2021 ASEE ANNUAL CONFERENCE
Virtual Meeting | July 26–29, 2021 | Pacific Daylight Time
Paper ID #34418

Diversity, Equity, and Inclusion in Civil and Environmental Engineering Education: Social Justice in a Changing Climate

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Diversity, Equity, and Inclusion in Civil and Environmental Engineering Education: Social Justice in a Changing Climate

Abstract

In this paper, we describe the broad-spectrum efforts of the Department of Civil and Environmental Engineering at Carnegie Mellon University to interweave Diversity, Equity, and Inclusion (DEI) principles and practice into our pedagogy and culture. We discuss specific curriculum development and redesign efforts, both at the undergraduate and graduate levels, which empower our students to reason critically about inclusive and equitable engineering. These efforts focus on identifying and combating inequities associated with race, gender, sexual orientation, disability, socioeconomic status, and intersections thereof. We also detail the creation of, and activities spearheaded by, our departmental DEI committee.

The DEI Committee, composed of faculty, staff, and students, has the responsibility of examining and correcting institutional biases and to improve understanding and experience for all within the Department through, for example, active dialogue within the Department, seminars, and actions.

At a more distributed level, instructors began to deliberately confront issues of DEI in multiple courses in different ways, including class discussions, team projects, problem sets, and writing assignments. These efforts include discussions of how civil engineering projects are linked to inequitable pollution concentrations, lack of access, mass incarceration, and displacement of low income communities. We have used readings to investigate the social cost of not considering social justice in investment decisions and have engaged in design and build projects to contribute to the revitalization of historically-underserved communities. To reflect the diversity that we seek to encourage, we have placed particular emphasis on assigning readings from scholars who are Black, Indigneous, People of Color (BIPOC). This is especially important given structural biases that lead to their voices being less cited and consulted in our scholarly advancements . We have also developed exercises to identify prominent non-white or non-male-identifying engineers who have played important roles in engineering science and practice. We present preliminary results detailing the preliminary assessment of some of our DEI efforts. Overall we highlight how integrating DEI into the classroom and the department stimulates higher level thinking on the Bloom's Taxonomy scale, greater engagement, and can promote a more inclusive and equitable learning environment. Through this work our goal is to equip instructors and students with the ability to think critically about how they can make change within their own institutional systems and in their future careers.

1.0 Introduction

To properly contextualize Carnegie Mellon's work around DEI, we need to situate it within a larger movement that has gained traction and momentum around engineering and social justice [1]-[3]. These happenings build upon the seminal work of Baillie [4], Riley [5], and their joint work with their collaborators [6]. This has sprung a series of engineering and social justice-related or -infused courses, seminar series, and workshops across engineering campuses such as

those at the University of San Diego [7], Colorado School of Mines [8], Purdue [9], Stanford [10], the National Academies [11], and others. The most recent illustration is a series of global, humanitarian, and peace engineering programs that have now arisen to offer not just course material, but entire degrees centered around issues at the nexus between engineering and social justice. For instance, there are now centers, certificates, and/or degree programs in the realm of social justice, global, humanitarian, development, and peace engineering at the University of San Diego [12], CU-Boulder [13], UC-Berkeley [14], Colorado School of Mines [15], Drexel [16], Penn State [17], Oregon State [18], Duke [19], Purdue [20], University of South Florida [21], Baylor[22], and MIT [23], amongst many others. This growing trend is bringing important pedagogical advancements that are asking us all to critically explore our engineering legacy, history, and future. In particular, this is leading to important reflexive questions as to the tacit, and even possibly harmful, assumptions that we are making as a profession as to who can participate in engineering, let alone call themselves engineers.

We are seeing a similar trend as specifically applied to Civil and Environmental Engineering (CEE). As recognized through the American Society of Civil Engineers, CEE has a direct impact on communities and individual lives, and biases that manifest therein, especially in our infrastructure systems. Yet most engineering curricula are devoid of social justice topics. In order to create socially conscious engineers, CEE curricula must make diversity, equity, and inclusion (DEI) an integral part of coursework. CEE programs need to prepare students not only with the knowledge to tackle technical challenges, but also with the historical and cultural perspectives and critical thinking skills to bolster and center social justice in CEE endeavors. This includes not just the communities affected by our work but also the web of institutional relationships that influence our engineering options and decisions. In order to prepare socially responsible engineers, professors need to educate themselves, and devise new pedagogy aligned with culturally responsive teaching and learning [24].

One proposed method to develop socially conscious students is through global citizen programs [25]. While we need global citizens, there is also a need to connect students to social justice in their local areas and to highlight how social justice plays into decisions they will make in their careers. Moreover, these programs still treat social justice and engineering as siloed inquiries and do not join them, which makes it difficult for engineers to learn how to bring these critical social issues explicitly into engineering decision-making.

In this paper, we describe the broad-spectrum efforts of the Department of Civil and Environmental Engineering at Carnegie Mellon University to interweave DEI principles and practice into course pedagogy and our department culture. We discuss specific curriculum development and redesign efforts, both at the undergraduate and graduate levels, which empower our students to think critically about inclusive and equitable engineering. These efforts focus on identifying and combating inequities across race, gender, sexual orientation, disability, and socioeconomic status. We also detail the creation of, and activities spearheaded by, our departmental DEI committee.

2.0 Integration of DEI Issues into Courses

Our curriculum development efforts have sought both to inform our students and empower them to make a difference, especially in communities that have been negatively impacted by a history

of racially-biased infrastructure and environmental decisions. We have sought to deliberately confront issues of DEI in multiple courses via class discussions, team projects, problem sets, and writing assignments. Through this work our goal is to equip students with the ability to think critically about how they can make change within their own institutional systems and in their future careers. This section is organized by course to illustrate how different types of exercises can be implemented.

2.1 CEE Project Course for high school students from underrepresented communities

Since 2017, Carnegie Mellon University's CEE department has sponsored a hands-on CEE project course as part of the University's Pre-College Summer Academy of Mathematics and Science (SAMS) Program that prepares high school students from underrepresented communities for STEM-related careers [26, 27]. This course is developed and taught by Carnegie Mellon's faculty and alumni who work together to create an inclusive curriculum bearing in mind the broad range of STEM experiences offered in the participants' high school curricula. The majority of the students have never seen a female or BIPOC engineer, so a portion of the course involves guest lecturers who dispel the belief that there is no diversity in STEM. Students have the opportunity to see the significant impact of CEEs through field trips to public works, like dams managed by the U.S. Army Corps of Engineers who plan, design, build, and operate locks and dams.

Current undergraduate students have shared that we need to highlight more exciting and technologically-savvy opportunities within the field and share the opportunities to make a social impact if we want to attract more students from underrepresented communities to the field of CEE rather than other engineering fields. To do this, the course has adapted over the years by posing more socially-meaningful design problems that are not typically addressed in early engineering courses and requiring the use of cutting-edge tools. Projects and topics have included sensor networks for monitoring natural water systems, engineering resilience under natural disasters, intelligent systems, environmental sustainability, and innovative materials. The most recent project focused primarily on designing, building, and testing several types of wireless sensor networks for reducing risks associated with natural disasters. Students learned how to estimate the state of multiple CEE systems using Arduino microcontrollers and various sensors (water quality, stress/strain, and air quality).

The CEE project course and SAMS more broadly have helped to increase the number of applications from students from underrepresented communities at Carnegie Mellon in CEE and other STEM-fields [28] and have prepared many cohorts of students who pursue CEE at top universities across the country.

2.2 Exploring CEE: Infrastructure and Environment for a Changing World

In this introductory course for first-year engineering students, we center the concept of the engineer's responsibility to all of society. For most of the students, this is the first college-level engineering course they will take. Before the first class, we assign an article detailing the historical connection between racism, traffic congestion, and infrastructure [29]. At the beginning of class on the first day, the students divide into groups and discuss this article, and

then reflect on their group discussions with the broader class. The students discuss the roles of the actors involved in the article that built racism into infrastructure, including the roles of the engineers, and reflect on the generational longevity of infrastructure decisions. We use this discussion as a springboard to other focused content throughout the class on the roles and responsibilities of engineers in providing equitable and just infrastructure systems. This includes environmental justice issues such as the impacts of energy and transportation infrastructure locations on pollution and health outcomes, the disproportionate damages to vulnerable communities from climate change impacts, and other topics. The revised ASCE Code of Ethics details the engineer's responsibility to society, the natural and built environment, profession, clients and employers, and peers. We use the Code of Ethics for focused discussions about centering inclusivity, equity, climate mitigation and resilience, and social justice in their engineering work. These activities fall under ABET student outcome 4 (an ability to recognize ethical and professional responsibilities in considering the impact of engineering solutions in a global and societal context).

2.3 Computational and Data Science for Civil & Environmental Engineering

In Spring 2021, we adapted a sophomore-level CEE course focused on computational and data science to include DEI topics. This multi-pronged effort aims to improve DEI outcomes through a variety of new practices in curriculum, course staffing, and logistics.

2.3.1. *Integration of historical and modern-day techno-social content and discussion*. In a typical introductory computational science and engineering curriculum, the only "historical voices" that appear are those people who have left their names on the subject's core algorithms and techniques (e.g., Newton, Euler, Riemann, Dirichlet, von Neumann, Runge, Kutta). Although each of these individuals played an instrumental role in founding numerical computation, limiting the curriculum to these names creates the harmful misconception that this field only counts "dead white men" amongst its champions.

To diversify the curriculum, the instructor developed an approximately biweekly course tradition ("Get to Know a Computational Scientist or Engineer!") that highlights the contributions of women, people of color, and non-cisgender/heterosexual individuals to computing and data science. These profiles (typically five to eight minutes in length) feature both historical and technical detail, and are deliberately scheduled at points in the semester where the profile can seamlessly merge with technical lecture content.

For example, during the unit on numerical interpolation, students are introduced to Dr. Gertrude Blanch, who led the Mathematical Tables Project, which generated unprecedentedly comprehensive tables of special functions (thereby enabling unprecedentedly accurate numerical solution of mathematical problems via interpolation). The associated social justice discussion spans themes of sexism, xenophobia, and political persecution, all of which Dr. Blanch faced during her career. Other profiles presented in this course include Dr. Alan Turing (during the unit on probability and random processes), Dr. Katherine Johnson (during the unit on root finding), and Dr. Phyllis Nicolson (during the unit on ordinary differential equations).

2.3.2. *Extensive discussion of the intersection between data science and discrimination*. During the unit on numerical linear algebra, students were encouraged to engage with a set of readings on the intersections between data science and racial bias, a topic of significant modern-day techno-social concern. Students are invited to participate in (optional but encouraged) office-hours discussions of this material. When this activity was piloted in the Spring 2020 semester, nearly a quarter of the class engaged in voluntary out-of-class discussions on these readings. These conversations indicated immense interest in humanizing data science and in critically assessing the field's ethical ramifications.

2.3.3. *Dramatically expanding support resources for students with less computing background*. A core inclusivity challenge in all computing coursework is the (often dramatic) range of computing background within the course participants. To ensure that students have ample access to computing support, course staff (including the instructor, teaching assistant, the department's computing coach, and peer tutors) have office hours available six days of every week (Sunday through Friday). Although data has not been collected, anecdotal evidence and qualitative feedback suggest that students with less computing background have benefited significantly from these expanded resources.

2.3.4. *Prioritizing accessibility of course materials for students with disabilities*. Course instructional materials are only provided in file formats that are conveniently compatible with common technological solutions for students with disabilities. For example, although it is of course possible to increase the magnification of any digital material, it is in practice much easier to do this if the font size can be controlled natively within the application. For example, in the MATLAB programming environment, this accessibility consideration is a subtle but meaningful differentiator between script (.m) files and live-script (.mlx) files, especially for students with visual disabilities (font sizes are much easier to dynamically adjust in the latter file format and don't require making preference changes at the application level, which don't automatically save in between sessions on a computing cluster computer).

2.4 Introduction to Professional Writing in CEE

The elective course Introduction to Professional Writing in CEE is a writing & expression general education elective option for sophomores, juniors and seniors. Genres covered in the course include individual and team professional reports and presentations. Because the focus of the instruction is on the genres, students can choose their own CEE topics.

The individual and team modules are introduced with small and large group discussions of articles as a way to generate topic ideas. For the Fall of 2020, these articles covered topics such as environmental racism [30], redlining [31] and global access to renewable energy [32]. Students then chose DEI-themed CEE topics for their reports and presentations. Group reports focused on global access to sustainable energy, the impact of climate change on the need for prison reform, and accessibility concerns in smart infrastructure. Students frequently had an impact on each other's understanding of stakeholders, particularly of vulnerable communities, in the development of their reports. For example, in the smart infrastructure group, one student advocated for including a section on the needs of people with disabilities.

The course size is typically about 15 students. The small environment allows for community building to occur early in the semester, starting with an acknowledgement in the syllabus of the impact and challenge of current events on the students' lives.

> Take care of yourself. Do your best to maintain a healthy lifestyle this semester and practice self-care. You are my primary concern. No class lecture or assignment is as important as we are as individuals. The past several months have been rife with heinous, traumatic acts of racism, as well as stressful health, economic and isolating conditions, which affect us at our intersectionalities. All of us benefit from support during times of struggle. If you would like to take all or part of any given class session to pause our studies and have a class discussion (a "mental health day" of sorts), please just say so, either privately to me or to the class as a whole.

Students asked to enact this policy three times during the semester, centering on racist vandalism on campus and on issues surrounding the election. In addition, students often checked in on each other when they were in breakout rooms as their community bonds deepened. It was apparent from social interactions with the students in the following semester that several new friendships were formed during the class, including between students who were on campus and who were remote. A teaching consultant from the university's teaching resource center conducted an early course evaluation mid-semester. Students also completed an evaluation at the end of the semester. Student comments from those evaluations are included in Section 4.

2.5 Environmental Engineering

The junior-level Environmental Engineering course was redesigned to show the impact of civil and environmental engineering infrastructure and decision making on the public. The primary change was a reorientation of the water chemistry content (about ⅓ of the course) around the Flint water crisis. The reorientation began by leading students to recognize the potential of engineers in affecting social and environmental justice or injustice. Students consumed stories from popular media (a video, podcast, and/or detailed written report) on the crisis that unfolded in Flint. In class we discussed the details of the crisis, the engineering practices that contributed to it, the decisions that led to both, and the definition and examples of environmental injustice.

With this context, we proceeded to dive into the water chemistry content that comprises the objectives for the first third of the course. All the while, we referred back to details from Flint to demonstrate the real-world relevance of objectives around ionic strength and precipitation-dissolution equilibrium reactions, for example. Students have continued to read a popular text about the crisis, too -- *The Poisoned City: Flint's Water and the American Urban Tragedy* by Anna Clark [33]. We will conclude this section by engaging with a panel of stakeholders involved in municipal water resource and treatment decision-making from a large and growing metropolitan utility (that is not Flint). The panel will build upon what we learned about Flint, where an underserved community declining in size and investment was harmed by water decision makers, and explain how their decision-making process uses issues of social and environmental justice to motivate more equitable decision making.

As part of the writing initiative within our department, assignments focused on writing for the general public are included in the Environmental Engineering curriculum. Example op-eds are read and discussed as an introduction to the op-ed writing assignment, in which students can choose their own topic, state their position, and support their position with sources. For Spring 2021, example op-eds included “Not Just Another Pipeline” by Louise Erdich [34] and “I’m a black climate expert. Racism derails our efforts to save the planet.” by Ayana Elizabeth Johnson [35]. Students discussed the op-eds in small groups and shared the key points of their discussions with the whole class. They then completed a draft and revision of their own op-eds. Topics for the student-written op-eds included environmental justice & climate change, fenceline communities, and food deserts.

2.6 CEE Capstone Design

Historically, many infrastructure choices and designs have had disproportionately negative impacts on minority and low-income communities. Changes were implemented in the senior-level CEE capstone design course to prepare students to design equitable engineering solutions that consider the diversity of stakeholders. The project was developed with a community partner organization that was interested in an aquaponics facility that could provide the organization with an income stream that would allow them to be self-sustaining. This organization is located in an area of the city that has been neglected and serves a predominantly minority population. It was expected that students would be motivated by the opportunity to use their engineering skills to make a difference in others’ lives.

Through the course of the project, the students were encouraged to consider the stakeholders who could be influenced by the project, including those who we did not get to meet through the process. Students interacted with a leader from the community organization via video conference, in-person conversations, and email to learn about the project and to present their designs at the conceptual, preliminary and detailed design phases. Because of Covid restrictions, only a few students were able to visit the site, and we were not able to interact with community members outside of leadership at the community organization. As seniors, it was expected that students were capable of conducting independent research to learn about the community. They were given links to the community organization’s website, but were given little additional information about the community. In 2020, students were provided with minimal instructions on effective communication with a diverse range of stakeholders, but adding explicit instruction on this would improve future interactions.

At the end of the conceptual design phase, the client expressed interest in a few of the recommended concepts. To make the decision, students were asked to consider the ethical implications of the alternatives through different ethical decision-making frameworks. Small groups of students discussed the decision using the multiple frameworks and the class together decided which alternative to pursue. These ethical decision-making frameworks helped students to evaluate the impact of their potential decisions on all stakeholders.

An ultimate goal for the course was to construct a modular aquaponics system and building and then transport it to the site a few miles from campus. Due to calendar changes and Covid-related restrictions for on- and off-campus work, only prototypes of parts of the system were produced

during the fall semester. A number of students were joined by juniors and graduate students to complete the final design and construction of the aquaponics system in spring semester.

The instructor evaluated the effectiveness and impact of addressing social justice through design through a post-course student survey and student anecdotes. Preliminary results are presented in Section 4.

2.7 Civil Systems Investment Planning and Pricing

Traditionally, investment decision making has focused on economic metrics, and has left social justice impacts (i.e. number of people impacted) out of the equation. Within the Civil Systems Investment Planning and Pricing graduate level course, the instructor introduced diversity issues and ethical decision making by reframing homework problem sets in the class. This flipped classroom approach allowed the instructor to focus the majority of class time on teaching technical topics.

In the first week of class, the students are taught different estimation techniques, and traditionally the students have been asked to estimate how much of a specific technology has been deployed in the US. This year in the class, the students were asked to estimate the number of minority workers in the energy sector. Then in the homework assignment, the students were asked to comment about the uncertainty in their estimates, and comment about whether they thought the energy sector had a "good" level of diversity. While the instructor expected the students to comment on their estimated numbers compared to the level of minorities in the US, many ignored this question. Instead, students focused solely on the estimation techniques and uncertainty inherent in the data. This highlights a fundamental gap in students' initial ability to reflect on the implications of their estimates in a broader societal context.

In the next assignment, the students were exploring data visualization. The instructor provided the students with information on the number of people incarcerated in the US [36], and asked the students to remake the pie charts into easily digestible graphics which explained the mass incarceration problem in the US. Then in the third homework assignment, the students were asked to evaluate investment decisions for a fictitious company. Upon completion of the initial assignments the students were given the following prompt, "Company X is thinking of reducing their costs by Y%. To do this they would outsource jobs to the local prisons. Recalculate the company's profits and provide a recommendation." The students then needed to state the social justice implications of their decision.

The instructor evaluated the class by evaluating whether student final exam answers included social justice when unprompted, where those exam answers ranked on the Bloom's Taxonomy scale, student anecdotes, and faculty course evaluations. The preliminary results of this classroom redesign are discussed in Section 4.

2.8 Engineering and Social Justice

Within the context in the Introduction, Daniel Armanios spearheaded a new Engineering and Social Justice offering at Carnegie Mellon University. The aim was to provide a novel organizational sociological lens to these issues at the nexus of engineering and social justice that

builds off of these important preceding pedagogical and research advancements. The class proceeds in four sections.

In the first section, students are introduced to key terms and asked to ascertain what social justice is for themselves. In that light, they are asked to decide what their key fight is at this nexus; how they will proceed to fight it; and what challenges they may face in that fight and how they will try to resolve them. For instance, students are asked what philosophy they most resonate and espouse per the different social justice traditions nicely presented in Riley [5]. They are then asked to ascertain whether they are more "realists" who feel they are best equipped to work within the existing system, or "idealists" best equipped to change the system to bring about their desired change [37], and what are the challenges they will face in either approach.

We then finally conclude by asking how they will reconcile their own moral views and fights in the context of having to join an organization whose mission and ideals may not completely align with their own. In other words, how will they resolve conflicts with their own "sphere of justice" (i.e., [38]) overlaps but differs with those of their own organization.

In the second section, students are asked to deconstruct their legacy as engineers. We deconstruct this in two ways. First, we deconstruct our own assumptions and how they have persistent deleterious effects on society. For instance, we discuss the legacy of Frederick Winslow Taylor [39] and his assumptions around blue collar workers as only desiring job security and wages and that the job of the engineer is to "educate" these workers as to the proper ways to do their work. From the perspective of Taylor, the notion of engineering is one "benevolently" doing the thinking for the worker while the worker obediently does it. Armanios then shows how these deleterious assumptions persist today with a Job Interests Survey. He asks the students what they prefer in a job, and then asks them what they think *blue collar workers* prefer in a job. In virtually every instance he has run the survey, while engineering students say they prefer interesting work that uses their mind, they assume, just like Taylor, that blue collar workers just care about job security and wages. He then analyzes data from the General Social Survey [40] on job preferences between white and blue collar workers and shows their preferences are virtually similar. Next, Armanios discusses the impact of engineering standards on society. For example, standard female crash dummies [41] may actually lead to a far greater likelihood that females will die or get seriously injured in crashes than males [42]. Finally, we deconstruct our own legacy within the engineering profession. In particular, we focus on how movement for change within engineering has brought both positive but also negative impacts to our own inclusivity [43][44]. We also discuss how that still manifests today in micro-aggressions on underrepresented students in STEM in the present [45].

In the third section, we explore the social justice consequences of a variety of engineering systems as a result of our own implicit or explicit biases as a profession. For instance, we discuss how they bias artificial intelligence algorithms around everything from hiring, assessing beauty to search results tied to specific races and genders (e.g., [46];[47]). We discuss how a focus on means instead of distribution skews access to transportation [48], and that even biases more upstream in terms of infrastructure, whereby not all races and genders can even access a bridge equally, only worsens such access disparities [49][50]. How our lack of proper protections of the vulnerable through purposeful informed consent in our experimentation has led to devastating health consequences as seen in the Tuskegee Experiments [51]. Even our primacy of English as

the predominant language medium of scientific dialog has systematically obstructed those scientists whose first language is not English [52][53].

Finally, we discuss various methods engineers can use to identify and address social justice issues in engineering systems. For instance, this includes mixed methods that combine qualitative data to identify justice or inequity dimensions previously unknown and quantitative data that subsequently tests the generalizability of such dimensions (e.g., [54]). We also discuss multi-criteria decision models that create different equity scenarios based on differences in stakeholder priorities (e.g., [55]). Image classification and search techniques that make more transparent and salient the biases of existing algorithms used in such processes (e.g., [56]). Finally, we discuss quasi-experimental techniques that help isolate particular inequity dimension along gender or race so as to inform particular policy recommendations to alleviate them (e.g., [57]-[59])

Understandably, ensuring constructive, safe, and inclusive dialog around the heady topics covered in an engineering and social justice course requires careful and diligent planning. Armanios used the following principles to help guide his thinking. The first was co-construction of class norms. Armanios first set up some initial principles, and then invited the class to edit those norms. The intent was to ensure everyone felt ownership in the norms and that he and the students were equals in this educational journey of trying to make sense of these difficult issues. Before every class, he briefly puts up those norms as a reminder of what we all agreed to uphold in class dialogue (himself included). The second was to not just discuss but to directly live justice in the class. If the course does not reflect the justice you wish to see, then it is hard to convince students to take the takeaways from it seriously. As such, Armanios worked hard to ensure the course materials reflected the diversity of the classroom. Twenty-four of the twenty-eight readings were from BIPOC scholars, and all guest speakers were BIPOC and compensated with an honorarium for their time. Anytime he could anticipate, he also put in trigger warnings as to the sensitivities around course content and why they were pedagogically included. The third was experiential learning opportunities. Anytime there was a current event that related to class, Armanios took time to discuss it at the beginning of the class, and he offered bonus point opportunities to attend events where such justice issues were at play such as community or town hall meetings. Those who chose to attend would then debrief about what occurred and how it tied to class material. The final guiding principle was multiple avenues of participation. In this way, he leveraged virtual tools afforded through Zoom to allow for breakout rooms that allow for smaller group discussions, as well as direct messaging and email for more private reflections that some find more comfortable for sharing their thoughts.

3.0 Departmental DEI Committee

The CEE Department instituted a DEI Committee in the summer of 2020 to develop a strategic plan for DEI. In addition to faculty and staff who typically comprise departmental committees, graduate and undergraduate students were asked to join the committee so that all community members are represented. Volunteers from each of the community groups were sought to ensure that committee members were deeply committed to and interested in the cause. Since creation, the committee has been meeting on a weekly basis to develop the strategic plan, discuss ideas for improving DEI in the community, and plan events and other actions to promote DEI.

The goal of the DEI strategic plan is to create a diverse, equitable, safe and inclusive environment where everyone feels that they belong to the community, are supported by the community, and have equal opportunities to thrive and succeed. We note that a clear distinction needs to be made between "safe" spaces (i.e. a place where we can push our limits, and have tough conversations without threat of retaliation) and "comfortable" (i.e., familiar thoughts, places, habits in which we do not feel challenged) spaces, because we wished for this effort to provide a space for students and the CEE community to discuss tough topics. To develop the strategic plan, the committee focused on developing goals and strategies to promote DEI for all stakeholders including faculty, staff, undergraduate students, graduate students, and external affiliates. The objectives of the plan include increasing the diversity of people and perspectives at all levels of the department; creating a safe, equitable and inclusive climate; improving the incorporation of DEI into our core values and curriculum; increasing engagement with the local community; and improving accountability and rewarding success with respect to DEI. To ensure that all voices in the community have the opportunity to be heard, the committee shared a draft of the plan with proposed goals and actions with the department community, sought feedback including additional ideas through small group meetings with voluntary representatives of each stakeholder group, and incorporated their ideas into the plan. The draft strategic plan is currently under review and further details may be available to share in the future.

The committee has held a number of information and listening sessions to help our community members to understand how racism is manifested in academia, to hear how our community members are affected and provide them with support, and to co-produce actions to create a more diverse, equitable, and inclusive community. Presentations and discussions have included discussions of the Black Lives Matter movement and advancing solidarity with people of Asian heritage, as well as monthly presentations by faculty that address how civil and environmental engineering works have negatively impacted underserved groups in our society. In addition to department-wide events focused on DEI, initial actions taken by the committee include creating a department DEI website [60] to highlight the diversity within our community, to give community members a way to get involved, and to provide means for community members to anonymously report incidents to the CEE DEI committee.

The committee has developed an extensive list of goals and actions that will be implemented in the coming months and years. While the committee will focus on implementing the actions in the strategic plan, we plan to be responsive to the changing environment to ensure that all members of our community feel welcomed, heard, and respected.

4.0 Preliminary Results

As with many universities, our DEI efforts, although long overdue, are still in their infancy. That said, through our university's center for teaching excellence and educational innovation (herein called "Center"), we have been able to develop a suite of mid-semester feedback channels that provide rich and important qualitative data. We have initiated some survey experiments to see if student social justice attitudes change throughout the duration of the course. We will shortly report these insights for the previously aforementioned classes.

However, before proceeding, we must caution the reader not to over-glean insights from these early-stage evaluations. Using course-based metrics to judge social justice initiatives as "successful" makes a value judgement that prioritizes student satisfaction in these efforts, at the expense of DEI's intrinsic and long-term value. For many students, DEI emphasis may initially seem distant and disconnected to the more technical considerations that dominate our engineering work. In fact, when required, students may even bristle at such initiatives, leading to lower satisfaction and engagement rates. Thus, we emphasize that these evaluative tools are best used not to assess overall satisfaction but rather to infer whether students are retaining the learning objectives or spirit that the instructor seeks to convey in these social justice initiatives. These goals inevitably prioritize more qualitative data that better captures such complexities over quantitative metrics (such as faculty course evaluations) that cannot adequately unpack these particular pedagogical innovations. As such, we provide these preliminary and qualitative data to shed insight on how students seem to benefit from discussions of social justice and DEI issues; we do not ascribe normative value to these data.

4.1 Computational and Data Science for Civil & Environmental Engineering

Mid-semester evaluations yielded the following feedback related to DEI initiatives within the course. "GTKACSE ["Get to Know a Computational Scientist or Engineer!"] is very informative." "It's great to learn about people I'd never heard about before." "Office hours and one-on-one support… is a great resource." "It's so helpful to be able to talk through things any day of the week."

Within these mid-semester evaluations, 14 students (out of 30 students in total) referenced the positive impact of expanded support resources. Four students specifically referenced the biographical profiles of women, people of color, and non-cisgender/heterosexual individuals as a positive feature of the course.

Although no formal data were collected, we also note that there was significant after-class and office-hours engagement with each module of techno-social content. For example, after an in-class lecture on eigendecomposition, singular value decomposition, and image compression (which included discussion about and demonstrations of the ways in which seemingly innocuous choices of cutoff in the eigenvalue spectrum can adversely affect the compression of images of individuals with certain skin tones), 12 students sought out further discussion on this topic with the instructor. In general, we believe that robust out-of-class engagement with DEI-centered subject matter indicates strong student interest in, and receptivity to, our DEI efforts.

4.2 Introduction to Professional Communication in CEE

Students completed an anonymous mid-semester evaluation facilitated by a teaching consultant from the Center. Comments about the classroom culture reflected the efforts on creating an inclusive environment, especially while conducting class in a hybrid environment due to the pandemic. Casual daily interactions at the start and end of class helped to provide all students with a welcoming place to share their views.

> Andrea is very thoughtful and always checks in on everyone, and we appreciate the beginning-of-class chats we always have.
>
> The class setting is great. Being able to feel like we're having discussions and joke around is nice and makes it feel more welcoming. The class is very good right now, especially compared to other classes. The vibe is friendly and it makes it feel like we can have and express our personalities in the class.
>
> Because I'm taking the course asynchronously, I watch lecture recordings and Andrea's greetings and constant communication by referring to me by my name made me feel like I'm in the class despite being halfway across the world. Also, Andrea has constantly sent me emails to describe what happened in the class, to give additional information I'd need, and to check how I'm doing. Andrea has been extremely welcoming, inclusive, and supportive.

In an evaluation after the course ended, students reflected on their overall experience with the classroom culture.

> Andrea is so kind and always made sure to check in on us and make time for conversation about our lives before each class. She was very realistic with expectations of the course, and always had our wellbeing and learning as her first priority. She took many measures to make sure that the remote students, including those in different time zones, felt included and got a lot out of the course as well. I like how Andrea encouraged collaboration between students of different class levels, and I feel that everyone in the class made new friends and connections as a result. This class was overall such a joy to be a part of and I learned so much!
>
> I will try to make this short, but this was far and away my favorite class this semester. I learned valuable lessons, got to write about thought-provoking topics, and thoroughly enjoyed my class members and got closer with them each week. Andrea was so thoughtful, especially through the loss of a family member. I am so thankful that I took this class- it made me think in a different way about how I present my information to a given audience, and highlighted to me that I am someone who likes to question things in curiosity and absorb more information.

4.3 Environmental Engineering

In the junior-level, required (for CEE graduation) Environmental Engineering course, changes were made to reorient water chemistry content (about ⅓ of the course) around the Flint water crisis. About half-way through the semester, on a midterm exam, students were asked to identify a single positive and negative aspect of the course so far: “What have you liked so far this semester about 351? What could be better about 351?”

Students earned one extra credit point for answering each question (on an exam out of 75 points).

There are 32 students in the class, and 31 completed the extra credit questions. Eight students explicitly mentioned learning about the Flint water crisis and/or environmental justice as what they have liked. An additional student did not explicitly mention Flint or environmental justice, but did single out the course's interdisciplinarity. No students identified anything connected to the reorientation as a negative.

4.4 CEE Capstone Design

In a post-course survey, students emphasized that they believe it is imperative to address social justice concepts and issues related to DEI in the engineering curriculum:

> It's important because engineers have a large social responsibility due to our work in communities, especially civil engineers. To not address the issues of social justice, diversity, equity, and inclusion would be setting students up for possible failures (with regards to these values) in the future.
>
> Engineers develop infrastructure and systems that inherently affect everyone. We incorporate existing social biases into our design and help make them become systemic biases.
>
> If engineers are not educated on social justice issues, they will build systems that perpetuate injustice and inequity.

The majority of students believe that including social justice concepts in engineering classes helps their learning because it helps them to realize that they are designing for people. It can also help them to understand how they can create systems that serve everyone, not only the people who look and think like themselves. While some students felt that addressing social justice had little effect on their learning, no students felt that it impedes their learning.

When asked how working on a design project to benefit an underprivileged community impacted their learning, students shared that they appreciated that their work was going toward a useful pursuit and that it helped them to understand what underprivileged communities are looking for from engineers. They also expressed a desire to learn more about the community's history and needs so that they could better understand how their work could impact the community. They also stated that they did not get to interface directly with the community.

4.5 Civil Systems Investment Planning and Pricing

In the first mid-semester evaluation the students commented that "jumping to social justice concepts before fully grasping a handle on the technical material is confusing," with many reporting difficulty dealing with the weight of heavy social justice topics amidst a pandemic. Following this evaluation and the first homework assignment the instructor reframed class examples to include social justice framing. During the class examples she provided feedback on the trade-offs made between different engineering and investment decisions as well as reminding the students that there were no perfect answers.

In the second homework there were higher levels of cognitive thinking among the student answers, with many highlighting the pros and cons of different investment decisions. These preliminary results highlight the value of in-class guidance for improving the problem-analysis skills of students.

While there were higher levels of cognitive thinking, many students commented about the difficulty of the prison labor question, because often Company X provided a service that would benefit disadvantaged members of the community. For example, Company X might have built vans for disabled populations, or tiny homes for homeless youth. In the mid semester evaluation minority students highlighted the extra burden they were placed under when the social justice questions centered on their communities. Following these comments the instructor included a broader range of social justice concerns (e.g., immigration ploicy, undocumented workers, displacement of rural communities by hydroelectric facilities) into the homework assignments and class examples. In the end of semester exam the instructor gave the students the following prompt:

> Assume that you are working at a water pipeline company, which monitors water and sewage flow. You need to decide where to invest some of your company's money. There is uncertainty about how many people will be impacted by different investments, the risk of lead and harmful chemicals leaking into the pipes, the final costs of different investment strategies, and many other factors. To help you with this decision a team member has created some models of how your investment would impact company profits. How would you evaluate the suitability of the economic and decision models for informing your decision? If it helps you can think of the water pipeline company as a Firm operating in Flint Michigan, who needs to think about how to invest in making sure clean water gets to your customers.

While the students were not directly asked to evaluate the social justice implications of the different investment decisions, the instructor found the majority of students (69%) in the class showed some level of bloom's taxonomy thinking. Figure 1 shows the class breakdown of social justice thinking by the class. This is a sharp improvement from the first homework when the instructor found that only 17% of the class mentioned social justice in their homework assignment, which explicitly asked them about the impact of their analysis.

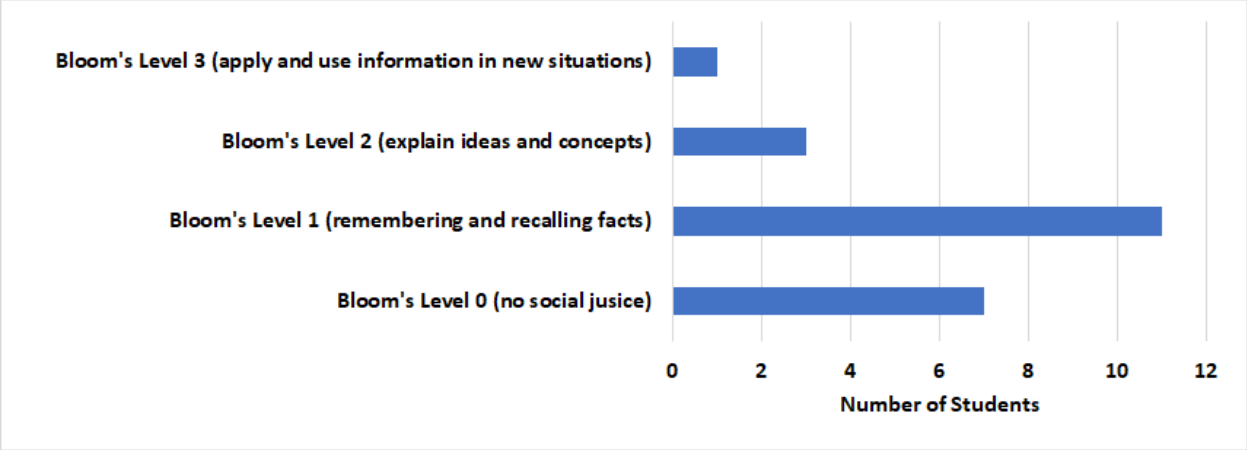

Figure 1. Where student's exam answers fell on the Bloom's Taxonomy scale for cognitive thinking about social justice at the end of the semester, when unprompted.

While a few students complained that the course was overwhelming and the social justice topics too complex, the instructor received overwhelmingly positive feedback about the course in her FCEs with the students (N=18) rating the overall quality of the course a 4.39 out of 5. In the comments one student wrote, "I wish all my engineering classes included as many social justice examples as this class did. I learned a great deal and always enjoyed attending (virtual) class because Professor Nock is full of energy and makes learning enjoyable."

4.6 Engineering and Social Justice

From early course feedback from our university's Eberly Teaching Center, we are able to glean several insights not just for this course but for how to incorporate social justice material into one's curriculum.

First, students seem to particularly pay attention to not just the course content but also the sensitivity and care through which the instructor conveys such content and facilitates discussion. For example, here are two indicative examples:

> The follow up on information and individualized attention to students is incredibly beneficial. This care and attention to students makes students want to do the readings and show up to class. For a couple of us, the structure and care has made us actually do the readings and participate in ways we haven't before.
>
> We appreciate that Professor Armanios is really understanding and recognizes how touchy/sensitive the topics are. We do feel like we are in a safe space! We appreciate how often he asked for feedback (even at the start of every class) before this evaluation. We love the class!

Second, the need to accommodate and even encourage non-traditional assignments. Given social justice is a complex concept that intersects technical and social issues, conveying that even in written form is not always clear. Therefore, encouraging even more audiovisual forms of assignment delivery seem to resonate with students. For example, here is one indicative quote:

> We've never been encouraged to express our ideas artistically in a STEM-focused space before.

However, the other side of this issue is that it is not quite clear what is expected in the assignment deliverables. As some students noted:

> Sometimes it was unclear if the reflective questions/personal writing prompts had to be answered with class readings instead of only personal experience.

As such, the instructor has tried to make rubrics clearer for both traditional essay writing assignments, as well as non-traditional forms. He has also tried to post anonymous exemplar assignments to clarify what is hoped from these exercises. That said, more explicit rubrics, especially for non-traditional assignments are likely needed in future course iterations.

Third, there is debate amongst engineering students as to the degree to contextualize and situate readings. On the one hand, with careful curation of readings that are in tractable language, there is less need for contextualizing the importance and insights of the reading materials. As some note:

> We like the balance of academic literature and book chapters/other reading types.

> We like the readings and how they tie in with the lecture's overall theme. And that the lectures are not repetitive with the readings.

However, for some students, especially younger students who have not yet grappled with these issues, this scaffolding may not be adequate and so a minority of students did ask the instructor to incorporate more lectures. Thus, the balance that seems to work for this instructor is to use the first 15 minutes to explain why the reading was assigned, its key findings, and its methods. Then, he situates the material in more general issues in the present-day before segueing into discussion, and then finally, recapping the key takeaways. This was noted in the following:

> Professor Armanios takes the first few minutes of class to synthesize the readings and draw connections to past topics we've covered.

This was especially the case with methods as many of the methods used in identifying social justice issues, even in engineering, require understanding of how social science methods operate as this quote indicated:

> It would be nice to have some more resources about social science methods for people who do not have a background in social sciences.

To address these issues, the instructor built a PowerPoint primer slide deck of how to read typical social science methods output as well as their aims to provide additional scaffolding for the class. He also explained the intuition underlying these methods in class to further instantiate these points.

Fourth, given the sensitive nature of the topics covered in this class, welcoming numerous varied forms of participation have been noted as especially helpful to students. This is observed in that certain students seem to prefer certain forms of participation. A set of students prefer private messages via our Zoom platform directly to the instructor for which he synthesizes in an anonymous way. Others prefer discussion posts used through our online Canvas course platform. Others seem to enjoy more in-class comments and public chats. Thus, one unknown is how this can be encouraged when this class goes in-person and not virtual following the pandemic. In particular, how to facilitate in-class anonymous contributions as is done virtually through Zoom is unclear and will be something to carefully consider in the second iteration of this course. Moreover, some students felt a greater sense of community would be possible if there were some assignments that were group-based, which the instructor is hoping to instantiate in the next iteration of this course.

5.0 Future Work and Areas for Improvement

The work here presents the case for integration of social justice topics into engineering curricula. There is a strong need to have a deeper integration of social justice with engineering curricula in order to ensure that students are able to make social justice and economic trade-offs when evaluating engineering decisions. In order to have a strong connection with social justice topics, the students also need relevant, timely examples.

Our methods for integrating social justice into classrooms span tools for increasing cognitive thinking among students, and heightening representation of diverse scholars. In the Civil Investment Planning and Pricing class we instituted methods for increasing the Bloom's Taxonomy level at which students evaluate different engineering investment decisions. The instructor found that a broad range of social justice topics meant that there was limited depth in any one area, but this reduced the burden on minority students who felt overwhelmed by diversity and mass incarceration social justice topics. In one class period she used the federal highway system as an example, but many students viewed this as outdated and did not feel like this was a piece of infrastructure they would be able to influence one day. This highlights the need to connect historical injustices with current day decisions. One possibility is to use energy infrastructure since this is highly linked to climate change, which many of the students had a strong interest in. In order for more instructors to incorporate these topics into their classes we need to have modular activities that instructors can use as a one off, or series of activities, (ex. [61]. This could be used to promote interest in engineering within diverse groups, and solidify concepts, particularly in global learners.

We also recommend that there be an inclusion of diverse scholars and calls for including diverse perspectives in infrastructure decision making. Because engineers impact the world in profound ways, they need to understand how their technology impacts people, and they need to learn to recognize who is not at the table when making decisions.

Whatever the specific engineering context, students will benefit from more awareness of the contributions made by non-white/non-male-identifying engineers and scientists. One modest approach to recognizing the role of diverse individuals to advancing engineering and science was implemented in our CEE undergraduate- and graduate-level environmental microbiology course. The instructor acknowledged that still today almost white male contributors to the field are

almost exclusively recognized. To address an assignment was added where students identified prominent non-white/non-male-identifying individuals who have contributed to the advancement of the field. Students identified a broad array of prominent engineers and scientists, including: William Augustus Hinton, who helped design a syphilis diagnostic test and was the first African-American professor at Harvard Medical School; Sally Chisholm, who discovered the ocean's most abundant photosynthetic organism, *Prochlorococcus*, and is now a professor at MIT; and Alice Catherine Evans, who discovered the threat of unpasteurized milk in the early 1900s; among many others.

If we want our engineering graduates to avoid the mistakes that past generations have made we need to give them realistic problems that require them to consider equitability when making design choices and we need to provide them with a set of tools to do so effectively. Tools and frameworks need to be developed and integrated into the design process. When community-based projects are assigned, an emphasis needs to be made on learning about the community's history, social injustices that have impacted the community, current needs of the community, and different members of the community who will be impacted by the design. We believe that this learning will be most impactful if students are given the opportunity to visit the community and meet first-hand with community members.

We hope that this paper can provide a source of inspiration for how instructors can incorporate social justice into their curriculum, in an effort to promote the development of socially conscious engineers.

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