Trevor.
- Desire to fix environmental problems such as climate change and issues associated with developing communities (n=3); Kaitlin, Katie, Sarah.
- Desire to live in harmony with natural systems (n=2); Kaitlin, Nelson.
- Desire for outdoor work (n=2); Shawn, Tanya.
- More interested in engineering as a whole versus environmental issues (n=1); Katherine.

Thus, while there were some common themes, the students each had a unique set of goals and experiences that led them to major in engineering in general and EnvE specifically.

## **RQ2. Pathways**

The pathways of the twelve students who entered engineering with strong environmental interests are summarized in Table 1. Only two of the students, Tanya and Sarah, persisted to graduate with B.S. degrees in the same engineering disciplines in which they started. Five transferred into other engineering disciplines. Four students switched majors out of engineering; one of those eventually dropped out of college. The final student was suspended from college, but had an enduring interest in environmental engineering. A number of students changing majors and leaving college is not unexpected [21, 35]. By comparison, among the students in the overall interviewed cohort without a strong initial environmental interest, 25% left engineering (lower than the 42% of the "env" cohort), 15% transferred to other majors within engineering (lower than the 42% of the "env" cohort), and 60% graduated in their initial engineering majors (higher than the 17% of the "env" cohort). The reasons and motivations for each of the different trajectories of the 12 students with initially strong environmental motivations are described in more detail below.

### Transferring to other engineering disciplines

The five students who changed majors out of EnvE into other engineering disciplines described a number of reasons. Two who struggled in chemistry and/or didn't like chemistry transferred to civil engineering (Kim, Trevor). Trevor at MPU stated: "I started off in environmental, but I didn't really care for chemistry that much and I would've had to take two more semesters of chemistry. So I talked to my advisor and switched to civil." In the year 2 interview, Kim at LPU stated similar concerns, "there is just so much chemistry involved in the classes that I have to take in the future that I just, like, I don't know, it's not really my strong point, I guess. And I don't want to set myself up to fail." Brandon described chemistry at TU as a "weeder class" where many students struggled, but he did well. Jocelyn did not initially major in environmental engineering because it seemed like too much chemistry. This points to the particular importance of chemistry as a gateway class in EnvE. More often, math has been explored as a barrier to engineering persistence [36]. A chemistry class taught with applications to environmental issues might be more motivating to EnvE students. At LPU the course is taught through chemical engineering, with a decades-long negative reputation.

The fact that there were more future job options with civil and chemical engineering degrees were cited by the students who transferred to these disciplines. Katherine stated, "there's just a lot of variety and it opens a lot of doors." Kim stated: "I feel like with civil I can kind of be more broad." Shawn transferred to chemical engineering, noting that he could make more money in that discipline and wanted more "value" from the investment he was making in his education. Brandon believed that he could be more involved in design in civil, versus in EnvE he was worried that he would just help companies do the minimum for regulatory compliance "which is tough to deal with not only ethically, but I didn't really want to do that I guess." As they continued in their new engineering majors, most of these students described working hard, liking their classes, and having internship experiences that they enjoyed.

### Transferring Out of Engineering

Two common themes in the stories of students who transferred out of engineering were struggling academically in core, early courses (like chemistry, physics, and/or math; Kaitlin, Katie, Nelson, Travis) and disliking the courses/curriculum in engineering. This mirrors common themes in the engineering persistence literature: grades and conceptual understanding, self-efficacy / self-confidence, and classroom and academic climate [22]. Academic struggles did not guarantee a change of major; Tanya stated that she did not pass pre-Calculus the first semester, but she persisted in EnvE. Three students discussed that the content in the courses was not interesting (Kaitlin, Nelson, Katie) and that the curriculum was too narrow/confining (Nelson). One student really disliked her summer internship experience (Jocelyn). The students discussed these concerns at length, as well as what they liked about their new majors (which related in all cases to the environment). The stories of these students are presented in detail below.

Despite struggling academically in both calculus and chemistry, Nelson stated in the first interview, "I was really underwhelmed by what we were learning, which was really nothing. We didn't learn anything." He contrasts his expectations with reality: "I thought it would teach ways to mimic natural systems, or if not mimic to integrate well into them. A building that really requires no outside energy and collects all its energy through a photovoltaic array or a small geothermal.... that's really interesting to me... and what I expected to learn. And it looks like

there are other ways to approach it here at [MPU] outside of the college of engineering [where] you are very locked into a specific schedule of courses.” He explains, “the environmental studies major at [MPU] is self-designed which is the exact opposite of the engineering major and is hugely more attractive to me because of that.” But in the year 2 interview, Nelson voiced dissatisfaction with EnvS, and planned to take time away from college. “I am just feeling a little frustrated because it feels I am not learning the details that seem to matter to me in my classes....” His frustration seemed to stem from gaining a greater understanding of all the vast problems but not seeing a path to solutions. By the year 3 interview Nelson had been away from college for a year, and returning to college seemed uncertain. With more perspective on both EnvE and EnvS, Nelson noted: “I felt like I belonged somewhere in between the two programs.” He discussed many “big ideas,” but concern about having any real impact. He also noted that “the environmental science major would have involved a lot more intellectual climate science to go along with the knowledge of the chemistry that was happening around us.” So he had considered that EnvSci might have been the best fit to his interests and goals.

Kaitlin was disappointed that what she found in her EnvE education did not match her goals. Among the students interviewed, she was the closest to being an environmental activist, stating “I’ve wanted to protect the environment. Coming here kind of upset me because [MPU] tries to sound so green [but] it’s really not a green campus. So it’s frustrating for me because I would rather be somewhere doing activism....” She had big, creative ideas that were forward-thinking but felt the EnvE was not “paradigm shifting” enough:

When I majored in environmental engineering, I was picturing large-scale greenhouse operations, vertical agriculture, maglev technology for transportation, solar everything. But we are still learning about the current systems that are not working.... 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. ... everything I was learning felt a little bit archaic.... [EnvE] didn’t excite me or make me feel like new things were happening.

She also described how she felt that the engineering curriculum was lacking appropriate attention to broader economic, political, and societal issues: “...this is probably ultimately what my problem is, ... where the problems that we’re facing are monetary and political and it’s really a social structural problem. And I feel like given the circumstances right now in the world that our engineering classes should be also teaching us how we’re going to deal with taking down that social structure to allow for change.” Kaitlin went on an exploratory journey at her new university, trying landscape architecture for a year, then thinking about hydrology, and eventually settling on sustainable agriculture.

Katie started as a civil engineering major, and was also participating in a global studies academic program. In the first interview she described what interested her most about engineering was making a difference: “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. With engineering I can go ahead and make people’s lives better immediately.” Her father was a mechanical engineer and Katie spent seven years growing up in the Philippines. She was interested in a career “helping clean up communities and schools... I see myself working in a developing community helping to implement either clean water, or work on some sort of sustainable living system, whether it’s building houses or devising a better energy

system.” By fall sophomore year Katie found that she was unhappy and uninterested in her courses. In the year 2 interview in Spring, Katie was planning to major in EnvS with a minor in computer science. She noted “I did want to continue with something technical” but there was not an EnvSci degree at LPU. She described wanting to have a “meaningful college experience” and “leading a life that is meaningful to me.” She discussed meetings with the academic advisor in the EnvS program, selecting courses that excited her and “fit exactly what I wanted to do.” She contrasted the coursework in EnvS compared to EnvE: “This degree brings so many different students and that I’m getting perspectives from the political science aspect of it, from political affairs or from the biology field or whatever. And as a result, I think that I am actually learning way more in my classes that are way more valuable information than I was in my engineering courses.” By the third-year interview she had dropped the computer science minor but was really enjoying EnvS: “I made exactly the right choice for me. I’m loving the balance between science and policy and wider variety of people here and I’m in Santiago and studying abroad.”

Jocelyn stuck with mechanical engineering for two years, then transferred out after disliking her summer internship. Jocelyn selected engineering due to liking hands-on and being good at math and science; her dad was a nuclear engineer. She wanted to “go into renewable energy” and “save the world”; “I like the outdoors” and “I’m obsessed with the environment.” She considered majoring in EnvE but changed the summer before college into mechanical, mostly due to a summer engineering camp where environmental “was a lot of chemistry” which did not interest her. She transferred schools the summer after her first year of college to move closer to her family. She found her mechanical engineering classes “extremely interesting.” She also noted that with mechanical engineering, “there is a ton of possibilities for what you can do with it.” She still discussed an interest in renewable energy. However, in the year 3 interview Jocelyn was on a different path. She had a summer internship with an engineering company and “really hated it.” In December of her junior year she switched her major to environmental science and policy. She noted, “It was the hardest thing because I’ve gone so far in engineering and it was definitely strange to change my mind.” But in her new major, “I really, really like what I am in now and since I started my new major it’s been doing a lot more science and less computers which was never my favorite. ...I decided I’m going to law school...” She stated that via environmental law she “can make a bigger impact.” She also discussed she would be graduating a semester early (after 3.5 years of college), since her new major required fewer credits. She noted that she was looking forward to getting to pick her classes in the final semester.

#### Persisting in Original Engineering Disciplines

A large contributor to Tanya’s persistence in EnvE may have been her early mentoring relationship with an environmental engineering faculty member. The instructor of her first-year EnvE course pulled Tanya onto his research team in the first year. This evolved into a full-time research job in the summer, and continued into future academic terms. The research was an exciting combination of being outdoors collecting samples from a nearby lake and analyzing the samples in the lab. The work also involved K-12 outreach to teach kids about the environment, via the lake sampling. Tanya also formed a cohort with other undergraduate and graduate student researchers.

Sarah was majoring in civil engineering, primarily due to a desire to “make things to help people” and “helping the environment and stuff like that.” She also described an interest in

Engineers Without Borders. She noted that her sister was an environmental engineer and her cousin a civil engineer. When she was asked directly why she did not choose to major in EnvE, Sarah responded:

I am more interested in the structure and the foundation that goes along with civil... reservoirs and tanks and processes, stuff like that. ... in environmental you really pick... water, soil, or air. And you deal with biology and chemistry and organisms and ecosystems and that just doesn't really appeal to me as much as the civil does.

So similar to a number of the EnvE majors who transferred to civil, civil engineering was seen as a path to have a positive impact on the environment. Sarah did a co-op that she enjoyed. She enjoyed some of her civil engineering courses, such as water resources, transportation, and professional practice; she disliked other courses such as materials. The combination of good internship experiences, enjoying the classes, and staying with a vision of helping society were reasons Sarah stayed in civil engineering.

### **RQ3. Environmental career goals for engineering students**

The seven students who initially had environmental goals and persisted to earn engineering degrees discussed their career goals and responsibilities with respect to the environment in different ways in their final fourth-year interview. Five of the seven remained strong in their environmental convictions. When Kim was asked what would make her job rewarding she said, "The main things would be just like knowing that you are not causing harm to the environment and you are helping it. And then with that, that could be helping people as well." Katherine's answer was similar, "I think it would just be having a positive impact so whether that be making a system more efficient so it leaks less water and is better for the environment...." Trevor described his responsibilities as an engineer to "perform all of my work to the best of my ability and make the client happy. More broadly it would probably be to try to build sustainably, to try and make sure that the client is happy with it, but making sure that the environment won't suffer because of it. Not take shortcuts for economic reasons that would impact the environment negatively, so try to find a balance between the two." Tanya responded to a question regarding her responsibilities as an engineer as: "I believe all engineers have responsibilities to incorporate the surrounding community and environment when you design the system." In response to the question who would he be responsible for as an engineer, Brandon's response included end users, world and environment, the workers making it, and yourself.

Two other students seemed to lose their passion for helping the environment through engineering. Sarah did not mention environmental concerns in year 3 (and did not participate in an interview in year 4). In year 2 Shawn said, "I feel like environmental is where my passion is and where I should ultimately be." But in year 3, Shawn stated:

When I first got into college I was a real big proponent of we need to do whatever we can to make life on earth and make human beings sustainable [but] I think that we are basically screwed... as a species... I do what I can in my sphere with myself and my friends, but I don't think I can make a huge impact ... I just want to have a job and get rid of some student debt and you know, live a comfortable life for little bit and then maybe after that do some networking and I'll look around for a better job....

In year 4 Shawn acknowledged that as an engineer he was responsible to himself and the company; as he expanded on that answer he added the people your job impacts and the

environment in general. But his commitment to the environment seemed limited to avoiding harm versus a real motivation.

The decreases in environmental commitments over time by Sarah and Shawn are somewhat similar to the decreases in social responsibility [19] and culture of disengagement [37] in engineering that have been found in other studies. This diminished concern for helping society through engineering has been attributed to the heavy technical focus and decontextualized nature of much of engineering education. Sarah was enrolled in civil engineering and Shawn in chemical engineering, so the lack of strong environmental focus in the majority of the courses in these majors is not particularly surprising. In contrast, four of the students who were initially EnvE majors and transferred into civil engineering largely retained their environmental commitments (including one student in the same civil engineering program at TU as Sarah).

## **Discussion**

Students who entered engineering with environmental interests also had other elements that drew them to engineering. These complementary elements commonly included family connections in engineering and interests in math/science. While similar to many other entering engineering students, the specific focus on environmental issues may be quite unique; institutions with a common first-year curriculum for all engineering majors may struggle to retain environmental-motivated students, given differences compared to more typical engineering majors. The courses in the first year had a big impact – students who struggled or did not enjoy the classes looked to find majors in or outside of engineering that better matched their strengths and/or interests. Some of the students with the “biggest ideas” around advancing novel, environmentally-friendly designs were disappointed that the engineering courses seemed to be focused on teaching current practice rather than creative solutions. Given these findings, it might be impactful on retention to have EnvE students take a course specific to environmental engineering and/or one that allows them to be innovative in envisioning solutions to problems of their interest (such as a project-based course that allows students to select a project of interest, and significant latitude in creatively exploring solutions).

Students who felt that their education should be more balanced between technical and societal issues were also dissatisfied. Heavy workloads in many courses, few choices, and high number of total credits in engineering were viewed as too big of a sacrifice by some of the students. Thus, the extent to which EnvE curricula can be designed to offer students choices, via electives, will allow students with diverse interests to find courses that match their goals. In addition, engineering courses that bring in societal issues and provide meaningful context for fundamentals will be motivating to students with broader interests.

Environmental science might offer a good compromise between the quantitative/science mindset of some students, integration of societal issues, and more choice/flexibility in the courses to earn a Bachelor's degree. However, environmental studies curricula that focus too heavily on discussing the vast array of environmental problems in the world without a balance on how to work toward solutions may frustrate some students. The availability of many degree options that encompass working to protect and clean the environment allow students to find the best match to their interests and future career aspirations. At institutions with these multiple degree options,

faculty should discuss with students how the majors are similar and differ, both in terms of curricula and future career options. Faculty should be open about the pros and cons of the various choices, and understand that student movement among disciplines is to be expected. Some interaction among these related disciplines might be warranted, perhaps in project-based courses that could bring these different majors together. Alternatively, allowing students to take EnvS and EnvSci courses as electives could be very attractive to EnvE students.

Overall, EnvE instructors should consider the ways that their EnvE students are similar and different from typical engineering students, and elements of EnvS and/or EnvSci that may be appealing and meaningful. Many EnvE faculty were trained in other disciplines, and should be aware that the “culture” around each engineering discipline is somewhat unique; EnvE is building its own emergent culture. The extent to which EnvE can retain students with diverse interests and goals will ultimately strengthen the profession. EnvE faculty may also want to work with faculty in other engineering disciplines to ensure that environmental protection issues are addressed. This could include giving guest lectures in courses, particularly design-focused courses where environmental considerations should be part of the constraints and criteria for all engineering projects.

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