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Integrating Social Responsibility and Climate Justice in Engineering Education through the Engineering for One Planet Framework

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Integrating Social Responsibility and Climate Justice into Engineering Education: The EOP Framework in Action

Abstract:
Engineering education is at a critical juncture, with increasing recognition of its potential to contribute to social justice and sustainability and this **practice paper** explores the integration of the Engineering for One Planet (EOP) framework into engineering classrooms to equip students with the tools to address systemic inequities and environmental challenges. Grounded in culturally sustaining and anti-deficit pedagogical practices, the EOP framework leverages tools such as the STEEP framework (Social, Technological, Economic, Environmental, and Political) to foster systems-level thinking and engage students in critical discussions about the intersection of engineering, equity, and justice. This paper examines a case study where the EOP-aligned curriculum was implemented in a course analyzing the Atlanta water main crisis. Faculty training, supported by the STEEP framework and reflective practices inspired by Schön's (1984) concepts of "Reflection-in-Action" and "Reflection-on-Action," enabled educators to design and facilitate learning experiences that connected technical problem-solving with social and environmental responsibility. Student reflections (n=30) were analyzed using the Constant Comparative Method (CCM) to evaluate the impact of these tools on their understanding of sustainability, social justice, and engineering's role in addressing systemic challenges. Findings reveal that the EOP-aligned curriculum significantly enhanced students' ability to connect technical solutions to broader societal and environmental issues, fostering critical thinking and ethical decision-making. Students demonstrated increased awareness of the intersections between climate change and marginalized communities, proposing actionable solutions that integrated equity and sustainability into engineering practices. Faculty outcomes highlighted shifts toward justice-oriented teaching strategies and identified opportunities for institutional support to sustain these efforts. This study underscores the transformative potential of embedding sustainability and social responsibility into engineering education, even amid political resistance to DEI initiatives. By framing the classroom as a terrain of struggle and a site of possibility, the EOP framework advances

the goal of preparing engineers to lead with equity and sustainability at the forefront of their work.

I. Introduction

A. Background and Rationale

(1) Importance of Embedding Social Responsibility in Engineering Education

Engineering classrooms have long been sites of both struggle and possibility, where technical expertise can be cultivated alongside a critical understanding of societal inequities and the systemic challenges faced by marginalized communities. The integration of social justice and sustainability into engineering education reflects a growing recognition that engineers are not just problem-solvers but also ethical actors with responsibilities to society and the environment. This transformative vision aligns with the Engineering for One Planet (EOP) framework, which equips engineering educators with tools to embed sustainability, equity, and justice into their curricula. By incorporating frameworks like STEEP (Social, Technological, Economic, Environmental, and Political), the EOP initiative prepares students to tackle complex societal challenges, such as climate change and infrastructure inequities, while fostering critical awareness of their professional and social responsibilities [1].

At the same time, these efforts are unfolding in a contested political landscape. In Georgia and across the United States, legislative actions targeting diversity, equity, and inclusion (DEI) initiatives have sought to curtail critical discussions on race, equity, and social justice in higher education [2]. Such policies threaten to limit academic freedom and undermine efforts to create inclusive, culturally sustaining classrooms that engage with the liberatory potential of engineering education. This political climate compels educators to navigate tensions between institutional constraints and their commitments to fostering transformative learning experiences that center social justice and sustainability.

Despite these challenges, engineering classrooms remain fertile ground for advancing anti-deficit and culturally sustaining pedagogical practices. The classroom can serve as a terrain of struggle against oppressive systems and as a site of possibility for cultivating relationships with social justice movements. Through reflective practices and critical pedagogy, educators can empower students to view engineering as both a technical discipline and a tool for liberation. The EOP framework, in particular, offers a means to integrate these values into engineering education, enabling educators to address the intersecting crises of climate change, infrastructure inequity, and systemic marginalization without explicitly positioning their work within contested DEI frameworks.

(2) Intersection of Climate Change and Marginalized Communities

Climate change disproportionately impacts marginalized communities, exacerbating existing inequalities and creating new vulnerabilities. Low-income and minority populations are more likely to live in areas with higher exposure to environmental hazards, such as flood zones, heat islands, and polluted industrial sites [3]. These communities often lack the resources and political representation necessary to adapt to or mitigate these risks, creating a cycle of environmental injustice.

For instance, events like Hurricane Katrina and the Flint water crisis demonstrate how climaterelated and infrastructure challenges disproportionately affect vulnerable populations [4]. Engineers are uniquely positioned to address these inequities by designing resilient infrastructure, incorporating community voices into decision-making, and prioritizing equitable resource allocation. The integration of frameworks like STEEP (Social, Technological, Economic, Environmental, and Political) in engineering education equips students with the tools to evaluate these complex challenges holistically and design solutions that account for social justice and sustainability.

By embedding discussions of climate justice and marginalized communities into engineering curricula, students gain the awareness and skills necessary to address these pressing issues. As [5] argues, incorporating social justice into engineering education creates more inclusive and ethical professionals, ensuring that engineering solutions advance equity and sustainability rather than perpetuating disparities.

B. Purpose of the Study

This paper examines the implementation of the EOP framework in a Kennesaw State University (KSU) engineering course addressing the Atlanta water main crisis while also evaluating the effectiveness of an EOP focused faculty training program that led to this course modification. The training program emphasized the intersection of environmental sustainability, social justice, and technical problem-solving, equipping faculty to integrate these critical perspectives into their teaching practices. Faculty training included tools such as the STEEP framework and reflective practices grounded in [6] concepts of “Reflection-in-Action” and “Reflection-on-Action.” By embedding culturally sustaining and justice-oriented principles into technical curricula, this initiative demonstrates the potential to transform engineering education into a space for the cultivation of socially conscious engineers.

II. Conceptual Framework

A. The EOP Framework

The EOP Framework serves as the foundation for embedding sustainability and social responsibility into engineering education. The core principles of the EOP framework emphasize equipping engineers with the knowledge, skills, and mindsets necessary to address global challenges through sustainable and ethical practices. The framework encourages the integration of multidisciplinary approaches to engineering education, promoting a balance between technical proficiency and a deep commitment to societal and environmental well-being [7]. The relevance of the EOP framework to social responsibility and climate justice lies in its commitment to fostering engineers who can engage critically with the intersection of technological advancements, environmental sustainability, and the needs of marginalized communities. By doing so, it provides a pathway for addressing pressing global issues such as climate change, inequitable resource distribution, and the disproportionate impacts of environmental crises on vulnerable populations [8].

B. STEEP Framework

The STEEP framework is a multidisciplinary tool that guides students in analyzing complex challenges by examining interconnected factors across diverse domains. Originally developed for strategic planning, the STEEP framework enables students to deconstruct issues such as the Atlanta water main crisis, exploring how social equity, technological innovations, economic feasibility, environmental sustainability, and political dynamics influence potential solutions [9].

In the context of the EOP curriculum, the STEEP framework fosters systems thinking by encouraging students to recognize the interdependencies between technical and non-technical factors. It equips them with the skills to propose solutions that are not only technically viable but also socially and environmentally equitable. For example, students analyzed how green infrastructure investments and public awareness campaigns could mitigate the crisis while addressing long-term sustainability goals.

C. Reflective Practice Approach

The study draws upon [6] Reflective Practice Approach, emphasizing the iterative process of "Reflection-in-Action" and "Reflection-on-Action." [6] describes reflective practice as a complex cognitive exercise which requires practitioners to revise, modify and refine their expertise Reflection can be a systematic and purposeful methodology to examine ones' teaching practice [10]. The process of reflection requires teachers to identify an issue of practice, frame that issue of practice using their beliefs and previous experiences, develop solutions and implement solutions for solving issues of practice, and reframe the issue based on new evidence that arises during their examination [11]. By engaging in reflective practice, teachers can construct and reconstruct their practices so that they can provide optimum learning conditions for their students these concepts are instrumental in fostering faculty development and teaching improvement.

- **Reflection-in-Action** occurs during the teaching process, allowing faculty to adapt their strategies in real-time based on student engagement and learning outcomes.
- **Reflection-on-Action** takes place after the teaching process, encouraging faculty to critically evaluate their practices and identify areas for refinement.

This reflective approach enhances faculty's ability to integrate social responsibility and sustainability into their teaching by fostering continuous improvement. It also aligns with the EOP framework's goals by encouraging educators to model the ethical and critical thinking behaviors they aim to cultivate in their students [6].

D. Integrating the Frameworks

Together, the EOP and STEEP, supported by reflective practices, create a comprehensive conceptual foundation for transforming engineering education. They emphasize the interconnectedness of technical knowledge, sustainability, and social responsibility while equipping both faculty and students with the tools to address the multifaceted challenges of the 21st century. This conceptual foundation enables engineering education to move beyond traditional paradigms, fostering the development of engineers who are prepared to lead with ethics, equity, and sustainability at the forefront of their practices.

III. Methodology

A. Faculty Training Sessions

One month prior to convening the Faculty Training Sessions, two of the four workshop facilitators had the opportunity to attend a week-long training at

Villanova University, which centered on developing communities of practice and designing training programs for implementation at other institutions. Although the training was not explicitly focused on social justice or environmental justice, these topics naturally emerged during group discussions. Many attendees shared personal stories of navigating systemic challenges, including the growing impact of anti-DEI legislation in higher education. These accounts illuminated the critical need to address such injustices within academic contexts and inspired deeper conversations about integrating equity and justice into engineering education. It was within this collaborative and reflective environment that the idea of emphasizing climate justice and its disproportionate impacts on marginalized communities as a key focus of the KSU training began to take shape. This dialogue underscored the urgency of equipping faculty to address these pressing issues in their teaching practices.

At the KSU Training, which convened a month later, faculty participants engaged in three halfday virtual workshops during the summer, strategically scheduled to allow participants ample time to revise their fall course plans without the pressures of teaching a full load. This intentional timing underscored the commitment to ensuring that faculty could thoughtfully integrate social and environmental justice principles into their curriculum.

Day 1: Introducing the EOP Framework and Initial Exploration of Social Justice The first day focused on introducing the EOP framework and its role in fostering socially and environmentally conscious engineering education. Workshop facilitators emphasized the intersection of climate change and marginalized communities, encouraging faculty to reflect on how they could embed these discussions into their teaching practices (see example content in Figure 1). Faculty shared initial reflections on connections they had already established with students, providing examples of course activities that explored equity, access, and environmental responsibility.

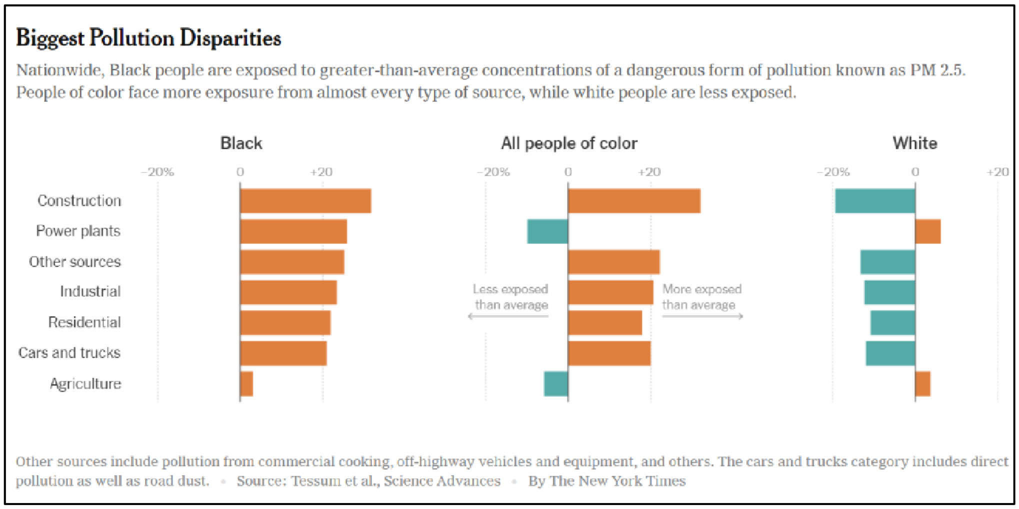

Figure 1: Example Figure from Training Session showing Pollution Disparities

To deepen faculty engagement, the STEEP framework was introduced. Participants engaged in an experiential activity designed to model how the framework can uncover the broader impacts of engineering decisions. Faculty worked collaboratively on a scenario, examining how issues like infrastructure challenges disproportionately affect marginalized communities. The day concluded with participants brainstorming ideas for embedding the STEEP framework into their fall courses and example STEEP rubrics were shared (see Figure 2).

STEEP Rubric

Source: https://open.library.ubc.ca/soa/cIRcle/collections/52657/items/1.0064738

	Assigned Value	RED		YELLOW			GREEN
	-3	-2	-1	0	+1	+2	+3
S	Negative impact on more than one social group or geographic population **AND** impact is severely infringing on health, wellbeing, or rights.	Negative impact on one social group or geographic population **OR** impact on more than one social group or geographic population is negative but not severe.	Risk of negative impact to one or more social groups or geographic populations **OR** social factor has risk of negative impact on system.	Impact is neutral. Social impact is insignificant **OR** positive and negative aspects of impact are relatively equal.	Potential for positive impact on one or more social groups or geographic populations **OR** social factor has potential for positive impact on system.	Positive impact on one social group or geographic population **OR** impact to more than one group is positive but not extremely beneficial.	Positive impact on more than one social group or geographic population **AND** impact is extremely beneficial to health, wellbeing, or rights.
T	Significant gaps exist in available technology **OR** impact of lack of technology (development and/or accessibility) is severe.	Small gaps exist in available technology **AND** impact of lack of technology is not severe.	Risk of negative impact from new technology **OR** future risk of negative impact from existing technologies.	Impact is neutral. Impact of technology is insignificant **OR** positive and negative aspects of impact are relatively equal.	Potential for positive impact from new or existing technology **OR** research on new technology is showing positive preliminary results.	Technology innovation adequately addresses previous gaps **AND** impact of technology is positive but not extremely beneficial.	Technology innovation fully addresses previous gaps **OR** impact of technology is extremely beneficial (widespread application, accessibility).
E	Negative economic impact on more than one group or industry **AND** impact is severe.	Negative economic impact is limited to one group or industry **OR** impact to more than one group or industry is negative but not severe.	Risk of negative economic impact to one or more groups or industries.	Impact is neutral. Economic impact is insignificant **OR** positive and negative aspects of impact are relatively equal.	Potential for positive economic impact to one or more groups or industries.	Positive economic impact on one group or industry **OR** impact on more than one group or industry is positive but not extremely beneficial.	Positive economic impact on more than one group or industry **AND** impact is extremely beneficial.
E	Negative impact on more than one environmental impact category or geographic region **AND** impact is severe (in size and/or scope).	Negative impact is limited to one environmental impact category or geographic region **OR** impact in more than one category or region is negative but not severe.	Risk of negative impact to one or more environmental impact categories or geographic regions.	Impact is neutral. Environmental impact is insignificant **OR** positive and negative aspects of impact are relatively equal.	Potential for positive impact on one or more environmental impact categories or geographic regions.	Positive impact in one environmental impact category or geographic region **OR** impact in more than one category or region is positive but not extremely beneficial.	Positive impact on more than one environmental impact category or geographic region **AND** impact is extremely beneficial (in size and/or scope).
P	Significant gaps exist in policies and legislation **OR** impact of current policies and legislation (or lack thereof) is severe.	Small gaps exist in policies and legislation **AND** impact of current policies and legislation (or lack thereof) is not severe.	Risk of negative impact from potential policies or legislation (or lack thereof).	Impact is neutral. Impact of policies and legislation (or lack thereof) is insignificant **OR** positive and negative aspects of impact are relatively equal.	Potential for positive impact from potential policies or legislation (or lack thereof).	Policies and legislation adequately address issues **AND** impact of policies and legislation is positive but not extremely beneficial.	Policies and legislation fully address issues **OR** impact of policies and legislation is extremely beneficial.

Figure 2: Example STEEP rubric shared during Training

Day 2: Systems Thinking and the Sustainable Development Goals
The second day began with a recap of the first day's discussions and an in-depth session on systems thinking, a critical approach to understanding the interconnectedness of engineering, society, and the environment. This session included an introduction to the Iceberg Model, which emphasizes addressing systemic issues underlying visible events, such as environmental crises. Faculty explored how adopting a systems-thinking approach could help students connect technical problem-solving to broader social and environmental justice issues.

Building on this foundation, the United Nations Sustainable Development Goals (SDGs) were introduced as a guiding framework for sustainable and equitable solutions. Faculty participated in an interactive activity to identify opportunities for aligning their courses with specific SDGs, considering how these goals could be addressed through systems thinking and project-based learning. For example, faculty discussed how to incorporate SDG 10 (Reduced Inequalities) into engineering courses by addressing disparities in access to clean water and sanitation.

Day 3: Course Development and Actionable Modules
The third day focused on supporting faculty in the practical development and revision of course materials for the fall semester. Faculty were given dedicated working time with guidance from workshop facilitators, who provided feedback on how to strengthen the integration of the EOP framework and social justice principles into their teaching. Participants shared drafts of their revised course units (see Figure 3 and 4), fostering a collaborative environment where faculty could exchange ideas and insights.

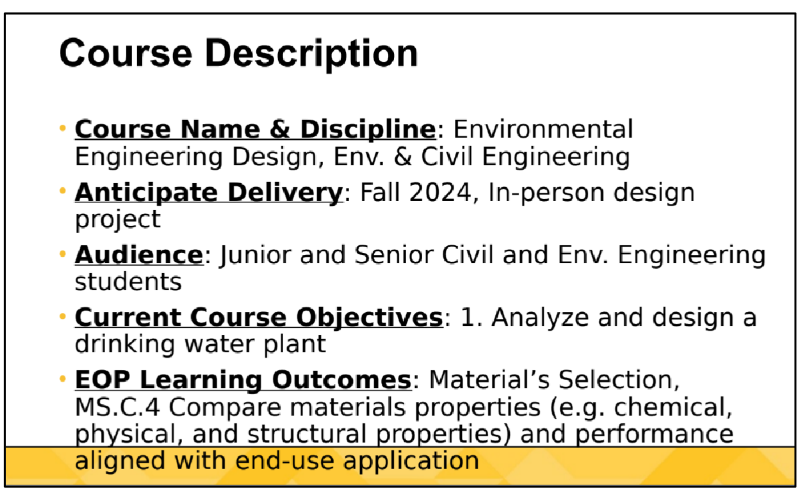

Figure 3: Learning Tool developed during Training (Course Description)

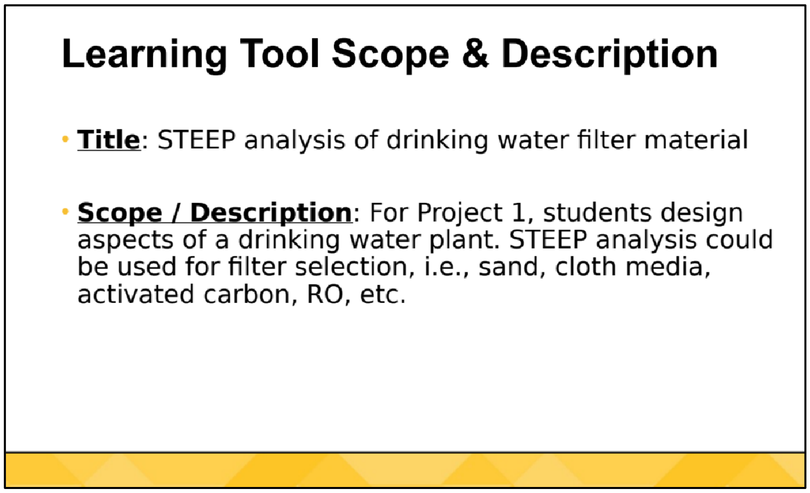

Figure 4: Learning Tool Scope and Description

The workshop concluded with a reflective session, where participants shared their experiences and outlined plans for continued integration of social and environmental justice into their courses via the EOP Framework. Faculty were encouraged to embrace these changes not only as pedagogical enhancements but also as contributions to broader equity-focused educational reform.

B. Study Design

This study had 2 main aims: (1) to evaluate the effectiveness of a targeted EOP training to equip faculty with tools to integrate critical conversations around social justice and environmental sustainability into their teaching practice; and (2) to evaluate the impacts on the students because of the EOP-aligned curriculum. A mixed methods approach was adopted to address aim (1), and a qualitative analysis was used to examine student work samples to evaluate impacts in aim (2).

C. Data Collection

Aim 1: Data were collected through a structured survey distributed to KSU faculty participants who attended the summer training (n=12). A total of 9 faculty responded to the survey, which included both open-ended and closed-ended questions designed to capture faculty perspectives on the following:

1. Characteristics of effective EOP-aligned curricula.
2. Areas needing improvement in content delivery.
3. Challenges encountered during planning and implementation.
4. Changes in teaching practices following EOP integration.
5. Changes in faculty understanding of EOP principles.

6. Influence of EOP on content integration.
7. Faculty interaction and collaboration.
8. Resource needs for sustained implementation.

The survey responses aimed to evaluate how faculty training and application of the EOP framework influenced their ability to engage students in critical discussions about sustainability and social responsibility. The survey responses also evaluated the status and ease of implementation.

Aim 2: Student reflections (n=30) were collected from one course where the EOP-aligned curriculum was implemented. These reflections required students to apply the STEEP framework to analyze the Atlanta, Georgia water main crisis comprehensively. Assignments were designed to encourage critical thinking about the interconnectedness of social justice, sustainability, and engineering solutions. Reflections also included personal insights into the societal and environmental impacts of the crisis and the role of engineers in addressing these challenges.

D. Data Analysis

Aim 1: The open-ended responses from the faculty survey were analyzed using the Constant Comparative Method (CCM), a qualitative research approach designed to systematically identify and refine themes through iterative coding. First, open coding was conducted to label recurring concepts and patterns across the responses, such as sustainability awareness, teaching practices, and resource needs. These initial codes were then grouped into broader categories during axial coding, allowing related concepts to be organized under overarching themes, such as "Teaching Enhancements," "Ethics and Sustainability Awareness," and "Resource and Funding Needs." This iterative process ensured a comprehensive understanding of faculty perspectives, while cross-referencing themes with the EOP framework provided alignment with the study's objectives. By constantly comparing and refining codes, the analysis captured both commonalities and unique insights across faculty experiences, offering a nuanced perspective on the efficacy of the training program and its impact on teaching practices.

The closed-ended responses from the faculty survey were analyzed to evaluate the effectiveness of the EOP framework training and its integration into teaching practices. The analysis focused on questions that provided categorical response options, such as the extent of faculty implementation of EOP concepts and their willingness to share implementation experiences. First, the responses were examined using descriptive statistics to calculate raw counts for each response category, providing a foundational understanding of the data distribution. Percentages were then calculated for each category to allow for a clearer interpretation of trends and proportions relative to the total responses. This combination of frequency distributions and response percentages enabled a detailed assessment of the faculty's engagement and perceptions of the EOP framework. The analysis offered insights into key themes, such as faculty adoption rates of the EOP framework, interest in collaboration, and potential barriers to implementation. These findings were then contextualized within the study's objectives to evaluate the broader impact of the training program on fostering social and environmental responsibility in engineering education.

Aim 2: The CCM was also employed to analyze the student reflections:

1. **Open Coding:** Responses were coded for recurring ideas across the STEEP domains. Initial codes included "Public Engagement," "Equity in Access," "Innovative Monitoring Technologies," and "Green Infrastructure."
2. **Axial Coding:** Related codes were grouped into broader categories, such as "Social Equity and Engagement," "Infrastructure Resilience," and "Policy and Funding Priorities."
3. **Selective Coding:** Overarching themes were identified to connect STEEP insights to the EOP framework's goals, emphasizing sustainability, social responsibility, and critical thinking.

E. Ethical Considerations and Validation

This study adhered to rigorous ethical standards to ensure the integrity and reliability of the research process. Institutional Review Board (IRB) approval was obtained prior to data collection, guaranteeing compliance with ethical guidelines for research involving human subjects. Faculty participants were informed of the study's purpose, their voluntary participation, and their right to withdraw at any time without penalty. Informed consent was obtained, ensuring participants were aware of the potential risks and benefits associated with the study. To maintain confidentiality, all survey responses and student reflections were anonymized before analysis. Unique identifiers were used to ensure data could not be traced back to individual participants. Data storage adhered to institutional data protection policies, with access restricted to authorized researchers.

The validation of qualitative findings was achieved through methodological triangulation, combining open coding, axial coding, and selective coding to ensure a comprehensive understanding of themes. Regular peer debriefing sessions were conducted to refine codes and themes, enhancing the credibility and reliability of the analysis.

IV. Results and Discussion

A. Aim 1: EOP Training Effectiveness

The analysis of the closed-ended survey responses reveals critical insights into faculty engagement with the EOP framework and the training program's effectiveness. The following is a summary of findings:

1. **Faculty Implementation of EOP Concepts** - Most faculty respondents (68%) reported having integrated the EOP framework into their courses. This demonstrates a strong level of adoption following the training. A smaller but notable portion (20%) indicated they had not yet implemented the framework, while 12% were uncertain about their level of integration. These findings highlight both the effectiveness of the training and the potential need for additional follow-up or support for those who have not yet fully implemented EOP concepts.

2. **Willingness to Share Experiences** - An overwhelming majority of respondents (78%) expressed a willingness to share their experiences of implementing the EOP framework with their peers. Only 15% indicated no interest in sharing their experiences, while 7% were undecided. This strong interest in collaboration suggests an opportunity to leverage faculty insights to refine and expand the program's impact.

3. **Key Observations** - The survey results revealed several important insights into the adoption and potential of the EOP framework training. While most faculty members successfully integrated the framework into their courses, a subset of respondents indicated barriers to implementation, such as difficulty aligning EOP principles with existing course objectives or challenges associated with competing professional demands. These findings suggest the need for tailored support, including additional resources or guidance to address these specific issues. Furthermore, the high level of willingness among faculty to share their implementation experiences underscores a strong potential for community-building. For those who have not yet implemented the framework, targeted interventions could focus on addressing hesitations and encouraging adoption, ensuring the framework's principles are more widely understood and applied.

The qualitative analysis of faculty survey responses provided rich insights into how the EOP framework training influenced teaching practices, awareness of social justice, and sustainability integration. Using CCM, the following key themes emerged that illuminate both the successes and challenges associated with the implementation of EOP principles:

1. **Integration of Sustainability and Social Responsibility** - A recurring theme across faculty reflections was the emphasis on integrating sustainability and social responsibility into engineering curricula. Faculty frequently cited the relevance of linking technical concepts to societal and environmental contexts, with one respondent noting, “Sustainability isn’t just an environmental issue; it’s a social justice issue too.” This underscores the transformative impact of the EOP training in expanding faculty perspectives on the broader implications of engineering decisions. Moreover, faculty highlighted how tools like the STEEP framework enabled critical analysis of real-world challenges, fostering deeper student engagement with sustainability principles.

2. **Enhancing Student Engagement and Awareness** - Another significant outcome of the EOP training was its influence on student engagement and awareness. Faculty described how applying the framework allowed students to consider multidimensional aspects of engineering problems, particularly their social and environmental impacts. For instance, a faculty member shared, “Using STEEP helped students connect technical solutions to community outcomes, making them more conscious of their role as socially responsible engineers.” This demonstrates the framework’s ability to foster systems thinking and ethical awareness, aligning with the program’s overarching goals.

3. **Challenges in Implementation** - Despite the positive outcomes, faculty identified notable challenges in implementing the EOP framework. A common issue was balancing the integration of sustainability and social justice topics with existing technical content. One respondent reflected, “It’s difficult to focus on social impacts when so much of the curriculum is driven by technical requirements.” This highlights a tension between traditional engineering education priorities and the interdisciplinary nature of EOP principles. Additionally, faculty noted resource constraints, including the need for readyto-use instructional materials and support for activity design.

4. **Building a Community of Practice** - The qualitative responses also revealed opportunities for enhancing faculty collaboration. Many participants expressed a desire to share their experiences and learn from peers, indicating potential for a community of practice centered around EOP implementation. As one faculty member remarked, “Sharing ideas and materials with colleagues has been invaluable in refining my

approach." Establishing such a network could address challenges and promote sustained adoption of EOP principles.

B. Aim 2: Student Impact

Student reflections (n=30) revealed rich insights into how the EOP-aligned curriculum influenced their understanding of social justice, environmental sustainability, and their roles as engineers. The STEEP framework (Social, Technological, Economic, Environmental, Political) served as a lens for students to critically analyze the Atlanta water main crisis and connect theoretical concepts to real-world challenges. The following themes emerged from the CCM analysis:

1. **Social Equity and Community Engagement** - Students consistently recognized the social consequences of infrastructure failures, emphasizing the disproportionate impact on marginalized communities. For example, one student highlighted, "Hospitals and senior centers struggled to meet basic needs during the water crisis, putting vulnerable populations at risk". Another student noted the frustration expressed by residents, stating, "The delayed communication from city officials amplified the distrust between the government and the people they serve"

2. **Technological Innovation and Infrastructure Challenges** - Reflections frequently cited the aging water infrastructure as a critical issue. One student commented, "Atlanta's pipes, many over 80 years old, require not only replacement but also the integration of smart monitoring systems to detect issues early". This sentiment was echoed in discussions about the importance of adopting advanced technologies, such as ultrasonic testing and leak detection systems, to enhance resilience and efficiency in water management.

3. **Economic Impacts and Funding Priorities** - Students identified significant economic consequences of the water main crisis, including business closures and revenue losses. One participant wrote, "The economic toll on local businesses, especially those reliant on water access like restaurants and tourist attractions, highlighted the importance of proactive investment in infrastructure". The discussion also revealed a strong consensus that prioritizing funding for infrastructure upgrades is essential to mitigate such events.

4. **Environmental Sustainability and Resilience** - Students demonstrated an advanced understanding of the environmental implications of the crisis, including water contamination and runoff. "The flooding caused

significant pollution of local waterways, exacerbating existing environmental challenges and underscoring the need for sustainable urban planning solutions like green infrastructure," one student reflected. The emphasis on environmental stewardship was often linked to discussions about climate change adaptation.

5. **Political Accountability and Governance** - Political leadership and its role in addressing the crisis were critically examined. A student reflected, "The lack of a comprehensive response plan and delayed communication from officials not only prolonged the crisis but also eroded public trust in local governance". Many participants suggested that political leaders must prioritize transparency and involve communities in infrastructure planning.

V. Conclusion

A. Summary of Key Findings

This study demonstrates the transformative potential of the EOP framework in fostering socially conscious and environmentally responsible engineers. By integrating the STEEP framework into the curriculum, students demonstrated enhanced critical thinking and systems-level analysis of complex environmental crises, such as the Atlanta water main incident. Key findings include:

1. **Broad Impacts Identified**: Students effectively utilized the STEEP framework to connect technical, social, and environmental dimensions, showcasing an ability to analyze issues holistically.

2. **Increased Awareness**: Students' reflections revealed a deeper understanding of sustainability as an integral part of engineering, emphasizing its role in addressing societal challenges.

3. **Practical Recommendations**: Students proposed actionable solutions, including investments in green infrastructure and advanced monitoring systems, reflecting critical thinking and real-world applicability.

Additionally, faculty engagement through the EOP-aligned training program enhanced their ability to embed sustainability and social responsibility into their teaching, as evidenced by changes in teaching strategies and curriculum design.

B. Study Limitations

While the findings underscore the success of the EOP framework, the study faced several limitations:

1. **Sample Size**: The study analyzed reflections from a limited number of students (n=30) from a single course, which may constrain the generalizability of the results to broader engineering education contexts.

2. **Short-Term Focus**: Data collection focused on immediate outcomes following the implementation of the EOP curriculum. The long-term impacts on both faculty teaching practices and student career trajectories remain unexplored.

3. **Institutional Variability**: As the study was conducted in a single institutional context, the findings may not account for differences in institutional priorities, resources, and student demographics at other universities.

C. Future Research Directions

To build upon these findings and address the identified limitations, future research should:

1. **Expand the Scope of Analysis**: Incorporate reflections and feedback from diverse engineering programs and institutions to assess the adaptability and scalability of the EOP framework.

2. **Conduct Longitudinal Studies**: Investigate the long-term impact of EOP training on faculty teaching practices and students' professional careers, particularly in fostering ethical decision-making and sustainable engineering solutions.

3. **Assess Institutional Support**: Explore the role of administrative and institutional support in facilitating the integration of sustainability and social justice into engineering education.

4. **Develop Enhanced Resources**: Investigate the effectiveness of tailored teaching resources and case studies in enabling faculty to implement EOP-aligned curricula effectively.

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