Social Justice within Civil and Environmental Engineering: Curricular Interventions and Professional Implications

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Around the United States (U.S.), the state of infrastructure needs improvement. The 2021 American Society of Civil Engineers (ASCE) report card gave US infrastructure a C- rating [1]. ASCE reports that in the U.S., a water main breaks every two minutes, 43% of U.S. roads are considered poor or mediocre, and overall the infrastructure Americans rely on every day is out dated and failing [1]. For civil and environmental engineers, failing infrastructure presents an opportunity to incorporate new ideas and design infrastructure better suited for the future. To meet this challenge, engineers need to be able to examine the past, understand what has and has not worked, and how to approach design to prevent future failures.

Within the context of civil and environmental engineering, failure has come at a high cost to the people who rely on infrastructure systems that no longer work. Though the current mediocre state of US infrastructure is mostly due to age, U.S. infrastructure has historically failed some of the people that it is built to serve. By not considering all people in a community when designing the infrastructure, engineers often incorporated their own biases, thereby reinforcing social norms and making it more difficult for people who were already marginalized to exist in the built environment.

Examples of such infrastructure projects can be seen throughout US history. Around the US, landfills, wastewater treatment plants, and industrial waste sites have commonly been placed in low-income communities of color [2]. These sites often place a burden of harm on the people in that community, reducing their quality of life and potentially exposing them to high levels of air pollution, polluting their water sources, and making parts of the community unusable [2]. A 1983 report stated that all six of the City of Huston's garbage dumps were placed in Black neighborhoods, though only 25% of the Huston population was Black at the time [2]. Another more famous example is the area of Louisiana known as Cancer Alley. The 85-mile area along the Mississippi River has a majority Black population and is home to 14 major manufacturers [3]. People in the area are frequently exposed to high levels of toxicity and are noted to have a shorter life expectancy, as many community members die younger from cancer [3]. These are just two examples; this type of dumping occurs in neighborhoods of color throughout the US [2].

Along with being exposed to solid and hazardous waste, communities of color in the US are exposed to higher levels of air pollution [4]. Black and Hispanic people in the US experience 56 and 63% more exposure to fine particulate matter than white non-Hispanic people [4]. This inequity can be attributed to the placement of point source emitters (such as power plants) and non-point source emitter (such as freeways) near communities of color. As of 2019, one out of ten power plants are located on Native American land in the US. In the late 20th century in New York City, nine of the ten bus depots for the City were placed in Harlem, a predominated Black neighborhood [2]. With the increase in air pollution the people of color in the U.S. are exposed to, they are also three to four times more likely to die or be hospitalized for asthma [2].

Beyond polluting vulnerable populations, infrastructure can also be built in a way that excludes certain people. An infamous example of injustice in engineering projects is the freeway system from New York City to Long Island that was built with bridges too low for busses to pass,

making it harder for low-income people in the city to make it to the beaches of Long Island [5]. Throughout the 20th century, the practice of redlining, or drawing red lines on maps to indicate neighborhoods that were "higher risk," motivated mortgage lenders to be less likely to invest in those areas [6]. Usually, risk was determined by the predominant skin color of that neighborhood; this practice made it difficult for many people of color, especially Black Americans, to gain wealth, keeping these populations in poverty [6]. Even today, formerly redlined neighborhoods continue to be economically disadvantaged and primarily minorities [6].

Infrastructure has also been built in ways that erase communities. Around the U.S. the development of water infrastructure came at a high cost to indigenous nations as the land occupied by many indigenous communities was flooded to build new dams [7]. For example, to build the Grand Coulee Dam on the Columbia River in Washington in 1940, approximately 21,000 acres of land of the Confederated Tribes of the Colville Reservation was flooded, including sacred sites and cemeteries, and people living on the land were forcibly removed [8]. In CA, large water projects moved water from areas of the state that have access to surface water to the Los Angeles metropolitan area and large farms, leaving communities dry that once where rich with water, such as the Owens Valley. These projects do not serve the small communities through CA housing farm workers and other necessary laborers around the state, leaving them to depend on well water [7].

Though issues with injustice may seem like a past problem, without understanding how and why these problems were built into engineering designs, addressing the impact engineering projects have had on communities, and changing the way engineers design new products and systems, such injustice may perpetuate.

Professional engineers have begun to recognize and advocate for the need to address social justice and community impacts in engineering in new infrastructure projects. As professionals, engineers will be expected to manage both technical and social dimensions of projects [9]. Working on projects that generally directly impact the public, civil and environmental engineers are in a unique position to impact communities. Recently, intersections of social justice and engineering have become a talking point in engineering communities. ASCE ran a series of articles focusing on issues of Equity and Infrastructure, discussing opportunities for engineers to impact equity and describing equity initiatives in engineering [10]. One article notes how important it is to start with education [9]. Social justice was also made a center point for the 2021 Biden Infrastructure plan, which promised "40% of the benefits of climate and clean infrastructure investments to disadvantaged communities" [11]. These initiatives further the push for engineers to consider how engineering projects can serve both the technical requirements they are designed for and the communities they are built in.

Understanding the social aspects has traditionally come with professional experience; however, giving engineering students an understanding of the social elements during their time in school can encourage early development and implementation of this understanding [9]. Unfortunately, studies suggest that, as students progress through a typical engineering program, they tend to

become more disengaged in social issues, and this disengagement is seen to persist into their professional careers [12] [13] [14]. Lack of engagement around social issues can cause situations of environmental injustice to be perpetuated in engineered systems [12]. Still, in many engineering programs, "engineering neutrality" in design is a defined part of the curriculum, and students are explicitly taught to depoliticize their engineering solutions [15]. By depoliticizing engineering, students focus only on the technical aspects of a project and not the social implications. This pedagogical choice ultimately negatively impacts the engineering profession.

Focusing on social and environmental justice in engineering education can also be a tool for engineering design to develop better products by inspiring critical thinking. Considering justice ideas prompts engineers to develop socially-focused principles in the context of their engineering training, which leads to more creative solutions to implementing projects to better serve communities [16]. There have been many initiatives to encourage students to engage with social justice, ethics, and empathy focused material [17] [18] [19]. At the Colorado School of Mines, a program focusing on teaching engineering students' empathy through user emersion has seen students developing more thoughtful solutions that work better for a diverse public. The empathy focus expands students' ability to think creatively and their engagement in social topics more than a traditional approach [20]. This outcome shows how new design methods can help engineers build better products and systems. Similarly, they can also help engineers to build personal confidence. A study at Lafayette College found through emphasizing morals in the engineering classroom, students were more confident in their abilities to develop solutions in socially complex situations [21]. In another study at Loyola University in Chicago, it was seen that by including social justice topics across the engineering curriculum, retention rates of minority engineering students increased [17]..Students who have been negatively affected or seen their community impacted by an engineering project, may feel left out and disempowered when social justice topics are left out of engineering curriculum. Addressing the human impact of engineering throughout engineering education allows all students to be seen. By focusing so heavily on the technical aspects of engineering, curriculum may unintentionally teach students that the social aspects of a project are less important while also devaluing the understandings of students who may have experienced injustice due to past engineering projects. These teaching practices may also discourage students from seeking out better solutions for all people and stakeholders [15].

Methodology and Assessment

This study focuses on how the addition of social justice ideas to the environmental engineering curriculum may help students gain awareness of infrastructure inequity, improve empowerment and engagement in their engineering educations, and develop perspective on social justice opportunities in their future professional practice. Inspiration for this study came from a study at the Worcester Polytechnic Institute (WPI) [18]. In the WPI study, students engaged in role playing as different members of a community throughout the design process of engineering a sewer system, with the goal of showing students the complexity of designing in a diverse community setting [18]. The WPI study used a variety of data collection methods to assess

student learning, including a survey. The study found that combining the teaching of engineering design and socio-economic parameters in one class was effective [18].

This study was also directly inspired by a student-led initiative at California Polytechnic University, San Luis Obispo (Cal Poly SLO) during the 2020-2021 school year, as a reaction to the Black Lives Matter movement in spring of 2020. The student initiative worked to critically reflect on how social and environmental justice is portrayed within the civil and environmental engineering curriculum and inspired faculty to consider changes to the curriculum through emphasizing the importance of equity and sustainability through program learning objectives. The student's push to reevaluate how engineering is taught prompted this research into the potential impacts that the addition of social and environmental justice instruction could have on civil and environmental engineering students.

To determine the effect social and environmental justice focused instruction could have on environmental engineering students, a new instructional module was developed for the first-year introductory environmental engineering class, in conjunction with the course professor, and a survey was administered to students before and after the instruction. The survey was designed to determine whether adding social justice curriculum to an engineering class can help increase students' understanding of social justice, awareness of social and environmental justice issues, and awareness of the implications of social justice to their future profession. Four iterations of the instructional material and survey were delivered over four years (Fall 2020 through Fall 2023). Iterative improvements to the survey and the social justice instructional were made between each year.

Social and environmental justice focused instruction was delivered in the form of one two-hour interactive lecture and discussion. The first-year class is intended to introduce students broadly to the field of professional environmental engineering. A lesson was developed to introduce social justice topics by presenting ways environmental engineering can impact disadvantaged communities.

In Fall 2020, all classes were held online over Zoom due to the COVID-19 pandemic. In 2020, the class used two class sessions (2-hours each) to cover the social impacts of engineering projects and initiatives in two different aspects of environmental engineering: air quality and water quality. The classes were structured to encourage student discussion and interaction, with an activity in the second half of class. The same class structure of lecture followed by activity was used in 2021; however, only one class was dedicated to social justice discussions, and classes were held in person. The air quality aspect was removed in the second year, and the class engaged in a general discussion of environmental injustice and a water-focused case study of Tooleville, a disadvantaged community in Central CA. In 2022 and 2023, the lecture material was broadened to include discussion of three economically disadvantaged communities around the US, all facing water-related challenges: Jackson, MS and Flint, MI, as well as Tooleville, CA. In 2020 and 2021, the instruction was provided by a graduate student who developed this research. In 2022 and 2023, the instruction was provided by the graduate student's advisor as a

guest instructor to the introductory class. All four years included explicit discussion of the terms social justice, environmental justice, equity, equality, and stakeholders. The case study or studies provided context for discussion of terminology.

In 2020 and 2021, after a presentation on the community, the students were divided into stakeholder groups (Tooleville residents, residents of a nearby economically comfortable community, and the government oversight agency) to talk about the needs of their assigned stakeholder group how they could work to address these needs. After talking in common-stakeholder groups, students reorganized into groups with all stakeholder groups present to develop a potential solution together. The activity was designed to show the students the complexity of the issue and how different groups may be impacted by the final solution. The activity took a similar immersion format as was used in an experimental course designed to build empathy for first year engineering students at WPI [18]. In 2022 and 2023, students participated in brief small-group guided discussions after each case study with the goal of identifying questions (not solutions) they would ask if they were working with each of the communities involved. The goal of these discussions was to encourage students to develop skills in asking questions in context of community-centered challenges, without feeling pressured as first-year students to think of solutions. This change was based on feedback from students during the first two years that they felt overwhelmed and unprepared when asked to develop solutions.

A survey was designed for students to respond both before and after they experienced the social justice focused instruction. The pre-survey was opened a week before the social justice focused material was presented in the class, with students able to access it through their online portals until the start of the class. Students were then asked to complete the post-survey within two weeks after the class.

The survey included Likert scale questions to gauge students' understanding of social and environmental justice topics as well as how they think about engineering's impact on communities. A 5-point scale, like the one used in the WWPI Study, was used for all the Likert scale questions [18]. In 2020 and 2021, the survey also included a short "case study" question designed to see how students responded to a complex problem. Here, students were asked to choose between solutions and state why they chose the one they did as well as rank each of the solutions in terms of perceived equitability and feasibility. This combination of ranking and free response was based on the Engineering and Science Issues Test, a survey designed to determine the morality of STEM professionals [22]. Results from the case-study questions during the first two years proved inconclusive and student comments reflected their confusion in trying to respond to the case studies, so this part of the survey was dropped in subsequent years. Results of the case study responses from 2020 and 2021 are not included in this discussion. This study presents the results of the Likert scale questions, which were consistent across all four years of the study period. Values reported below are the averages for all responses, based on the 5-point scale defined for each question.

Results and Discussion

The social justice focused instruction showed an effect on the first-year environmental engineering students' understanding of social justice, their perspectives on equity in infrastructure, and their awareness of the potential impacts of their future profession. Similar to the WPI study, the instruction proved to be effective, with students engaged in the material during the lecture/discussion and showing increased understanding of the material and its implications for environmental engineering afterwards.

Likert questions of the survey were intended to gauge students' understanding on the role of environmental engineering in perpetuating or addressing social inequities in the past and present. The questions were deliberately vague to encourage students to ponder the question and potentially lead them to select an answer that was not absolute (not a 1 or a 5). Several questions focused on student considerations of equity issues at either local or global scales of impact. Figures 1 and 2 show student responses to the question "How much do you feel environmental engineering impacts local communities?" or "How much do you feel environmental engineering impacts global communities?" respectively. For each question, selecting a 1 indicated "No Impact" and selecting a 5 indicated "Impacts Everyone".

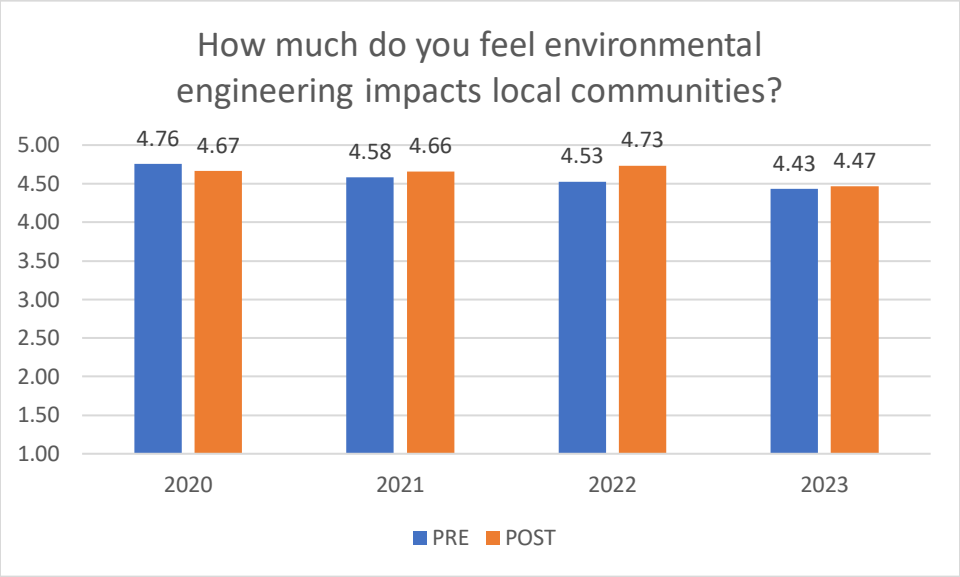

Figure 1. How much do you feel environmental engineering impacts local communities? Selecting "1" indicates "no impact" and "5" indicates "impacts everyone." [2020 PRE n = 33, POST n = 6; 2021 PRE n = 55, POST n = 56; 2022 PRE n = 74, POST n = 60; 2023 PRE n = 74, POST n = 64]

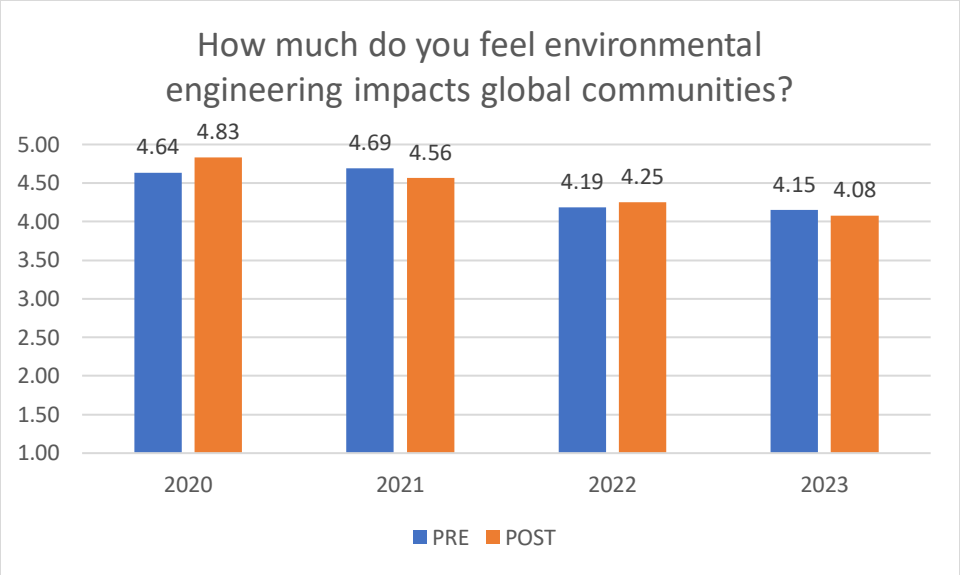

Figure 2. How much do you feel environmental engineering impacts local communities? Selecting "1" indicates "no impact" and "5" indicates "impacts everyone." [2020 PRE n = 33, POST n = 6; 2021 PRE n = 55, POST n = 56; 2022 PRE n = 74, POST n = 60; 2023 PRE n = 74, POST n = 64]

Responses to both questions were similar across all four years of the study. Average responses for both a local level and a global level were high (>4), indicating that most of students understand that engineering projects impact all people even prior to the social justice focused instruction. At the local-scale level, the pre/post response did not change appreciably before and after the instruction, though post-instruction responses did show a slight increase in later years. When considering impacts on a global scale, there was also very little change after the instruction, and no trend up or down in average response score across the study period. It is worth considering that the social justice instruction was focused on small communities within the US, rather than across the globe. This result may reflect first-year students' limitations in transferring instruction to larger contexts, or perhaps that first-year students typically have more limited awareness or consideration of world events [23].

On the questions asking who benefits from engineering projects, choosing a 1 indicated "Wealthy Community" or "Developed Country" and choosing a 5 indicated "Disadvantaged Community" or "Developing Country" (Figures 3 and 4, respectively).

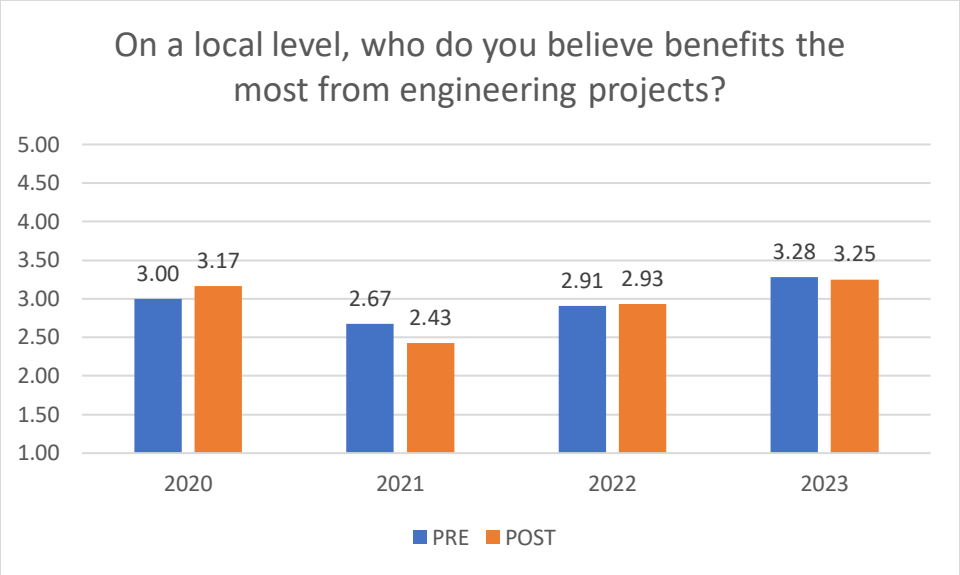

Figure 3 Access to clean environments is available for all people in the US. Selecting "1" indicates "wealthy community" and "5" indicates "economically disadvantaged community." [2020 PRE n = 33, POST n = 6; 2021 PRE n = 55, POST n = 56; 2022 PRE n = 74, POST n = 60; 2023 PRE n = 74, POST n = 64]

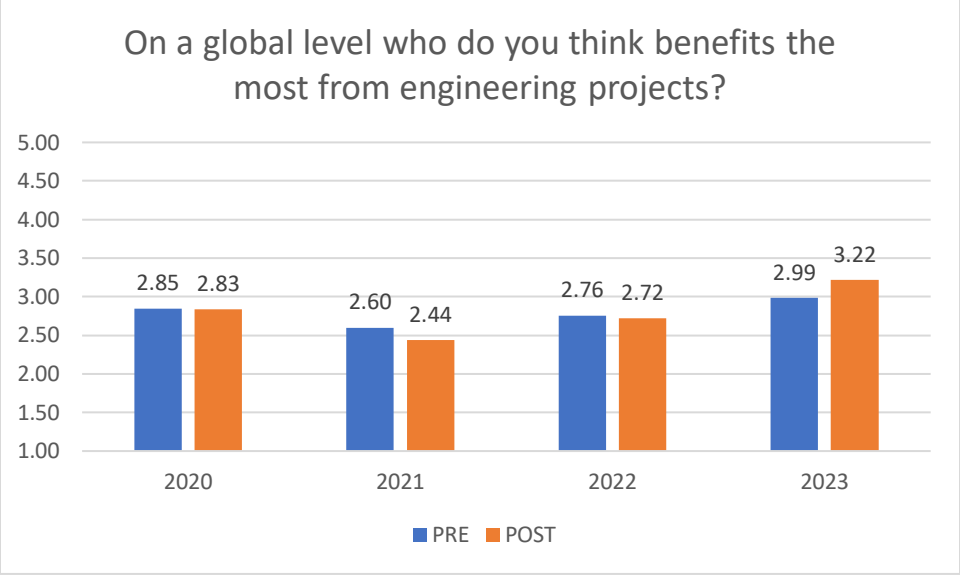

Figure 4. Access to clean environments is available for all people in the US. Selecting "1" indicates "developed countries" and "5" indicates "developing countries." [2020 PRE n = 33, POST n = 6; 2021 PRE n = 55, POST n = 56; 2022 PRE n = 74, POST n = 60; 2023 PRE n = 74, POST n = 64]

For both local and global scales, students tended to choose answers that were more central, with average values close to 3 for all responses. Answers trending toward the center likely suggest students had lower confidence in their answers and wanted to select an option that seemed "safe." Comparing local to global scale responses, global scale responses tended to be slightly

lower, suggesting a trend toward engineering projects favoring developing countries. These responses may be due to messaging many young engineers receive, of engineering being a tool for sustainable development and technologic advancement locally and in other countries [24]. Collectively, these results suggest an opportunity to more explicitly address the social justice question of "who benefits and who pays" for infrastructure projects, across both local and international scales.

Likert scale questions on whether people have access to clean environments were intended to gauge students' awareness of social and environmental injustice at different geographic levels, from worldwide, to in the US, and finally in California (Figures 5, 6, and 7, respectively). For these questions, students were asked if they agreed to the statement, "All people [on Earth/ in the US/ in California] have access to clean environments." Choosing a 1 indicated "Strongly disagree" and choosing a 5 indicated "Strongly agree."

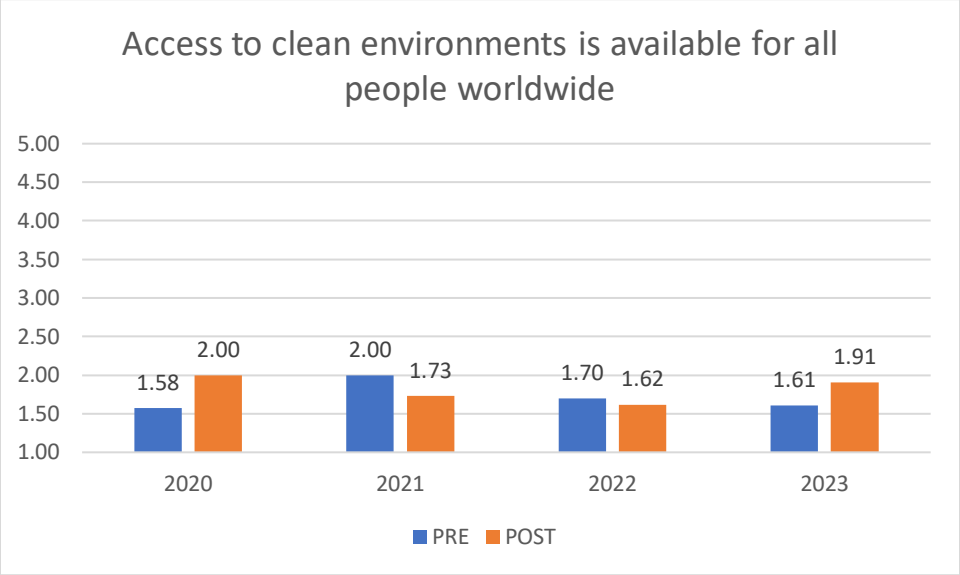

Figure 5. Access to clean environments is available for all people worldwide. Selecting "1" indicates "strongly disagree" and "5" indicates "strongly agree." [2020 PRE n = 33, POST n = 6; 2021 PRE n = 55, POST n = 56; 2022 PRE n = 74, POST n = 60; 2023 PRE n = 74, POST n = 64]

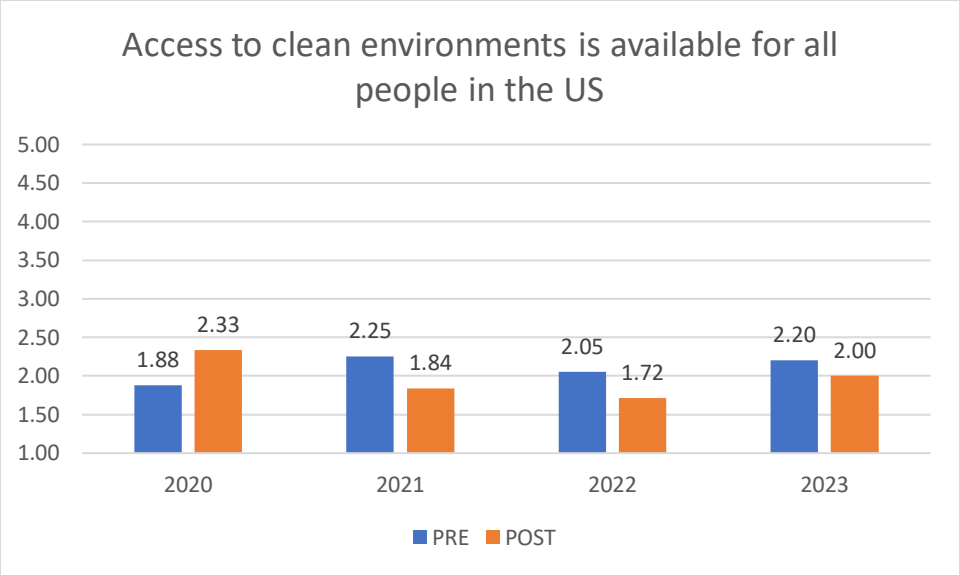

Figure 6. Access to clean environments is available for all people in the US. Selecting "1" indicates "strongly disagree" and "5" indicates "strongly agree." [2020 PRE n = 33, POST n = 6; 2021 PRE n = 55, POST n = 56; 2022 PRE n = 74, POST n = 60; 2023 PRE n = 74, POST n = 64]

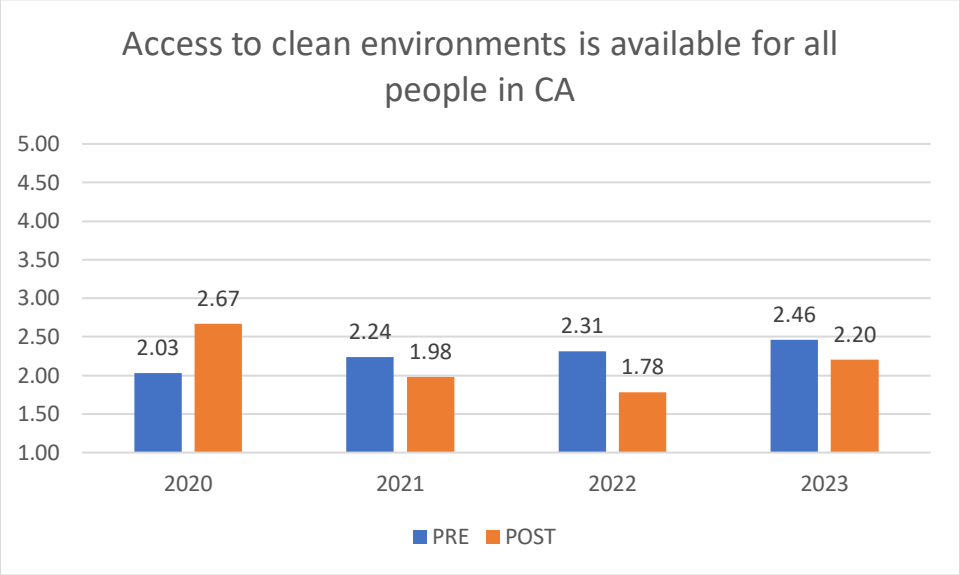

Figure 7. Access to clean environments is available for all people in CA. Selecting "1" indicates "strongly disagree" and "5" indicates "strongly agree." [2020 PRE n = 33, POST n = 6; 2021 PRE n = 55, POST n = 56; 2022 PRE n = 74, POST n = 60; 2023 PRE n = 74, POST n = 64]

In general, responses leaned toward disagreements with these statements, with all average responses less than 3 for both pre and post instruction surveys, across all 4 years of the study. No consistent trend was found in the pre/post responses to the "on Earth" question. However, there is an apparent trend in the post-instruction responses for 2021 – 2023, in both US and CA, that students became more aware of inequity after the instruction. Again, the instruction focused

on either a single community in CA or several communities across the US, rather than any international communities, so this may explain the lack of change for the post-instruction response for the global scale.

A trend in the pre-instruction surveys was slightly higher agreement that people have access to clean environments in the US and CA than globally. This result suggest that students may have a stronger feeling that there is inequity in access to clean environments in areas farther from where they live, supporting the idea that first-year students are less aware of injustice happening near them [25].

Together, these data sets may indicate different perspective between local and global environments that may be influenced by how students interact with local and global engineering projects in school. While local projects that are presented are often from industry professionals to both network with and help educate students, global projects that students often engage with come from non-profit organizations that focus on engineering in communities in need in developing nations, such as Engineers Without Boarders [24]. By not engaging with global for-profit projects and local non-profit engineering, engineering students may have only one view of engineering on these scales. By being presented with single story narratives, students' ability to think critically may be limited [26] [27]. Though they may be aware of injustices on a global scale, students may be unaware of the marginalized voices around them. These results reflect the single-story narrative students often received that developing nations need the help of western engineers [28]. This type of single story can be harmful when students do work on a global scale, as engineers may not understand or respect the local technology and knowledge that people in a different country may use [28]. Moreover, it is also important for engineering students to be aware of the injustices in their area. Most students will likely go on to work for engineering firms and government agencies in their own state and will be were unaware of different levels of injustice experienced within communities that they interact with, without specific instruction to address this knowledge gap.

Two questions addressed students' thoughts on the potential for environmental engineering to impact social justice. Students were asked whether they felt environmental engineering was more focused on human environments, reflected by a score of 1, or natural environments, indicated by a score of 5 (Figure 8).

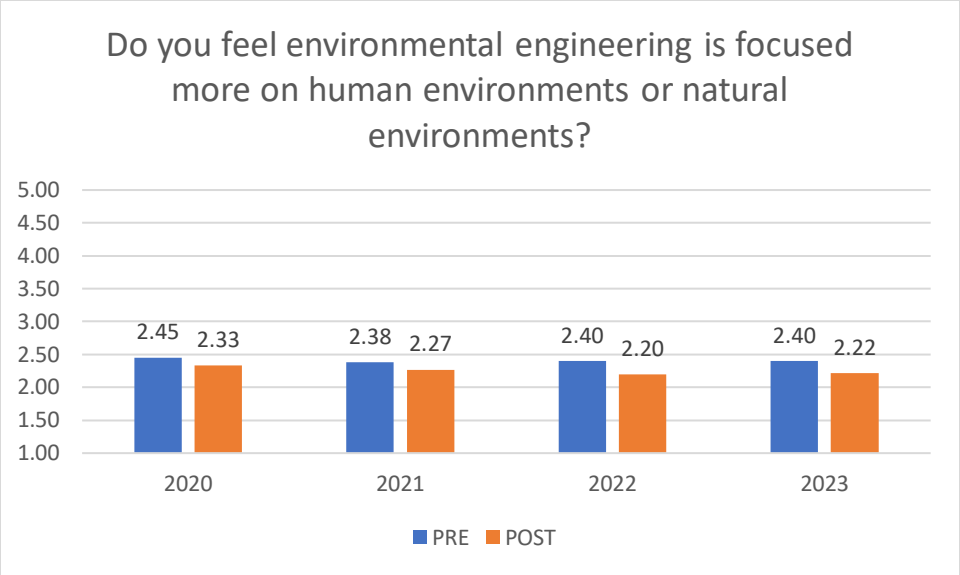

Figure 8 Do you feel environmental engineering is focused more on human environments or natural environments? Selecting "1" "human environments" and "5" indicates "natural environments." [2020 PRE n = 33, POST n = 6; 2021PRE n = 55, POST n = 56; 2022 PRE n = 74, POST n = 60; 2020 PRE n = 74, POST n = 64]

Pre-survey results skewed toward the center value (averages close to 2.5), possibly indicating that students were not confident in their answers, or perhaps that they felt or hoped that environmental engineering finds an effective balance between these two environments [23]. However, post-survey results showed a clear trend of increased consideration of human environments rather than natural ones, as all post-instruction averages were lower than pre-instruction results. This result could reflect some bias due to the socially-focused nature of the instruction, but, importantly, it emphasizes that social justice focused instruction allows students see the potential for their future careers to effect social change.

Students were also asked if they agreed that environmental engineers should work to provide access to clean environments. Selecting a 1 indicated "Strongly Disagree" while selecting a 5 indicated "Strongly Agree" (Figure 9).

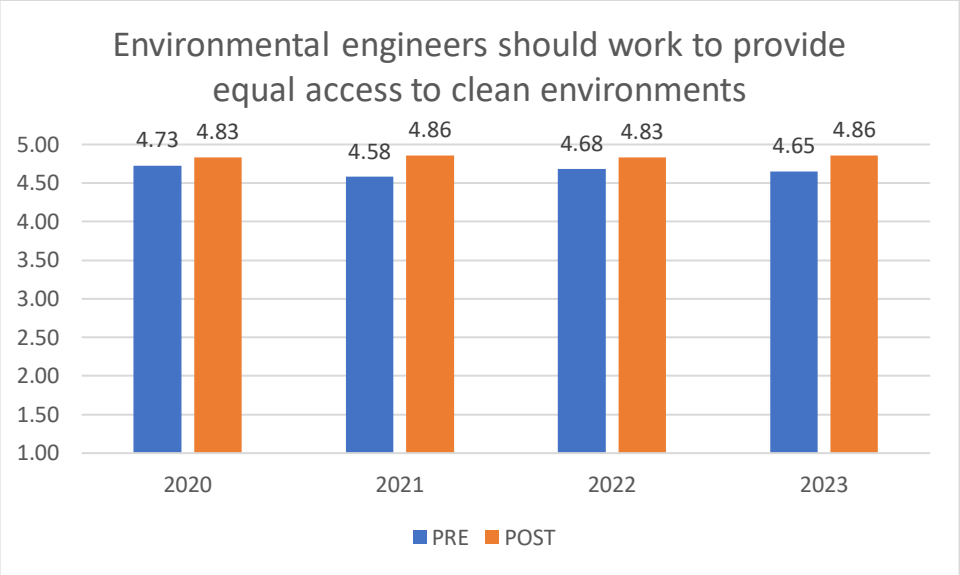

Figure 9: Environmental engineers should work to provide equal access to clean environments. Selecting "1" indicates "strongly disagree" and "5" indicates "strongly agree." [2020 PRE n = 33, POST n = 6; 2021 PRE n = 55, POST n = 56; 2022 PRE n = 74, POST n = 60; 2023 PRE n = 74, POST n = 64]

All four years showed an increase in agreement with this statement after the social justice instruction, though it should be noted that pre-instruction agreement was high. Environmental engineering students tend to select their major due to altruistic motives [23]. As social justice focused solutions offer a specific focus for this tendency, this is pre-survey result is not surprising. Further, the post-instruction response indicates that social justice may offer potential to counteract the disengagement often seen in engineering students, as the first years are becoming more empowered within their engineering curriculum. One of the main objectives of the social justice focused instruction is to give students a greater feeling of engagement in their work. The results show potential for this type of instruction to counteract some aspects of the culture of disengagement that is common among engineering students and professionals, as the first-year students were more concerned with accessibility after the instruction [12].

Implications for Engineering Education and Practice

The study shows the potential for positive impacts from social and environment justice focused education for first-year environmental engineering students. After working with the material, first-year students showed more awareness of the injustices in engineered environments around them, and they seemed more engaged in social issues. Though these changes were slight, the students only engaged with two hours of education on social justice topics regarding engineering before taking the survey. This shows further social justice focused education may strengthen engineering students understanding of social justice as it relates to engineering, their understanding of the impacts of engineering projects, and their ability to think critically about those impacts.

If a single instructional module in a first-year class can produce consistent improvement in students' awareness of equity and issues and opportunity for impact, it behooves socially-conscious engineering educators to incorporate such material more broadly into engineering education. To effectively consider social justice as an element of engineering design, theories for sustainable development, inclusive design, community outreach and the engineering design process should be considered and introduced in the classroom. New ways of thinking about engineering design can help civil and environmental engineers students develop the skills to design infrastructure that is equipped for the technical challenges of tomorrow and will meet the needs of people and the communities they are part of.

To better prepare future engineers, work has already been done to modify engineering curricula. ABET accreditation requirements for civil and environmental engineering programs have been updated to include sustainability as something that must be included in an engineering education. Many universities are also working to expand the curriculum even farther to include discussions of social and environmental justice and consider the ways that engineering systems may impact people and communities.

One such route is via the sustainability elements required by ABET. Formalized ideas of sustainable development and social justice within the engineering design process have been under development since the late 20th century. Much of this work has focused on designing products for diverse groups of people and ethical work in global conditions [24]. However, many of these ideas can also apply to engineering work on infrastructure within the US. The goal of sustainable development is to ensure that people are not disadvantaged in the future by the advancements of technology designed to meet current needs [29]. The ideas that are used to engage sustainable development in other countries can also be applied to local development. Sustainable development encourages greater communication with a community to avoid purely top-down engineering approaches [24].

Another growing approach to reconsidering traditional design is called Human Centered Design (HCD). HCD was organically developed by the tech industry to make their products more marketable by considering the needs and wants of individual product users; however, the concept has become a new way to frame the engineering design process, placing the opinions of the people an engineer is designing for at the center of the design process [30]. The use of HCD requires the engineer or designer to use empathy throughout the design process, listen to the needs of the users, consider their opinions, and reflect these into the design [31]. Though HCD offers a human-focused alternative to traditional engineering, it does not address the diverse needs of a community. HCD asks engineers to make a product or system better suited to individual people. For infrastructure projects, a system is implemented to serve a wide range of people in a community with diverse needs and opinions. Civil and environmental engineers can modify the HCD approach to adopt Community Centered Design (CCD). CCD acknowledges that infrastructure design requires consideration of diverse settings and the needs of the community as a whole rather than as a collection of individuals [32]. Too often, community impacts are only considered after the design has been developed according to the technical

criteria. Through the use of CCD, the design can be developed from the start with both technical and human criteria in mind. CCD emphasizes that both asking multiple community stakeholders what they need and observing how they interact with the system in question may be a better way to ensure the community feels heard and the engineer understands where improvements can be made to better fit the way people use a system [32].

Another approach to addressing sociotechnical problems such as equitable infrastructure design is to apply a Systems Thinking mindset. Systems Thinking encourages a problem solver to think not just about the issues in front of them but all the factors that are connected and may contribute to the overall problem [33]. This mindset allows a person to look at the design challenge as a piece of the whole or an element within multiple systems rather than as an isolated issue. Within engineering, ST encourages the engineer to consider how the product or system they are designing fits into the larger interconnected systems. For instance, a System Thinking approach would motivate an engineer to ask questions such as how infrastructure in one community connects to that of nearby communities, how a large infrastructure system connects to larger systems across a state, how infrastructure connects to natural systems, as well as economic, social, and political systems, etc. [33]

Another approach to improving equity in engineering solutions is inquiry-guided design. Because each community is unique and has its own set of circumstances, solutions to inequity must be uniquely designed to serve each community. By acknowledging that they are not the community experts but rather facilitators in the design process, engineers also acknowledge that they need to ask questions to begin a design [32]. Rather than telling people how things should be or can be, engineers should ask questions about what the people in the community want, need, are familiar with, and can envision. Only through such inquiry can appropriate and inclusive designs, systems, and products be produced. Engineers need to become skilled at asking questions that provide needed information on community understanding of the issue, background on the problem, context in which the engineer will be designing, and the infrastructure needs of the entire community. For instance, when approaching a project, Dr. Frederick Paige of Virginia Tech, makes sure to ask engineering students, “Who were the key stakeholders? Who were the people involved? What did it take to create this type of infrastructure?” [9]. For engineering students, the belief that there is always a “right answer” may contribute to the reproduction of bias by extinguishing creativity in potential solutions [24]. By starting with questions, rather than solutions, more creative and inclusive options can be developed. Learning to ask questions that lead to action is not often taught in schools, and it is a crucial skill for socially conscious engineers [34].

This research provided insight on how engineers can impact infrastructure projects to better serve the communities where they work and prevent infrastructure from harming members of those communities. Ultimately, engineers need to acknowledge they are not the sole experts in designing for communities, ask questions that may have multiple answer rather than one absolute truth, accept and respond to community input and feedback, always remain critical of their own

work, and acknowledge that the practice of engineering means they are in a constant state of learning. Developing that awareness is an important aspect of an engineering education.

Change in engineering to better consider equity and social justice is both important and possible, and it must begin with engineering education. Current students have already been advocating for more discussion on social and environmental justice in their curriculum, as evidenced at numerous programs mentioned herein, including Cal Poly SLO. During the social justice focused instruction in this study, students were generally excited and engaged in discussion. They developed ideas focused on both technical solutions and social considerations such as outreach to marginalized stakeholder groups. This material both engages them and empowers them to feel like they will be able to effect community change as professionals.

Students who were in the 2020 class that saw this material are now seniors. When asked how their subsequent engineering education and internship experiences have reflected social justice, several students noted that such instruction was present in later years primarily in the context of sustainability. In their internships with both public agencies and private firms, they are seeing social justice considerations become elements of project design – not predominate considerations, but present nonetheless. Seeing these design considerations in their professional futures, students continue to advocate for more equity-focused instruction. One senior noted "*It would have been helpful to discuss addressing social and environmental justice from the project management and planning perspective. And…within this course there should be discussion of how to implement steps to ensure a project is socially and environmentally just and navigating this conversation with a client.*"

Through intentional restructuring of the way engineering impacts are taught and moving social justice considerations into the classroom curriculum, we can better prepare engineers for the future. Through offering engineering students alternative ways of thinking about design, they may be more critical and creative in their professional lives, and more aware of the important role they can play in developing inclusive and just solutions. The ASCE magazine article on infrastructure and social justice notes how many civil engineers have begun to speak up. An engineer for the City of Springfield, Missouri notes how she is "empowered to insert myself into conversation where I can ask questions about what we are doing and what we can do to include equity in our planning process" [9]. By having discussions in their undergraduate education about community, equality, and inclusion as part of engineering practice, more engineers in the future may be similarly empowered to talk about social and environmental justice and ask difficult questions, combating injustice and designing a more equitable world.

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