Social and environmental justice in the STEM classroom: How do STEM instructors relate to the impact of their engineering work before and after a critical pedagogy intervention?

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Introduction

Due to the impacts of the engineering profession, social and environmental justice are growing concerns within current engineering practice and education. The engineering profession, although considered neutral by many, is closely associated with impacts on society and the environment due to its strong ties with the corporate world [1]. Leydens and Lucena [2] argue that social justice dimensions are inherent to engineering but are made invisible by the status quo of the profession. The social impacts relate to the dislocation of local communities, land dispossession, the exploitation of labor, social segregation, and the reproduction of prejudice and biases, among others [2,3,4]. On the other hand, the environmental impacts relate to pollution, environmental disasters, the exhaustion of natural resources, and others [5,6]. However, these issues frequently intersect, with many engineering activities simultaneously resulting in negative social and environmental impacts [7,8]. This has led many institutions and accreditation standards to adopt social and environmental justice as part of their goals for engineering students [9]. Thus, incorporating social and environmental justice aspects into the engineering curriculum has become increasingly necessary.

However, incorporating social and environmental justice into the engineering curriculum can be challenging because of an already busy curriculum and a lack of pedagogical guidance for instructors. Not addressing these challenges can thus hinder institutions' ability to develop socially and environmentally responsible engineers. Due to technological and scientific developments, the engineering curriculum is frequently expected to cover more and more technical content, which makes the incorporation of other aspects more challenging [10]. A horizontal integration of social and environmental justice is an effective approach to dealing with this issue, and it simultaneously helps defuse faculty resistance to non-technical content [11,12,13]. It has also been pointed out that social justice in engineering contexts usually necessitates the use of pedagogies that engineering instructors are not familiar with, including critical pedagogy [13] and teamwork pedagogy [14]. Pre-designed modules that can be incorporated to promote social and environmental justice into existing engineering classes then become a strategy worth exploring to address these issues and help instructors bring a social and environmental perspective into their practice.

In this work-in-progress paper, we explore the development process of modules that instructors can include in their engineering courses to incorporate social and environmental justice using critical and teamwork pedagogies. Our perspective is that engineering education should incorporate social and environmental justice to guide technology towards a sustainable, reciprocal, and just increase in the well-being of people and the Ecosystem. Our approach to developing the modules consisted of using the Mycorrhiza framework [15] along with critical and teamwork pedagogies in the design process. Our modules include potential activities that instructors can choose from and adapt to their specific engineering context through discussions

with the original designers of the module. Although our current progress does not allow us to answer it yet, our guiding research question is "How do STEM instructors relate to the impact of their engineering work before and after a critical pedagogy intervention?"

Theoretical Framework

The Mycorrhiza framework [15] provides the lens and philosophical guide for meaningful inclusion of Social and Environmental Justice in engineering education, arguing that Social Justice cannot be achieved without Environmental Justice. The framework proposes that the tenets of Paulo Freire's critical pedagogy—*Conscientização* or awareness, dialogue, and praxis [16]—are responsible for carrying the cognitive, emotional, and spiritual aspects of an individual's decision-making process through the levels of the individual, the people, and the ecosystem. The name, thus, comes from the analogy of Mycorrhiza as the symbiotic relationship between fungi and plants that cycles nutrients to the benefit of the whole ecosystem, with the engineering work also contributing to the ecosystem.

The framework recognizes that, as human beings, the things that we do are not exclusively the product of our cognition, with emotion and spirituality playing significant roles. Cognition refers to the rationality in the process, whereas emotion describes our feelings, and spirituality addresses our connection to other beings and things. Thus, the framework reinforces the role of these three aspects in the engineering decision-making process, specifically in terms of how they relate to different levels that will be impacted by the engineering work. The first of these levels is the individual, which refers to the aspects of decision-making that satisfy the person who is engaging in the engineering process. In other words, at the individual level, an engineering solution is being considered in terms of what technically solves the problem and how it aligns with the person's values and objectives. At the People level, the framework guides us to investigate who might be impacted by our engineering work. More importantly, the Mycorrhiza framework encourages bringing some of the people impacted into the design process, their contribution is essential to have an engineering solution that is socially just and true to their cognition, emotion, and spirituality. Finally, the third level is that of the ecosystem, with the framework guiding us through our decision-making process considering all other non-human beings. In this context, the tenets of critical pedagogy are seen as tools/perspectives to carry cognition, emotion, and spirituality through the individual, people, and ecosystem levels.

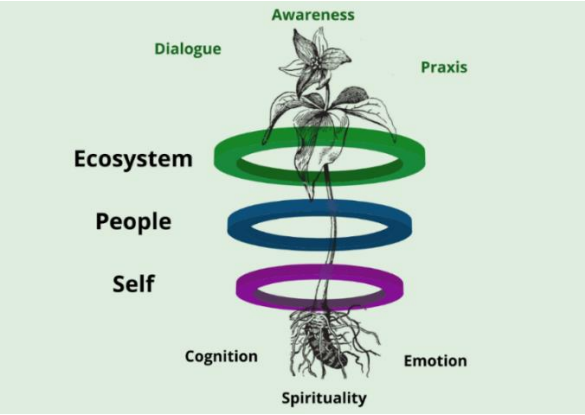

Figure 1. Mycorrhiza framework aligned with Critical Pedagogy

As shown in Figure 1, both the Mycorrhiza framework and the three tenets of the critical pedagogy complement each other. The framework necessitates users to visit each of the levels and consider how their engineering work impacts them as engineers creating a solution and how people and the Ecosystem are being affected by the extraction, creation, and end cycle process of their engineering work. Each of the levels should be analyzed rationally, emotionally, and spiritually, considering spirituality as a connection with other beings. The way those analyses happen is through raising awareness of the social and environmental impact of their work, creating dialogue to incorporate other ways of knowing and being, and finally applying what they have learned to their engineering work.

Modules

Development of the modules

This work is meant to help instructors promote questions, activities, and conversations around social and environmental justice. We intend to provide instructors with tools to raise awareness of the social and environmental implications of our engineering work, promote dialogue to share ideas and understandings of critical thinking around the engineering work, and find ways to apply the discoveries to team classroom activities and projects. At the individual or self-level, the instructor is whom initially uses the framework to adapt their own beliefs to their class activities. Then, the instructor encourages students to become the individuals who are analyzing their activity through the framework. Once the students are more aware of the impact of their engineering design on themselves, on the people involved, and on the Ecosystem that their engineering work transforms, the student must reconcile their project with their beliefs and include new restrictions that probably increase the complexity of the project. Yes, this framework will make projects more complex and at the same time intends to make projects more respectful, reciprocal, and fair.

Learning objectives

LO1. Examine the social and environmental impact of engineering solutions.

LO2. Propose engineering solutions informed by power relations involving participants in the process.

To support these learning objectives, we suggest learning activities developed with the Mycorrhiza Framework as a theoretical basis. Student participation in these activities will evidence the learning objectives above. Below, we provide a table and a description of select proposed activities, each of them following the three levels of the Mycorrhiza framework.

Content or activities

Activity	Learning Objectives	Description of activity
Hopes and Fears Poll	LO2	Have students participate in an anonymous poll about hopes and fears for the class, and use responses to create class norms. Create prompts that encourage students to think about social and environmental issues that happen in their

		classroom or their school. How can they address those issues by creating class norms?
Frayer Model Vocabulary Activity	LO1, LO2	Have students work in teams to discuss vocabulary related to environmental and social justice using a graphical organizer or other template. The goals are to find what daily vocabulary perpetuates social and/or environmental issues, and what more precise words should we incorporate into our daily lives.
Addressing Hesitancies	LO1, LO2	See below
This is what engineering looks like	LO1, LO2	Share images or media content that highlight the connections between engineering and justice. Discuss who engineering is for.
Design for good	LO1, LO2	As an activity to promote awareness of social and environmental justice within engineering design, we will ask students to act as design engineers. Participants will work in teams and be presented with a scenario for which they will develop a design proposal. As an example of a scenario: A parent of a child with a developmental delay would like to work with you on the design of an adaptive device that would allow his child to use scooters. Students will be responsible for meeting with the client, articulating the design challenge, and developing a prototype.
Community Reflection	LO1, LO2	This is a complement to any of the other activities. We encourage instructors to have reflections after any activity. Sometimes, it helps to share those reflections in the community. In teams, ask students to share their reflections on their learning, new social and environmental perceptions, and application to their lives in small groups.
Roleplaying	LO1, LO2	This activity aims to help students develop empathy through impersonating others [17, 18, 19]. Have teams come up with a current issue that they care about, then co-create different roles that stand for different reasons (e.g., Environmentalists, CEOs, workers, etc). Using the Mycorrhiza framework, each role should go through the process of reflecting on how they feel, think, and connect to the positionality of their role, the people impacted by the engineering process, and the Ecosystem changed by the engineering process. Each role should negotiate a decision at three stages, logical reasons, how each role feels, and what connections each role sees with other beings.

Addressing Hesitancies: As an activity to promote reflection on the Mycorrhiza framework, we will ask students to discuss possible hesitancies to participate in a learning community that incorporates values associated with social and environmental justice. The intention of addressing hesitancies is to facilitate a discussion that is inclusive of each student's lived experiences, academic background, and educational goals. The opportunity to discuss hesitancies will allow each participant to reflect on their learning expectations, challenges they may perceive, and their hopes for positively impacting the world. In teams or as a think-pair-share activity, have participants address each of the following hesitancies:

- Coverage of course topics. "I have so much material to cover; I don't have time to focus on justice issues, too."
- Skills/Expertise. "I don't have the necessary skills or knowledge to talk about justice issues. / I'd rather avoid it altogether than do it wrong."
- Ideas of Rigorous content. "Learning [my discipline] the real world is challenging. Justice issues take the focus off the challenging course content that is already present."
- Concerns about "ideological discrimination." "If I focus on social and environmental justice, won't I then just marginalize or exclude people with different political views?"
- Belief in a 'difference-blind' ideal. "Isn't it fairer to ignore different perspectives of justice and provide equal treatment to all topics?"
- Avoid difficult discussions (status quo is safe).

After providing time for participants to discuss hesitancy, ask them to share their reflections. Although there is no single conclusion that participants need to consider, a closing of the conversation can highlight any actions or resources that can mediate hesitancies and the value proposition of social and environmental justice that arise from the discussions.

Discussion and Future Work

Progress for the sake of moving forward, solving problems without considering beings impacted in the process, and other colonialist forms of supremacy, greatly impact the lives of underrepresented people and other beings. Engineering solutions must consider their impact on the engineer, and the people and Ecosystem being affected by all the processes of extraction, creation, transportation, and disposal. The modules presented in this work in progress, guided by the Mycorrhiza framework, serve as tools for instructors who want to implement critical thinking, and social and environmental justice in their classrooms. Incorporating these modules can lead to helping with the horizontal integration of Social and Environmental Justice in engineering classrooms, familiarizing instructors and students with critical thinking, and incorporating a deeper analysis that includes social and environmental participants, concerns, and voices into the engineering design process. Each module serves as a guide for the instructor to incorporate their own beliefs into the provided framework, so the classroom keeps the spirit of the instructor-student relationship while reducing resistance to include non-technical content in engineering courses. In future work, we will implement these modules with instructors who resonate with the ideas presented here. All the community is invited to reach us and participate in the process of incorporating critical thinking, and social and environmental justice in engineering education.

References

[1] D. Riley, *Engineering and Social Justice*. in Synthesis Lectures on Engineers, Technology, & Society. Cham: Springer International Publishing, 2008. doi: 10.1007/978-3-031-79940-2.

[2] J. A. Leydens and J. C. Lucena, Eds., "Social Justice is Often Invisible in Engineering Education and Practice," in *Engineering Justice: Transforming Engineering Education and Practice*, Hoboken, NJ, USA: John Wiley & Sons, Inc., 2017, pp. 45–66. doi: 10.1002/9781118757369.ch1.

[3] A. Moreton-Robinson, *The White Possessive: Property, Power, and Indigenous Sovereignty*. Minneapolis, MN: University of Minnesota Press, 2015.

[4] Benjamin, R. (2019). Race after technology: Abolitionist tools for the new Jim Code. Polity Press.

[5] Bielefeldt, A. R., & Silverstein, J. (2021). Environmental justice and equity issues: In our backyards and beyond. 2021 ASEE Annual Conference.

[6] Seay, J. R. (2015). Education for sustainability: Developing a taxonomy of the key principles for sustainable process and product design. Computers & Chemical Engineering, 81, 147–152. https://doi.org/10.1016/j.compchemeng.2015.03.010

[7] Beltrán, R., Hacker, A., & Begun, S. (2016). Environmental Justice Is a Social Justice Issue: Incorporating Environmental Justice Into Social Work Practice Curricula. Journal of Social Work Education, 52(4), 493–502. https://doi.org/10.1080/10437797.2016.1215277

[8] Doggett, O., Liu, J., Ovienmhada, U., Sabie, S., Gram, S., Perovich, L. J., Ratto, M., & Soden, R. (2023). Environmental and Climate Justice in Computing. Computer Supported Cooperative Work and Social Computing, 481–485. https://doi.org/10.1145/3584931.3611296.

[9] Tisdale, J. K., & Bielefeldt, A. R. (2023). Sustainability in Mechanical Engineering Undergraduate Courses at 100 Universities. ASME Open Journal of Engineering, 2, 021049. https://doi.org/10.1115/1.4063387.

[10] Thürer, M., Tomašević, I., Stevenson, M., Qu, T., & Huisingh, D. (2018). A systematic review of the literature on integrating sustainability into engineering curricula. Journal of Cleaner Production, 181, 608–617. https://doi.org/10.1016/j.jclepro.2017.12.130.

[11] Kamp, L. (2006). Engineering education in sustainable development at Delft University of Technology. Journal of Cleaner Production, 14(9–11), 928–931. https://doi.org/10.1016/j.jclepro.2005.11.036

[12] Barrella, E. M., & Watson, M. K. (2016). Comparing the Outcomes of Horizontal and Vertical Integration of Sustainability Content into Engineering Curricula Using Concept Maps. In W. Leal Filho & S. Nesbit (Eds.), New Developments in Engineering Education for Sustainable Development (pp. 1–13). Springer International Publishing. https://doi.org/10.1007/978-3-319-32933-8_1

[13] Leydens, J. A. (2013). Integrating social justice into engineering education from the margins: Guidelines for addressing sources of faculty resistance to social justice education. In J.

C. Lucena (Ed.), Engineering Education for Social Justice: Critical Explorations and Opportunities (p. 179–200). Springer Netherlands.

[14] L. Riebe, A. Girardi, and C. Whitsed, “A Systematic Literature Review of Teamwork Pedagogy in Higher Education,” *Small Group Research*, vol. 47, no. 6, pp. 619–664, Dec. 2016, doi: 10.1177/1046496416665221.

[15] J. Cristancho, (2024) “Mycorrhiza Framework: towards an Engineering Education Framework for Social and Environmental Justice”, CoNECD.

[16] Freire, P. (2017). Pedagogy of the oppressed. Penguin Classics.

[17] Hoffman, M. L. 2000. Empathy and Moral Development: Implications for Caring and Justice. Cambridge, UK: Cambridge University Press.

[18] T. Mattelmäki, K. Vaajakallio, and I. Koskinen, “What Happened to Empathic Design?,” *Design Issues*, vol. 30, no. 1, pp. 67–77, Jan. 2014, doi: 10.1162/DESI_a_00249.

[19] M. W. Tracey and J. Baaki, “Empathy and empathic design for meaningful deliverables,” *Educational technology research and development*, vol. 70, no. 6, pp. 2091–2116, Dec. 2022, doi: 10.1007/s11423-022-10146-4.