Empowering Change: The Role of Student Changemakers in Advancing Sustainability within Engineering Education

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Abstract

Over the last decade, we have seen an increase in the number of engineering programs that integrate sustainability. However, employer demand for green skills continues to outpace the supply. Furthermore, most engineering students are unable to access the educational experiences that will prepare them for sustainability-focused careers. Engineering for One Planet (EOP) is one of the initiatives working to address this gap by using a multi-pronged approach to support and accelerate the integration of social and environmental sustainability into engineering education. Supported by The Lemelson Foundation, EOP provides a framework of student learning outcomes, teaching guides, grant funding in collaboration with partners like ASEE, and support for the EOP Network (EOPN), an impact-driven network of diverse stakeholders committed to integrating environmental and social sustainability into engineering. EOP's efforts have proven successful in fueling hundreds of courses across disciplines to integrate sustainability. While the EOP initiative has intentionally engaged students through a number of avenues, faculty champions have been at the center of curricular change efforts. Thus, the approach has not yet tapped the full potential of student changemakers to advocate for and support curricular change.

This paper draws upon primary research conducted during a workshop at the Engineers for a Sustainable World (ESW) conference in 2023 to understand students' motivations and capacity to support curricular change efforts and students' innovative approaches and priorities for curricular change. The paper also integrates the autoethnographies of student participants of the Engineering for One Planet Network (EOPN). The ESW workshop findings underscore students' passion for climate action and sustainability and their desire to support curricular change. The autoethnographies of EOPN student participants provide a first-hand perspective of students' experiences, benefits, and challenges on their journey toward becoming changemakers. This paper advocates for the active involvement of students in curricular change and highlights the potentially powerful role of peer networks and student-led initiatives in promoting sustainability within engineering education. By leveraging student changemakers' enthusiasm and innovative thinking, we can collectively work toward a more sustainable future in engineering education and practice.

Keywords: Sustainable Engineering, Sustainable Development Goals (SDGs), Student Changemakers

Introduction and Background

Over recent years, numerous initiatives, funding opportunities, and research collaborations have been working to advance engineering education's focus on a sustainable future. This focus on sustainability was initially catalyzed in 1987 by the United Nations Brundtland Report, which called upon humanity to pursue sustainable development, and was furthered and explicitly connected to engineering in 2000 by the Grand Challenges in Engineering [1]. The Grand Challenges was quite unique at the time because of its student focus; it activated a grassroots effort among universities to identify a challenge and find students to meet a challenge, many of which are sustainability-focused. In 2007, the United Nations Sustainable Development Goals (SDGs) were born, which centered and directly connected sustainability to education [2], [3]. The SDGs provide an excellent framework for understanding which areas of sustainability require attention and what action might be taken, expanding beyond climate to areas of justice, equity, food insecurity, and wildlife conservation [4], [5].

These important initiatives have helped draw attention to, and engage students in, challenges related to environmental and social sustainability. Over the last decade we have also seen an increase in the number of engineering schools incorporating sustainability. However, few institutions have thoroughly embedded sustainability into the curriculum and there is little evidence that most engineering students are graduating having learned about it [6]. Undergraduate students in engineering, after completing their bachelor's degree, make a choice of continuing education (towards a secondary degree like M.S., Ph.D., M.D., etc.) or towards a non-continued education role, normally described as AltAc or Alternative to Academics. For Academics, we have seen an exponential increase in sustainability-focused publications and grants by both NSF [7], but also DOE, NatGeo, and Non-profit funders. For AltAc careers, in the LinkedIn Jobs report, we see "Green Jobs" as one of the largest growing markets alongside AI and machine learning researchers [8].

Several different initiatives and student organizations are working to address this education and skills gap, including Engineers Without Borders (EWB), Engineers for a Sustainable World (ESW), and Engineering for One Planet (EOP). ESW and EWB play an important role in undergraduate student education, providing students with sustainability-focused project-based learning. EOP is working to address the education and skills gap a little differently, by working to integrate sustainability across the entire engineering curriculum, such that all engineering students, no matter the discipline, graduate with the, "fundamental skills and principles of social and environmental sustainability [9]." The EOP framework, the cornerstone tool of the EOP initiative, provides educators with a comprehensive list of learning objectives, co-developed by hundreds of academics, engineering professionals and stakeholders [5], [10]. The learning objectives that comprise the framework, align with both the UNSDGs and ABET criteria. and are designed to be adopted and adapted by faculty across all engineering disciplines. The framework is accompanied by a series of teaching guides with recommendations and approaches for

implementation. The ASEE EOP Mini-Grant Program, funded by the Lemelson Foundation provides funding and mentoring to support faculty and their integration of EOP learning objectives into their classes.

EOP's efforts have been highly successful in supporting faculty to integrate sustainability into the curriculum with the ASEE EOP Mini-Grant program Cohorts developing 34 new courses that have impacted over 1600 students. Thus many students have benefitted from these curricular change efforts, but students, the target audience of these changes, have not yet played a significant role in shaping these change efforts. We hypothesize there is much to learn from students; students bring fresh, innovative perspectives, and the inclusion of students promotes a user-centric approach, whereby educational changes can be designed with their specific needs in mind. In this paper, we explore this hypothesis, sharing findings gathered at the Engineers for the Sustainable World Conference 2023 (ESWCon) about students' perspectives and experiences regarding sustainability as a part of their engineering education.

Methods

Student data was collected and interpreted using different forms of qualitative data collection, including open-ended response surveys, handwritten responses, and autoethnographies. Data collection was conducted at the annual Engineers for a Sustainable World Conference at Cornell University in November 2023. 121 students attended the conference, most of whom were undergraduates. Data was collected at two different points in time. First, the co-first authors surveyed a workshop session. Next, the co-first authors used an interactive whiteboard activity to gather data during the conference career fair. 22 students attended the workshop and were prompted to respond to the following two questions conducted using Slido poll software (slido.com):

1. What activities are you engaging in at your university with a sustainability focus?
2. What other activities would you like your campus to make available to you?

Survey question responses were anonymous. However, we logged that we had 19 unique responders to all of the questions, with some participants responding multiple times. For the interactive whiteboard activity, students were prompted to share their experiences and opinions in response to the following prompt: *Imagine if your college or university fully prepared you for a sustainability-focused career. What would that look like?* The whiteboard was then subdivided into two main areas with students adding their post-it responses to the prompt based on whether their chosen career path was academic or non-academic, and whether the various classes/experiences/support were already offered by their college/university, or not offered (see **Figures 1A and 1B**).

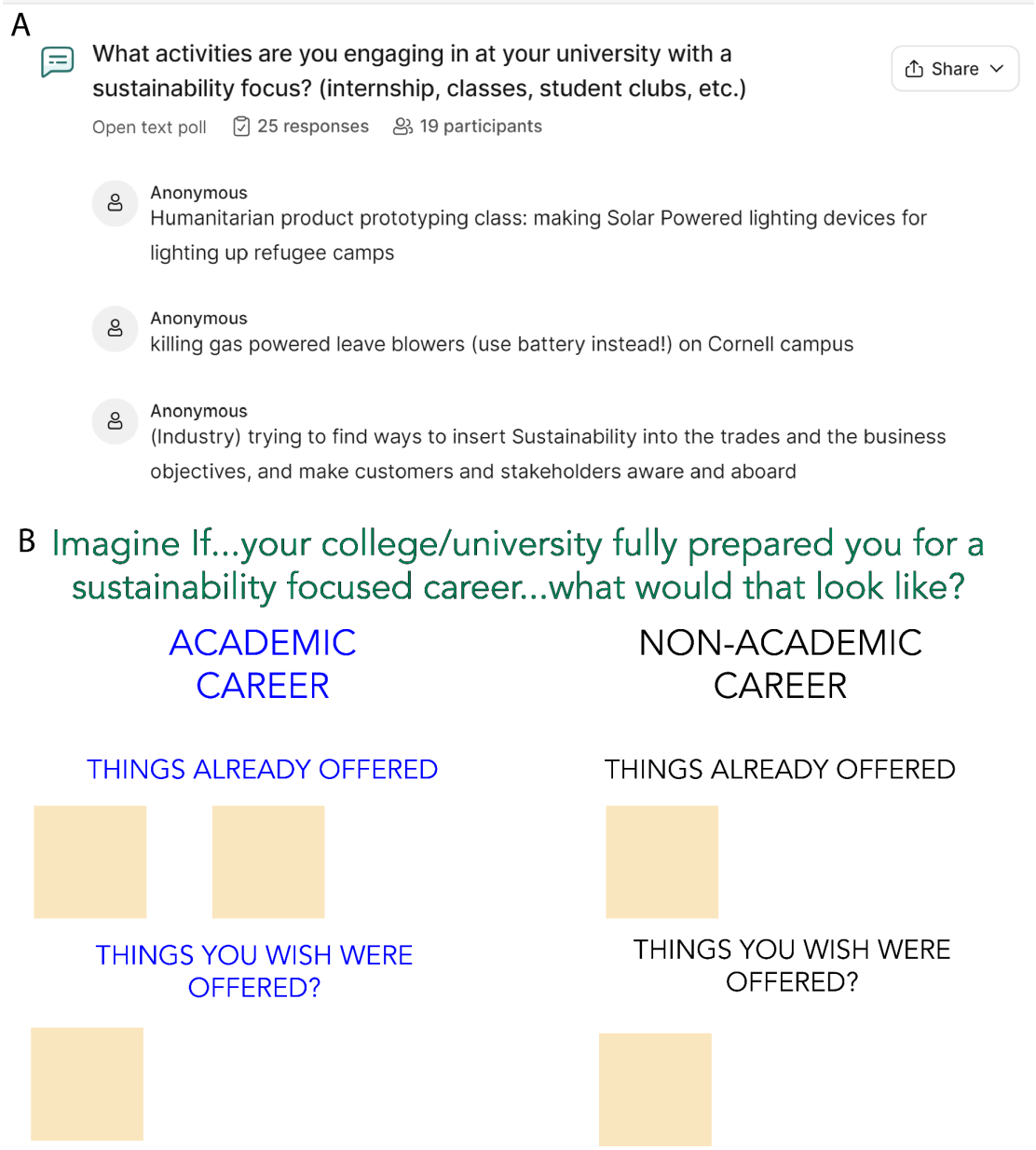

Figure 1. A) Example of a Slido poll used for students with student responses indicated. B) The engagement whiteboard with questions and specific whiteboard prompts for students to place sticky notes on.

Thematic Analysis

Student responses to the survey questions and whiteboard prompts were compiled and entered into a spreadsheet to interpret the common topics and themes. Themes were extracted using the grounded-theory framework approach [11], where common words/phrases are extracted and categorized based on specific themes, as shown in **Table 1** and **Figure 2**.

Collecting and Prompting Autoethnographies

As described above, the Slido polls and whiteboard activity conducted at ESWCon were designed to provide a high-level understanding of different sustainability-focused curricular, co-curricular, extra-curricular, and career preparedness activities that students are either engaging in or wished they had access to on their home campuses. By comparison, the autoethnographies were designed to capture the personal experiences, values, beliefs, and sociocultural contexts that shape students' experiences of, access to, and desire for sustainability-focused activities, as well as the degree to which they feel empowered to promote the kinds of changes they would like the see in the engineering education system.

Autoethnography is a technique that combines the personal reflection of autobiography with the examination of cultural relations, values, and beliefs that are characteristic of ethnography[12]. It may be argued that the qualitative nature of autoethnography runs counter to the more dominant quantitative epistemology in engineering. However, the socio-cultural insights it elicits can be both insightful and instructive when seeking to understand and support change in the engineering education system because systems change is, at its core, socio-cultural. Additionally, the very process of composing an autoethnography can serve to raise an author's awareness about the systems they are interacting with and thus further support them in fostering change[12], [13], [14].

A total of five authors were selected to write autoethnographies for this manuscript. Four are students selected such that they might represent the different career stages; two are undergraduate students, and two are PhD students. One additional author was selected due to her experiences running a student climate ambassador's program. The authors were provided with prompts to support the development of autoethnographies that would promote reflection on their own socio-cultural context as it relates to the sustainability-related experiences they have observed are currently missing from their own engineering education experience or that of others, and the ways that they personally, or other students, have worked to support changes to engineering education, and the levers and barriers they encountered.

Results

As described above, we thematically examined the students' responses to both the Slido poll questions shared during the ESWCon workshop and the whiteboard prompts at the ESWCon career booth. Themes were organized according to whether students were currently engaged in or had access to the various activities (Activities Available) and those that students wished they had access to (Activities Wanted) (**Table 1** and **Figure 2**).

Table 1. Student responses to the survey questions and interactive whiteboard prompts which are organized by activities available and activities wanted.

	Slido Poll: Activities engaging in at university with a sustainability focus		Whiteboard Activity: Classes/experiences/support already offered to prepare for a sustainability-focused academic career.		Whiteboard Activity: Classes/experiences/support already offered to prepare for a sustainability-focused non-academic career.		Total: All Activities Available	
	Activities Available	Activities Wanted	Activities Available	Activities Wanted	Activities Available	Activities Wanted	Activities Available	Activities Wanted
Project-Based Learning (Extracurricular e.g. as a part of clubs, competitions etc).	24	3	0	0	2	0	26	3
Research	7	0	7	1	0	0	14	1
Academic classes	7	8	6	4	0	3	13	15
Academic Programs	1	2	1	1	1	0	3	3
Internships	1	0	0	1	1	0	2	1
Project-based learning (curricular)	2	8	1	1	0	2	3	11
Career support	0	1	0	5	3	5	3	11
Project-based learning (outside the University)	1	7	0	0	0	0	1	7
Campus Sustainability Initiatives	1	8	0	0	0	0	1	8
University support for initiatives(centralized office, staffing, committees etc)	0	6	0	0	0	0	0	6
Networking among students	0	1	0	1	0	0	0	2
Mechanisms to provide feedback about education	0	0	0	1	0	1	0	2
Increase awareness of opportunities e.g. classes, clubs etc.	0	0	0	0	0	1	0	1
Connecting disciplines and theory to real world implications/applications	0	0	0	1	0	4	0	5

An analysis of the differences between activities that exist and activities sought by student respondents revealed a large disconnect, especially in the ranking, as shown in **Figure 2.** Students indicated that sustainability-centered *extracurricular project-based learning (PBL) activities* (26), *research* (14), and *academic classes* (13) are available. However, when looking at activities sought by students, academic classes remain sought after with a desire for sustainability-focused courses across the curriculum. We also saw students were interested in accessing sustainability-focused *career support*; 11 students indicated that these activities are wanted, but only three students indicated they currently exist.

This comparison of opportunities that are available to students versus those that are sought illuminates the disconnect between what students are seeking and what is available at their home institutions. For example, students indicated they had access to an array of extra-curricular PBL opportunities and expressed a limited desire for more. When students referenced access to extra-curricular PBL opportunities, they did so in response to the Slido question only; no students mentioned extra-curricular activities in response to the whiteboard activity about preparedness for academic and non-academic careers. This may indicate that students do not see such experiences as beneficial in preparing them for their future careers.

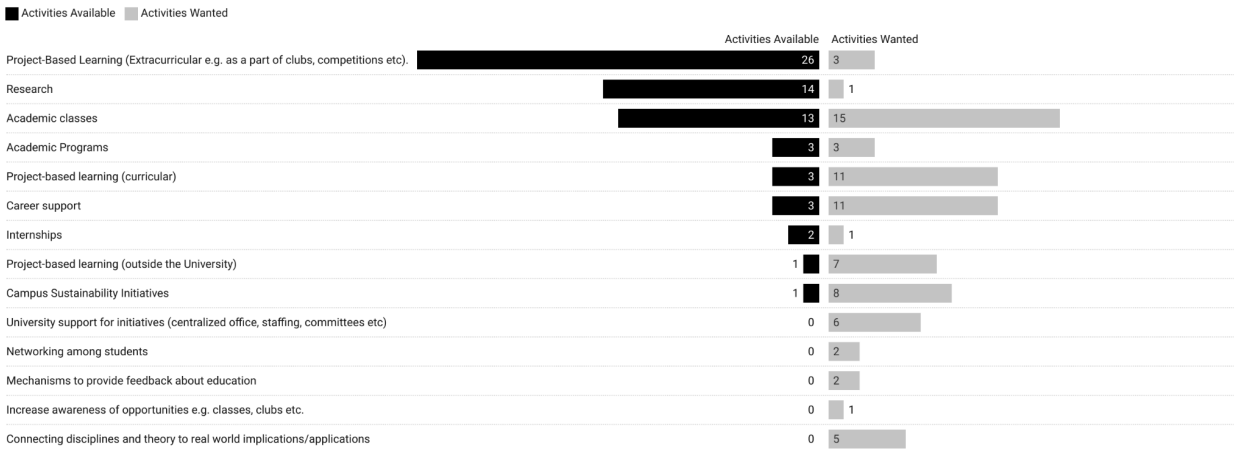

Figure 2: Results indicated the frequency and number of students that indicated activities that exist (black) and activities that are wanted (gray) for training at the undergraduate level of sustainability engineers.

Additionally, students expressed a desire for PBL opportunities that extend beyond the campus (*PBL outside the university*). One student explained that they would like to be able to "…connect across the country with other sustainability initiatives because in a college campus, the scope is sometimes only small…". Several students had specific projects in mind; for example, one student suggested "Engagement with the local community to build more sustainable systems (transport, food, etc)." In addition to these more expansive, off-campus PBL learning opportunities, there is also a desire to bring PBL into the classroom (*PBL curricular*). One student, for example, explained they are seeking "Classes that focus on local government and policies relating to sustainability and we can be a part of the community initiative."

While, as described above, students were seeking project-based experiences that extend beyond their campus, they also expressed a desire to work more closely with their campus on sustainability projects (*campus sustainability initiatives*). One student explained they would like: "Opportunities to work on projects that will benefit the university directly." Others suggested mechanisms that might enable students to support campus sustainability initiatives and goals, for example, through the creation of a "sustainability board for students to advocate for/ push ideas to university facilities", "a student committee on sustainability," and, "sustainability-focused campus jobs."

Research is another area where students currently have access to opportunities and expressed a limited desire for more. Students referenced individual research in conservation, sustainable polymers, algae for biofuels, solar cells, energy storage, and carbon capture. Only one student expressed a desire for research opportunities, and this was in response to the question about preparation for a sustainability-focused academic career.

Academic classes are the only category where students have indicated both reasonable access to classes and a desire for more. An examination of the student responses revealed that the classes offered are often specialized, elective classes, for example, focusing on "Global Warming + Climate Change Mitigation" or "Humanitarian product prototyping," or as one student explained are, "...locked to only the civil engineering department." Students recommend campuses offer a larger and broader array of courses, with recommendations for both introductory and advanced courses. One student explained, "My college has a class about climate change and engineers, but I think sustainability education should be mandatory." Another suggested that "All courses have a sustainability portion in their curriculum."

In addition to having broader access to sustainability courses, students also recommended some changes to the way specific majors and topics are taught. For example, one student explained, "I wish our school would have a pharmaceutical/medical sustainability class since there is so much plastic waste produced in that area," and another recommended, "More emphasis on power systems and the grid when it comes to paths for EE majors." Other recommendations included integrating sustainability into engineering design and business objectives.

Within their classes, students also sought a connection to real-world learning. One student explained, "I wish professors, when teaching courses, included: What our discipline is offering to the environment, how are we polluting, what our field [can do to] fix the problems." Another suggested "A clear ranking of open problems in our field that relate to climate change," and another recommended "Panels from professionals in individual fields who can advise students about how they can use their major for sustainability."

Academic programs are one area that students indicated needing more access to and a limited desire for more. All three students who shared they had access to a sustainability program explained it was a minor. Those students seeking a program expressed interest in a certificate program with one student explaining, "...I know some other universities have some graduate programs similar to that, but having something available to undergraduates would be great."

One non-academic area sought by students is *career support*. While three students mentioned they had access to career support, 11 said they would like access to this. The three students who referenced having access to career support did so in the context of the whiteboard question about preparation for non-academic careers. They referenced their engineering career center, career fairs and one referenced in-class career support whereby "Classes invite guest speakers to talk about their job and company, also recruiting for internships/work." One student seeking career support mentioned this in response to the Slido poll and referred specifically to accessing resources to prepare them for a career in industry. The remaining ten students seeking career support were split evenly between whiteboard responses to academic and non-academic career preparedness, respectively.

In response to the question about preparedness for academic careers, students referenced sustainability-specific career fairs and advice, including partnering with companies on such sustainability-focused efforts. There was interest in learning about how to prepare for a career in different sustainability-focused fields, and how your major prepares you for different sustainability-focused careers. Student responses to the question about preparedness for non-academic careers were quite similar and included green career fairs, and emphasized how specific majors and minors might prepare them for different careers. Additionally, students were interested in learning which skills were transferable into specific sustainability-oriented careers and which companies were sustainability-oriented. One student explained they would value "Notes on which companies have sustainability initiatives," and another expressed interest in, "Precise connection of talent to a position related to sustainability."

Students also referenced the importance of communication. Two students sought mechanisms for supporting their feedback and requests (*mechanisms to provide feedback about education*) . One spoke in very general terms and another specifically referenced initiatives like EOP as a mechanism to support them in their desire for change, "....continuous support from groups like YOU!" Two other students highlighted the importance of supporting communication among sustainability-minded students (*networking among students)* including a "Hub for sustainability-oriented individuals to communicate and share ideas" and "...having spaces (lounges) for students to meet and collaborate randomly." One other student referenced the importance of promoting existing sustainability opportunities (*increase awareness of opportunities*), explaining the need for, "More publicity about the relevant programs (clubs/projects/etc)."

Students additionally recognized that the changes being sought need to be resourced (*university support for initiatives*), with six students referencing this need. Students highlighted the importance of sustainability leadership roles such as a "dean of sustainability" or "sustainability director." Others referenced student committees, and consulting organizations to support the work, and another referenced a centralized location as critical to growth, "concentration of sustainability goals & activities to one central department/leadership group. Advancement of any sustainability activities cannot be long-term without this."

Autoethnographies

Autoethnography 1

I am a 20 year old caucasian woman with the pronouns she/her pursuing a bachelor's degree in mechanical engineering. I am currently a junior attending a private research university with approximately 19,000 students. My motivation to get involved in sustainability comes from my love for nature and awareness of the environment deteriorating due to the actions of humanity. Ever since I decided to be an engineer, I have

integrated sustainability into my designs because I wanted to make things while also bettering the world around me.

Approaching three years into my engineering education at university, I have barely seen sustainability integrated into my classes and education. A couple professors that have taught my classes have attempted to bring in sustainability to some degree, but it is always brief. These classes lack not only the discussion of sustainability, but the sustainable foundation that engineering should be based on. In engineering classes, content should build off the basis of sustainability, where sustainability is treated as fundamental as safety is when considering designs. When talking about designing for the market, safety is always a big factor that is discussed and taught to be considered. If sustainability were treated like this, engineering education would be training young minds to create a sustainable world.

As a student, especially at a private university run on donations of benefactors and alumni, it is hard to be heard. Similarly, change is hard to come by, things often stay the same because the donors and alumni want it to remain the same. Myself and my peers have attempted to make changes to our classes and education before, where behaviors on the part of the instructor jeopardized our grades, but have been consistently shut down. For example, we had a class where the teacher never opened up a quiz on Blackboard to be completed. Myself and many classmates went to higher ups and spoke about the issue and were told it would be looked into, only to find out many weeks later that nothing would be done. Due to this instance and many other instances of trying to get help from the school to change our education to be fair as well as beneficial, myself and my peers feel it virtually impossible to change anything within our education and school, so the prospect of getting the school to integrate sustainability seems impossible. I have peers who are also passionate about sustainability in engineering, but are so discouraged from past experiences with the school they do not want to make any further attempts at changing their engineering education.

Additionally, the way engineering is taught at my school is not the most intuitive. For example, there is a lot of theory and math with a lack of application and hands-on activities until you get to much higher up classes, where they throw you in the deep end and expect you to know what to do. This is completely different from when I first started learning engineering in high school. We were given the background as well as taught through hands-on projects and the ability to make mistakes in a forgiving but professional environment. Since I have been in college for three years now, and all of my classes have been taught with the discouraging approach I mentioned, I genuinely thought that was how engineering education was or was supposed to be and that my experience in high school was a fluke. However, after being a part of EOP and talking to all the engineering professionals and faculty, I realized how wrong I was. After sharing my experience at our

most recent EOP convening, I was surprised at the amount of shock people responded with and how appalled they were. It was then I realized that my engineering education should not be like this. Everyone in the organization had expressed support to me and talked about how student voices like mine should be lifted up. Though I could not really change my past or current education, it made a world of difference to be heard and be told that there is a chance I could help change education in some way so future students would not feel like I had.

Autoethnography 2

I am incredibly disappointed in the current lack of sustainability curriculum in engineering schools across the United States. As a 20-year-old female in engineering school at a large public university, the will to learn about sustainability is the only thing that has taught me about it. This will came from the roots up for me, starting with reading about climate change statistics in 2020, to now having friends from Caribbean countries that will be fully submerged in the ocean in less than 50 years. While I pursue my mechanical engineering degree, it has become apparent that at my university, although ranked #3 in the world in environmental science and engineering, there is a lack of sustainability curriculum in majors other than environmental and civil engineering. There is an ongoing sustainability crisis that engineers can tremendously help fix, so why are we not being given the resources we need to do this?
Engineers are the thinkers and doers of the future. Our job is to create solutions to modern problems. But how good are these solutions we produce if they further the destruction of the Earth, economy, and social equity? I have noticed a complete lack of foundation in sustainability in curriculums other than civil and environmental engineering. There is not a mandated sustainability-focused class to take for mechanical, electrical, or any other majors. In addition to this, while sustainability minors, clubs, and initiatives are relevant and accessible, they are not advertised well by the university. It took me 11 months of emailing numerous people to finally declare a minor in Environmental & Sustainability Studies. The university needs to shift their focus in the College of Engineering to be more sustainability based and make it easier to become a part of these kinds of organizations and academics.

As an avid environmental advocate, I have been a part of and led numerous sustainability projects around campus and as personal projects. As a board member of my school's Engineers for a Sustainable World (ESW) chapter, we have created boxes for native bees to procreate and thrive, a device that detects and reports invasive and endangered birds around campus, and are currently in the process of fixing a local nature center with gardens, solar panels, and activities for kids to learn more about sustainability. Additionally, I have used my role as a College of Engineering Peer Leader to present about sustainability to first and second year engineering students and am currently working on a personal project that will make all plastics clean and recyclable. I take pride in the things I have achieved and the goals I continue to work towards,

and they have been catalyzed but also hindered due to institutional and cultural aspects coming into play. In one way, being a part of a large institution with public goals of helping their students in any way possible has helped thrust my recycling bin project forward in many ways. One of the most impactful of these is the offering an entrepreneurial institute to all students. Here, students can come in with an idea for a product, software, or any form of business, and they work to help the student make it a reality. I have had infinite help and support in creating a business plan, getting design ideas and suggestions, and will eventually be set up with interns to help build and implement my recycling bins as soon as possible. Additionally, by sponsors and the university providing funding to ESW, we have been able to accomplish our projects to an extent that we can be proud of. However, with the 51,000 student population and numerous clubs, the amount of funding is incredibly limited. This being a factor, requesting funding can become troubling and it can be hard to get the funding needed to complete our entire plan. Culturally speaking, there are levers and barriers as well. Being a melting pot university, there are people from all different backgrounds and cultures. While some cultures promote sustainability and Earthly reciprocation, some people were brought up with a "profit over planet" mindset deeply rooted in unsustainable capitalism. When trying to engage the latter, I have personally been laughed at, had eyes rolled at me, and told it was "not worth my time" to do the projects I do.

The environmental sustainability initiative is crucial to understanding equity and environmental issues, but without having the proper resources and curriculum, engineers who are not concentrating on it will end up oblivious unless they research and find out. This is unacceptable. By implementing college-wide curriculum requirements with sustainability-focused classes, engineers will be able to achieve the highest goals of the sustainability movement. Without this and proper resources, universities are only hurting their students and the future of the Earth, economy, and social equity.

Autoethnography 3

I am a 28-year-old white Ph.D. candidate in environmental engineering (EnvEng), graduating in 2024. I am both female-identifying and presenting, using she/her pronouns. I am a United States citizen, which allows me to have the freedom to pursue any career path in the US without the need for visas or sponsorship, a situation which is sadly not true for many of my colleagues. My graduate and undergraduate institutions are private, medium-sized R1 institutions with small EnvEng programs. They are both located in liberal urban areas. Growing up, I was privileged to attend schools in well-funded public school districts with strong STEM programs and attend an international high school abroad for two years on a full scholarship. While my earlier schools briefly discussed sustainability and environmental issues, a focus of my international high school was sustainability and community engagement. When I arrived at my undergraduate institution, I was shocked by the lack of focus on community-driven and focused sustainability initiatives,

such as a lack of instructions and enforcement of sustainable waste disposal, which has slowly started to change, partially due to student pressure.

Entering college, I was unsure of my primary major. However, I knew I wanted to join an environmentally related STEM field. I had never heard of EnvEng, and I wouldn't until the winter of my sophomore year, not from any required advising session or professor, but from a younger student. The lack of effective general advising and limited understanding of the diversity in engineering degrees creates a barrier for individuals to pursue engineering, especially in less popular disciplines. Now, I routinely speak with high school students interested in environmental issues and sustainability and share my experience and love of EnvEng and engineering in general to address the environmental problems facing our world and communities. I am also passionate about developing ways to provide information on different career paths to current students from various backgrounds, a project I pursue through the Engineering for One Planet Network.

However, a lack of awareness of sustainable engineering practices for incoming and current students is only the first barrier. Once within an engineering discipline, barriers to gaining sustainable skills and pursuing sustainable career paths also present themselves. Core courses, whether required by ABET or the major, are, in my experience, rarely updated. ABET shows a commitment to sustainability, but that commitment is not translating to effective change for current students. New professors might be encouraged to develop or revamp a current course, but how student feedback and requests are collected and implemented varies by university. How are students who identify issues with courses and want to have more courses that integrate sustainable practices supposed to encourage or force classes to be updated?

As my role changed from undergraduate to graduate, I began to see the challenges from the professor's viewpoint, where in R1 institutions, research is more highly valued than teaching. Advocating for student voices on campus must come from a loud group of students who can force or encourage these changes and show them the success of pilot cases within and outside their institution. As I became involved with EOP and learned about the ASEE mini-grant program, I met not only professors and deans dedicated to sustainability but also saw a way to legitimize this push in a way universities understand: funding; funding, even on a small scale at first, can support faculty in making curricular change, and as I describe below, can help support students in accessing experiences that will significantly impact their career options and skillsets.

As a student at a wealthier institution, undergraduate research was readily available and well-funded. I worked in an environmental chemistry lab within an NSF-funded center focused on sustainable nanotechnology throughout all four years and completed a senior thesis. I was paid or received class credit, which allowed me to dedicate more time and learn more about sustainable and green chemistry. Not all students are this lucky, and as a graduate student, I have

openly talked about funding or credit options at my current institution with undergraduate researchers to ensure that needing a student job like I did is not a barrier to exploring sustainability through research. My research experience was one of the most important activities/classes I completed during my undergraduate years, as it exposed me to research questions related to sustainability and ideas for what to pursue for my Ph.D. I also gained invaluable mentors through the experience who provided more targeted career advice and network connections than any career office could provide.

I am about to graduate and have been focusing on my career path. While my current research topics are related to sustainability, it is not related to how companies and the general public might describe sustainability. Students graduating have these same questions. How can they land entry-level sustainability-focused jobs if they do not gain at least some of the skills employers are seeking in their classrooms? It is essential to continue learning about sustainability throughout your career and show that it can add value to your employer. To be a sustainable engineer, my title does not need to be "sustainability expert," but sustainability has to become more integrated into how I approach my duties, no matter the job. Early career individuals can push for this in their roles and also go back and tell their schools as alumni what to do. Alumni networks are the natural progression of on-campus changemakers. As I look towards my next step, I am thinking about how my experience can be shared with my current educational community.

Autoethnography 4

I am a black male with he/him pronouns. In May 2024 I will complete my Ph.D. in civil engineering at a public research university with approximately 40,000 students.

Over a decade and a half ago, I witnessed close relatives and friends becoming casualties of poor social and environmental policies related to oil exploration and infrastructure construction. As a young boy born and raised in the most populous black nation in the world, my career path was significantly shaped by this event and the dominant culture around me. As I near completion of my Ph.D. I reflect on how a systemic approach to environmental policies at the time could have made sustainability a habit and prevented the colossal damage caused to my people.

Reflecting on my own experience as a Ph.D. student, I have observed there is still oblivion towards sustainability in many research endeavors, as long as the technology developed serves the needs of the users. Many scholars pay little attention to the adverse effects of their material selection, material sourcing, waste generated, and the like. In my opinion, the missing link at the doctoral level is the unintended disregard for sustainability in engineering education and the prioritization of the economic benefits of innovation over the sustainability of the processes and

materials leading to it. It can then be surmised that this anomaly mirrored the type of education taught. A cultural and intentional shift is indispensable for a sustainable future.

While this kind of approach to doctoral research is not prevalent, I personally addressed some of the issues by trying to incorporate sustainability into the processes and material selection for my research. In one of my studies focusing on operational carbon reduction using phase change materials, I furthered the study to redesign some of the processes to involve zero energy requirements and non-toxic waste with a neutral pH. The university and various funding agencies have started paying serious attention to supporting sustainable research, considering the net-zero emission mission for 2050. Our research team has been one of the leaders in research related to the decarbonization of construction materials in the US. We have developed prototypes where CO2 can be permanently stored in concrete, accompanied by an increase in mechanical performance.

Other than research, I have been a harbinger of change by getting involved in organizations with similar interests, such as Engineering for One Planet (EOP). The EOP has been pivotal to my commitment to making sustainable engineering practice a culture. The EOP annual convening refreshes my belief that a sustainable future is possible from now if we act. My active involvement as a member of the advisory board of the American Society for Engineering Education (ASEE) / EOP Mini-Grant Program affords me the opportunity to review thought-provoking applications centered around sustainability submitted by faculty members in US colleges. Having reviewed more than 200 applications, I observed many colleges are modifying existing or creating new course modules for sustainability. I strongly believe this deliberate approach is fundamental to addressing some of the sustainability-related issues facing our planet. However, most of the time, these courses are optional and may not benefit some students who advance to the PhD level without any encounter with such sustainability-laden courses. Perhaps there could be a way to extend this initiative to graduate students who are at the heart of research that could change the world.

The challenges are far from over, and the journey to sustainable engineering is a process and not an event.

Autoethnography 5

When pursuing my undergraduate degree at a large public university in California, I was underwhelmed by my school's sustainability efforts, particularly in the education department. As an environmental science major, I was shocked to see minimal emphasis on climate change in my courses. It raised concerns for me that if the people in *my* major were not being exposed to this critical content, we were likely letting 5,000 students graduate annually without a holistic understanding of the climate crisis and the role they could play in it via their careers. It prompted

me to explore what other universities were doing to advance sustainability in curriculum, and how my school might learn from them.

Motivated by my observations, I started a climate change program for student volunteers during my first internship, while I was a student myself. The objective was to connect passionate students, who were working towards similar campus sustainability objectives like curriculum development, to collaborate and strategically accelerate mutual progress across campuses. Within our program's curriculum committee, students started by researching their university's efforts, then researched colleges that were leading the way globally, using prominent resources like AASHE's Resource Hub and STARS tool. By pairing proven models for curriculum development with each volunteer's unique campus situation, we brought valuable insight to struggling universities without reinventing the wheel.

In doing this research, it was difficult to find many schools with comprehensive sustainability curriculum across degree programs and the general education catalog. In analyzing those few successful colleges, we identified three key criteria that needed to be met to lay the groundwork for curriculum expansion: a governing body overseeing these processes, vetted sustainability learning objectives for academia, and regular involvement in decision making by students, i.e., those directly subject to and benefitting from curriculum. Our students prioritized meeting these conditions on campus before working to adapt existing courses, create new ones, or transform degree pathways.

Every time our volunteers pitched ideas to staff members, they were met with surprise that students cared about this particular initiative. It demonstrated the derogation of sustainability curriculum by even sustainability staff, and that higher administration typically pushed staff to prioritize more eminent issues like divestment, since such popular initiatives are closely linked with reputation. Because of this, the curriculum-focused students made the most progress of anyone in our program, since they were leading an issue that no one else had on campus.

Overall, it is clear that college is one of the best places for students to start learning about how to lead amidst the climate crisis. This is true both by enrolling in courses with career-focused sustainability learning and by spearheading new efforts to advance curriculum. It is also evident by my program's research that students are needed at all stages of curriculum development on campus, in order for proper representation and progress to be seen continuously. However, without widespread prioritization of sustainability curriculum in higher education and cross-stakeholder collaboration between campuses, it will likely be years before we see this become a trend.

Discussion

When we look at the results yielded from the surveys and whiteboard activities, it is apparent there is a disconnect between what students are seeking in terms of sustainability-focused

education and what is available on campuses. When these results are overlaid with the autoethnographies, that same disconnect is apparent. While there are a myriad of opportunities for PBL in an extracurricular setting, students are seeking PBL both within the curriculum and as part of more expansive, off-campus, community-based projects. We also observe that while students report there are sustainability-focused classes available, they are seeking more. Through the autoethnographies, we learn this is perhaps because the sustainability-focused classes offered are not broadly available because they are limited to environmental engineering or civil engineering majors; they are not core or foundational courses that all can access, and sustainability is not yet integrated across all classes as a fundamental consideration in engineering design, much like safety or profit. Respondents also indicate a need for career support that will help them select their program of study and educational experiences that will prepare them for a sustainability-focused job.

In addition to underscoring the disconnect described above, the autoethnographies also capture the deep motivation on the part of students to support curricular change. This is fueled by their own lived experiences and empathy for others. Such experiences include early exposure to climate change and social sustainability issues in high school, or living in a country, or knowing others who live in countries experiencing the effects of social and environmental inequities. This deep-seated motivation inspires students to not only seek out educational opportunities for themselves but also find ways to provide such educational opportunities for others.

While the passion described above may spur students to action–be that seeking or supporting the integration of sustainability-focused educational opportunities– such action is only possible when it intersects with other socio-cultural enabling factors. One such factor extensively referenced—likely due to the fact respondents were participants at the ESW conference–is the support of ESW in creating an array of student-driven, extracurricular project-based learning opportunities. While beneficial, it is worth noting that such opportunities would likely not be available on campuses without an ESW chapter. Also, the extracurricular nature of these project-based learning experiences excludes the involvement of students who need to work or support their families and thus have no additional time in their schedules. For these reasons, the addition of sustainability content within the curriculum is important if we are to ensure all students are able to access sustainability-focused experiences.

On some campuses, there are other enabling mechanisms that support access to or the creation of sustainability-focused experiences. One autoethnographer mentions an Engineering Peer Leader role that provides them with a platform for exposing other engineering students to sustainability. Another discusses their access to funded undergraduate research experiences, and two others explained that their PhD research focused on sustainability. While such mechanisms are important, access to the kinds of leadership and research positions described is limited, and as one autoethnographer explains, some students will be systematically excluded from research

experiences unless they are funded. Also, while PhD candidates have a level of autonomy that enables them to center sustainability in their research, that level of autonomy is not extended to undergraduate students. As one autoethnographer explains, undergraduate students' preferences and feedback do not currently compete with the preferences and feedback of donors or with a campus's focus on research.

As one autoethnographer noted, campuses that had comprehensive sustainability curricula were characterized by three criteria: "... a governing body overseeing these processes, vetted sustainability learning objectives for academia, and regular involvement in decision making by students, i.e., those directly subject to and benefitting from the curriculum." If institutions (and their students) are to benefit from adaptations to curricula that might emerge from the energy and insights provided by students, it's important to identify opportunities to engage and support student changemakers within the current engineering education system. One simple starting point identified is rethinking how student feedback and requests are collected and implemented. Another is leveraging the insights of alumni and recent graduates. However, for such seemingly small shifts in the engineering systems to take effect, the mindset of those who are part of the system also needs to shift. As the autoethnographers explain, faculty and administrators do not expect students to take an interest in curricular change, and integrating sustainability into the curriculum is typically not prioritized since such efforts are not directly connected to campus reputation.

However, attention to and support of sustainability initiatives in the engineering education system is increasing, as observed by the increase in research funding opportunities and faculty curricular change grants, like the ASEE EOP Mini-Grant Program. As described by some autoethnographers, initiatives like EOP and the EOP Network also provide would-be student changemakers with support, validation, and a frame of reference for what might be possible, even if that is not something they experience on their campuses. These shifts in attention and support provide an opening for institutions to identify ways they might work with students on their own campuses to identify and support sustainability-focused curricular changes. Some suggested changes for universities to implement are displayed in **Figure 3**.

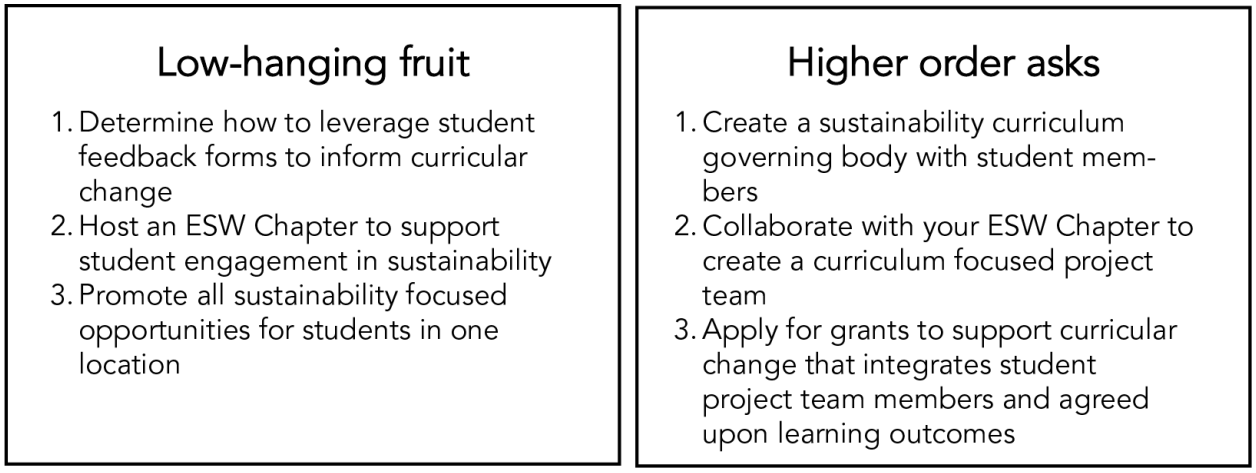

Figure 3: Suggested approaches institutions can consider to support students interested in sustainability.

Limitations and Future Work

This paper has potential limitations. The survey and whiteboard results were gathered from a small group of students at the Engineers for a Sustainable World conference, and the five autoethnographers were also selected due to their association with either the EOP Network or ESW. As such, the respondents and autoethnographers are already passionate about and engaged in sustainability, and their perspectives may be different from engineering students across the United States.

Future work will focus on addressing these limitations by expanding the scope to gather feedback from a broader group of students, both inside and outside of ESW, to learn which sustainability-focused experiences are currently available and unavailable on campuses, and to identify recommended next steps for supporting student changemakers.

Conclusion

In this paper, we utilized several different qualitative methods to explore the hypothesis that there is a disconnect between what sustainability-focused experiences students want versus what currently exists. Using a grounded-theory framework approach to explore undergraduate students' themes, we analyzed data collected from the Engineering for a Sustainable World (ESW) conference as well as student autoethnographies, which confirmed our hypothesis. Student respondents indicated that sustainability-centered extracurricular project-based learning activities, research opportunities, and academic classes are available. However, when looking at activities sought by students, academic classes continue to be in broad demand due to the limited number of classes offered, or the way that the classes are only available to specific majors, or the way that sustainability is not woven into existing classes. Students also expressed interest in sustainability-focused career support, and emphasized the need to embed real world, sustainability-focused learning into the curriculum such that all have access to it. We conclude

with some low-hanging fruit approaches that campuses might implement to help bridge the gap between sustainability-focused experiences offered and those desired. Future work will expand the scope of this early-stage research, to understand, from a broader group of students, what gaps exist in terms of sustainability-focused resources sought, and what universities could be doing to address these gaps both in the short term (<1 year) as well as in long-term strategic planning initiatives (>5 years).

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