Learning and Adopting Principles of Diversity, Equity, Inclusion and Justice through the Development of a Sustainability Mindset Among First Year Engineering Students

Abstract. Justice, Equity, Diversity, and Inclusion (JEDI) are important elements of a sustainability mindset. As part of an initiative to develop a new program in Sustainability Engineering at the University of Puerto Rico, Mayagüez, and to evaluate the growth of a sustainability mindset among participants, we performed a qualitative analysis of results from a cohort of first year students (5 men, 2 women) who completed a 1-credit JEDI seminar as part of their enrollment in the program. Based on coding student essays, we identified three themes that students expressed that indicate their development of understanding JEDI principles: (a) Diversity and Inclusion: Integration of Diverse Perspectives; (b) Equity, Justice, and Accessibility; and (c) Community-Centric Approach, although the evidence also suggests that not all students fluently apply these ideas in a problem-solving context. Overall, the results suggest that the 1-credit seminar is effective to build essential literacy of JEDI, which will be instrumental in future work in sustainability engineering and design.

1. Introduction

Justice, Equity, Diversity, and Inclusion (JEDI) are recognized as core components of education in sustainability. JEDI are essential principles of the UN Sustainable Development Goals (SDG's) (United Nations 2015) and intrinsic to specific SDGs (e.g., #5 gender equality; #10 reduced inequalities; #4 quality education). Indeed, "the SDGs recognize that addressing inequalities, empowering marginalized groups, and ensuring inclusive participation are essential for sustainable development…" (RELX, 2024, paragraph 6). Similarly, social equity is commonly recognized as one of the three pillars of sustainability, and appears as the fourth component of The Natural Step Sustainability Principles (The Natural Step, nd). These and other frameworks recognize the inherently deep connections between JEDI and sustainability principles and practices.

Recent studies have emphasized the need to integrate JEDI approaches into engineering and STEM education. Mehdiabadi and Atadero (2022) identified a significant lack of JEDI-related content in professional engineering societies, underscoring the urgent need to strengthen education in these areas to prepare inclusive and socially committed engineers. Armanios *et al.* (2021) highlighted how a curricular restructuring led to an increase from 17% to 69% in the incorporation of social justice concepts in students' final reflections, demonstrating the ability to include the social impact of engineering decisions. Similarly, Hess *et al.* (2024) emphasized the connections between ethics and DEI, identifying the need to integrate and unify strategies that enable engineering students to address both the social and technical aspects of their profession. Finally, Gupta, Talluri and Ghosh (2024) demonstrated the impact of inclusive educational programs in STEM, where a seminar and toolkit provided students and early-career professionals

with a safe space to develop inclusive communication skills while highlighting the structural barriers that persist.

This study aims to describe and highlight how a seminar focused on JEDI can strengthen the education of future sustainability minded engineers. Therefore, this work addresses the following research question: *how does a seminar focused on Justice, Equity, Diversity, and Inclusion within a sustainability engineering program influence students' learning and understanding of JEDI principles in sustainability?*

In this paper, we share a descriptive study of student learning in a JEDI seminar offered within a new sustainability engineering minor at the University of Puerto Rico, Mayagüez (UPRM), which is a public, Land Grant, Hispanic Serving Institution. First, we describe the setting and the development of the sustainability minor, followed by a description of the JEDI seminar. The study methods and analysis approach are presented next, followed by the results and discussion. Finally, conclusions and directions for future work are shared.

2. Setting and Description of the Sustainability Minor

UPRM has a large enrollment of nearly 5,000 engineering undergraduates, of which nearly 35% are women. The authors are part of an initiative to develop a new minor (curricular sequence) in sustainability engineering (ISOS, by its acronym in Spanish, from "Ingeniería de Sostenibilidad"), as a precursor to the development of a new bachelor's degree program in the same area. One of the most important features of the ISOS minor is that while it is open to any engineering student, it is intentionally designed to admit first year engineering students (few prerequisites are required). This provides an opportunity for first-year students to engage the broad and complex picture of sustainability and its commensurate challenges at the outset of their studies, to contextualize, motivate, and guide their learning pathways through their academic degree programs.

With support from the National Science Foundation, a scholarship was created specifically for new first-year students to encourage and support their immediate participation in the minor. This scholarship includes a summer camp, tuition for a university level summer course (with the purpose to create space in their schedule for ISOS courses), and a stipend to be activated in a subsequent year. Scholarship participants then take the course "Creating a Sustainable World" (3 credits) in the Fall, and a "Seminar on Diversity, Equity, Inclusion, and Justice" (1 credit) in the Spring. Thereafter, the students are required to complete a course "Wellbeing and Sustainability Economics", an elective social or political science course, a sustainability engineering elective, and a research or practical training experience (each for 3 credits), for a total of 16 credits to complete the minor. To date the program has admitted two cohorts: 11 students (7 men, 4 women) in 2023, and 12 students (8 men, 4 women), in 2024.

The initiative, and in particular the minor, were designed to value JEDI in two senses. First, we recognize JEDI as at the core of sustainability principles, so the inclusion of the JEDI seminar in the minor sequence is apt. It is widely documented, for example, that poor and marginalized communities disproportionately enjoy fewer benefits of industrialization, but disproportionately bear more of its costs and consequences (Adams, Klinsky, and Chhetri 2020; Harlan et al. 2015; Mendis *et al.*, 2023). Given our situation in Puerto Rico, fully understanding unsustainable practices and sustainable solutions requires inquiry of indigenous practices prior to industrialization, and invitations to reincorporate indigenous knowledge (Kimmerer, 2013; Mazzocchi 2020; Tom, Sumida Huaman and McCarty, 2019; Zidny, Sjöström and Eilks, 2020).

Second, the program aims to attract a diverse cadre of students and serve them by building a strong community of practice in which everyone's experience is honored by inviting them to bring themselves into the program. For example, to create this space, a privilege walk was conducted near the beginning of the semester in which each student had the opportunity to anonymously post various aspects of their identities and life circumstances on the wall, allowing all other students to read and reflect. With this in mind, a particular goal for the program is to attract women and first-generation college students. To date, the enrollment in the scholarship cohorts matches the approximate 2:1 men:women ratio of the overall enrollment in engineering at our campus (numbers of students reporting alternative gender identifications are small, and therefore not reported). As the program matures, more efforts need to be made to increase the number of women applicants and awardees.

In a prior work (Colón et al. 2024), the team provided a first view of the development of the students' sustainability mindset as a result of analyzing the participants from the 2023 sustainability engineering cohort, measured using a four-dimensional framework of knowledge (K), skills (S), behaviors (B), and attitudes (A). We found that students progressed in all four dimensions, both in maturation of their understanding of sustainability, and in their development of personal study and wellness habits. The scope of this article lies within the knowledge dimension, due to the dependence on evaluating student written work from the final essay of the seminar. Yet, as will be seen, some precursors of the other three dimensions are suggested by students' comments that express hypothetical actions or approaches that they propose.

3. Description of JEDI Seminar

In Spring 2024, we offered a seminar to help students understand the concepts of justice, equity, diversity, and inclusion, (JEDI) and how they apply to organizations and individuals, led by a senior faculty member with prior JEDI training. A second faculty member and a graduate research assistant attend most sessions as observers and commenters. The seminar met for one hour per week for 15 weeks. Among the eight (8) enrolled students, seven were members of the first-year sustainability engineering cohort from 2023 (5 men, 2 women); four of the members

from this cohort did not enroll due to schedule conflicts. The other student was an upper division student (man) not affiliated with the cohort.

Some of the goals of the seminar were to raise awareness and comprehension of perspectives that may differ of their own, to investigate techniques for promoting JEDI in both personal and professional settings, and to create a personal plan for promoting JEDI. Because the audience consisted primarily of first-year students, no prior knowledge of the subject was assumed. Further, due to the inclusion of the seminar as part of the new minor in sustainability engineering and due to the presence of the cohort students, the subtext of the seminar was clearly connected with sustainability. The seminar grade placed a strong emphasis on participation, with discussions and quizzes conducted to supplement reading and video assignments.

The course topics include Definitions Justice; Equality, Diversity and Inclusion (JEDI); Examining ourselves; Unconscious Bias; Intersectionality; Status of Marginalized Groups (including oppression and exclusion of women); Social Justice (including colonialism from the Puerto Rican perspective); Critical Thinking; Problem Solving; Inclusive and Universal Design; and Power, Privilege and Merit. To give a sense of how these topics were delivered, on the first day, the discussion focused on how to have respectful discussions when there are different perspectives, and using the privilege walk to both welcome everyone and also to engage students in respecting several different viewpoints and perspectives. Due to the inherent focus on Sustainability, the UN Sustainable Development Goals (2015) were emphasized as guides for our discussions. Students were prompted to discuss their own prejudices, unconscious biases, and stereotype threat, and were introduced to Crenshaw's readings and videos on intersectionality (Crenshaw 1991). In one assignment, a list of marginalized groups was presented; each student had to select one (or another marginalized group of their own choosing), and conduct a review of the literature on the group, and present their findings, aligned to SDGs and provide their own perspective on the topic. . Later, we invited Caroline Baillie (online) to present an overview of engineering and social justice, which addressed some aspects of colonialism and violence. Near the end of the course, the course addressed essential elements of critical thinking, constructive critique, and problem-solving techniques. The concept of inclusive and universal design concepts was then introduced in this light. Finally, we addressed power, privilege, and merit, partly through viewing the documentary "Picture a Scientist". At the end of the course, students completed a comprehensive final exam essay with eight questions aligned to JEDI, sustainability, and critical thinking (see Appendix A).

4. Methods and Positionality

For this study, we examined the final JEDI seminar essays of the seven (7) enrolled sustainability engineering first-year students from the 2023 cohort. We utilized a grounded theory approach to code the essays (Strauss and Corbin, 1990; Lambert 2019). Three team members independently

coded the essays, then created an Excel spreadsheet to examine codes across participants and coders. The team members worked together to develop axial codes and themes, considering the KSBA framework developed in the earlier work (Colón et al. 2024).

Our team includes the JEDI seminar instructor, two additional faculty members of the sustainability engineering minor, a doctoral research assistant, and the project's external evaluator. Several members of the team identify with the populations targeted in this initiative (women and first-generation college students). The seminar instructor and evaluator did not participate in the data analysis.

5. Findings

We identified three themes in the final JEDI essays: (a) Diversity and Inclusion: Integration of Diverse Perspectives; (b) Equity, Justice, and Accessibility; and (c) Community-Centric Approach. For each, we provide a description and illustrative examples from the essays.

A. **Diversity and Inclusion: Integration of Diverse Perspectives.** All seven participants recognized diversity either as an inherent good or as instrumental for integrating multiple and diverse perspectives to develop innovative and meaningful solutions, particularly within the context of sustainability. Students noted that integrating various backgrounds and experiences can enrich discussions and lead to more creative, inclusive, and thereby, effective outcomes. They indicated that embracing diverse perspectives ensures that solutions are well-rounded and consider various aspects of a problem, making them more effective and sustainable. This theme is illustrated by the following excerpts:

- "In the world today we are becoming more conscious of diverse environmental and social problems, equally of diversity and equity for which there are diverse strategies that have been implemented to solve these problems." (#2303)

- "Having representation of all sectors of the community is important since it helps to promote a healthier environment and it can be considered as a microcosm of our society, which also helps foundations and organizations to do better assessments and have better proposals for their future projects." (#2305)

- "A sustainable lifestyle encompasses the study of human interaction, lifestyles, and social beings as much as its environmental aspects; in its essence, it refers to the recognition of the interconnectedness of human well-being and environmental direction. … Everyone's ideals differ from one another due to their background, culture, or life experiences; this makes the ideas of diversity and inclusion essential for facing current situations within our society and achieving a more just, sustainable future." (#2308).

B. **Equity, Justice, and Accessibility.** This theme captures the idea that access to resources and potential benefits of (future) solutions must be fairly distributed and accessible to all community members. It also addresses inequalities, particularly by recognizing that people in marginalized communities often suffer disproportionately the consequences of climate change or industrialization. Some students also interpreted this theme of fairness in the sense of helping decision processes to be based on merit and by mitigating biases. All seven participants expressed at least one of these senses of equity, justice, and access. This theme is illustrated by the following excerpts:

- "Marginalized communities have a disadvantage when it comes to facing the effects of climate change. For example, a homeless person is more likely to suffer fatigue and the heat from our globe since they live outside, in comparison to someone who has a home and has the resources to own air conditioning …" (#2301)

- "Actively involving diverse stakeholders, including community members and representatives from marginalized groups, ensures that solutions are inclusive and address the needs of all." (#2302)

- When solutions are developed for challenges like climate change and pollution, then the next obstacle to face is the availability of such solutions. As with medical treatments that are not always accessible, the same can happen with solutions for modern problems. When this happens, marginalized communities, especially those with generally low incomes, become more vulnerable. … When selecting colleagues to form the team, I would design the applications so that they do not contain personal information, ensuring that all team members are chosen solely based on merit. This would help ensure that the biases of the person evaluating the applications do not affect the selection of team members." (#2307)

C. **Community-Centric Approach.** This theme highlights the necessity of involving communities directly in the problem-solving process. It involves understanding and addressing the specific needs and contexts of different communities, and relates to the concept of co-design (Silva Diaz et al. 2021) Participants emphasized the importance of community engagement in developing practical, relevant, and effective solutions tailored to the needs of the people affected by the issues, informed by the community in their voice. While expressions of the community-centricenic theme could be considered as examples of the prior two themes, they are distinguished in the sense that they are framed as potential actions, e.g., how to mobilize community participation versus simply stating that communities should be involved. Six of the seven participants expressed an idea in this deeper sense. This theme is illustrated by the following excerpts:

- "By centering the voices of marginalized groups in decision-making processes, we can develop targeted and effective solutions that address the root causes of environmental injustices." (#2302)

- "If I was leading a project, getting people with different mindsets (it could be experts, community members, representatives etc.) would help in the decision making throughout the development process. Especially the ones affected by a certain problem. Not only will it give a different perspective on the subject (because we are all different thus, we have a different way of seeing things) but also the solution will be put to the mind of the people." (#2304)

- "If I were leading, I would take a page from the book of Caroline [Baillie] and involve the local people for their knowledge of their problems". (#2307)

- "Conducting a comprehensive assessment based on the voices from the communities could allow for a better understanding of everyone's worries … . … certain advocates for all surrounding communities could be appointed to consult, share their knowledge, and serve as the voice of their respective communities. Only a collaborative and participatory approach to the development of this project and the active participation of community members in the decision-making process could lead to a sustainable solution that benefited all involved." (#2308)

In summary, the themes reveal that students have developed a basic working understanding of the concepts of JEDI, and how to connect it within the context of sustainability. These themes further illustrate how JEDI relates to critical thinking and problem-solving in general.

6. Discussion

The analysis demonstrates that all seven participants have developed a basic literacy and conceptualization of JEDI principles and how they apply to the context of sustainability. Most saliently, students were able to express the idea that it is essential to involve many actors in solving problems, and that marginalized communities often suffer greater negative consequences of current conditions, or receive fewer benefits of solutions.

Essentially all of the comments expressed by the students can be classified as elements of their knowledge (K) growth, which is associated with their growing awareness of core concepts. The other elements of skills (S), behaviors (B), and attitudes (A) are not directly identified within the scope of the present analysis, but some comments suggest that students are poised to apply or activate their knowledge into these other spheres. In particular, the comments pertaining to community engagement were frequently posed in the active sense "if I were leading" or clearly indicating that a participatory approach is necessary. These prospective assertions provoke future development of associated skills, behaviors, and attitudes that would be necessary to execute these approaches. It can be further argued that meta-outcomes of the essays are the students' skill (S) and ability (A) to communicate their ideas.

Our analysis was intentionally truncated to highlight as sharply as possible some distinct thematic ideas. However, just as the boundaries between K-S-B-A are sometimes fuzzy and arbitrary, so are the boundaries between J-E-D-I. Our analysis reveals that there may be some pairwise associations of D-I and E-J, and this is substantiated by noting that the roles of D&I and E&J are often interchanged in various organizations' working definitions[1]. Examining larger excerpts of comments reveals that students interconnect or weave multiple dimensions of JEDI. For example, consider the following essay excerpts:

- "For example, low-income neighborhoods often bear the brunt of environmental pollution due to the location of hazardous waste sites or lack of access to clean air and water resources. Indigenous communities face the loss of traditional lands and livelihoods due to deforestation and resource extraction. By centering the voices of marginalized groups in decision-making processes, we can develop targeted and effective solutions that address the root causes of environmental injustices." (#2302)

- "When solutions are developed for challenges like climate change and pollution, the next obstacle to face is the availability of these solutions. Just as medical treatments are not always affordable, the same can happen with solutions to modern problems. When this occurs, marginalized communities, especially those with generally low incomes, become more vulnerable. … Ensuring equal access to these solutions becomes crucial to securing equitable distribution and the well-being of all members of society. … If I were leading, I would take a page from the book of Caroline [Baillie] and involve local people for their knowledge about the problems." (#2307)

These and other examples illustrate students' abilities to integrate the various definitions into a common whole. For example, it is clear that they understand lack of representation (I) and also leading to injustices (J), and conversely, that inclusion (I) and diversity (D) of community members can lead to solutions that are equitable (E), accessible, and just (J).

Finally, the essays reveal different levels of fluency to connect responses to sustainability challenges with JEDI. Consider the following three excerpts:

- "There has been no recycling system [in my neighborhood] for as long as I have lived there and instead of stating employees are not doing their job, I could reflect on it and consider some issues that may not be visible to the public. There might not be enough vehicles to collect recycled garbage and take it to gathering centers or there is no personnel to manage large quantities of recycled bags (...) It is important that we take action in our daily life as well though. As part of the [Solid Waste project in my] student association, my team is starting to create manuals that influence how environmental conservation is being impacted on campus. We help reduce the use of plastics, consider

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composting food waste, and eliminate the use of materials that are difficult to recycle and reuse. By creating polls associated with students and faculty needs, involving ourselves with the community to talk and identify problems accessing sustainable resources and solutions, we would be able to ensure the guidebooks are being just, equitable and incorporating diverse perspectives throughout the development process." (#2301)

- "We need to take into consideration the sectors that don't really benefit from the current society. A product that I would redesign to make it more inclusive would be public transportation, adding ramps for people in wheelchairs and posters in those ramps written in Braille, as that is the language understood by blind people." (#2303)

- "Minimize the number of single-use plastics and other non-renewable materials that you consume. Energy conservation may be achieved using energy-efficient equipment, energy-saving behaviors, and, where possible, investments in renewable energy sources. … Reduce trash by recycling, composting, and adopting conscientious consumption practices." (#2304)

These examples illustrate different degrees to which students will spontaneously tie ideas together without prompting. In the second excerpt, the nature of the idea is inherently framed around access. In the first excerpt, the approach is primarily framed around the material aspects, but toward the end, the student recognizes the importance of involving the community as a partner. In the last example, the solution is framed entirely within the material-energy dimensions, and does not explore applications of JEDI.

Overall, given that the seminar was a 1 credit course (1 hour per week) and the participants were in the first year of the sustainability minor, these results are encouraging. As students progress in the program and receive more active mentoring, we anticipate they will sharpen their skills in communicating about JEDI in sustainability, and develop the writing skills to provide evidence behind assertions and integrate multiple dimensions of a problem-solution approach. We plan to examine other course and program artifacts (e.g., assignments, surveys, observation notes) to expand our understanding of the development of student knowledge, skills, behaviors, and attitudes in the application of JEDI to sustainability engineering.

7. Conclusions and Future Work

In conclusion, the results of the analysis clearly indicate that by the end of the seminar, students were able to articulate basic concepts of JEDI, and how they relate to the context of sustainability. The results are primarily classified within the knowledge domain of the KSBA framework, but some indications of potential future expressions of the other S-B-A dimensions were observed. Beyond the evaluation of the essay results, evaluation of student feedback and classroom observations are in progress.

Overall, the results seem appropriate given the 1 credit nature of the seminar, and given that the participants are first-year students. However, deeper understandings and connections between sustainability problem-solving and JEDI should be encouraged and fostered as the students progress through the minor. A particular future opportunity to put this into practice (and to express the S-B-A dimensions), for both students and faculty, will occur during the research or practical training experience. Future work will focus on emphasizing social justice within engineering, defining and practicing communication strategies for inclusivity, and exploring the concept of merit in greater depth in this seminar.

Acknowledgements

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Appendix A. Guiding Questions for Essay

1. How can promoting diversity, equity, and inclusion contribute to creating a more sustainable future in your community or organization?

2. Think about a specific environmental challenge we face (e.g., climate change, pollution). How might this challenge disproportionately impact marginalized communities within your city, country, or on a global scale?

3. Imagine you are tasked with leading a project to create a sustainable solution (e.g., renewable energy source, waste reduction program). How can you ensure this solution is accessible, equitable, and incorporates diverse perspectives throughout the development process?

4. Choose a real-world problem related to sustainability in your community or chosen field. How can critical thinking skills help identify the root causes of this problem and develop solutions that consider the needs of diverse populations?

5. Many sustainability challenges are complex and interconnected. Describe a situation where you used critical thinking to identify multiple perspectives on a sustainability issue, considering the potential impact on different identity groups.

6. Reflect on your personal values and how they relate to sustainability. Based on this course and your understanding of DEIJ, develop a personal action plan with specific steps you can take to promote a more sustainable future in your daily life.

7. Consider a product or service you use regularly. Identify ways in which this product or service could be redesigned to be more inclusive for people with diverse abilities, ensuring equal access to sustainable solutions.

8. Additional Comments