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Co-Designing Engineering Service Trips for Semi-Rural Amazonian Communities

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Work in Progress: Co-designing Engineering Service Trips to Semi-rural Amazonian Communities

Abstract

In 2025, a group of students from an interdisciplinary team at Universidad San Francisco de Quito (USFQ) organized a service trip to implement water purification systems in remote Amazonian communities in Ecuador. The goal of the trip was to provide safe drinking water by installing purification units at a local community school, delivering technical training on system maintenance, and conducting sanitation and hygiene education for community members. The intervention was co-designed with the community, following participatory design principles, to ensure that the solutions met the local cultural and environmental needs. This experience focused on the challenges and lessons learned during the co-design process, which were compiled into a best practices manual to support future projects in similar rural and rainforest settings. The project proposed adapting this methodology to facilitate collaboration between students, faculty, stakeholders, and communities for future humanitarian engineering interventions in Amazonian regions.

Introduction

The World Health Organization reports that a significant portion of the global population still lacks reliable access to potable water, adequate sanitation, and electricity [1]. In the coming decades, critical pressures will arise from increasing demands for energy, food, land, clean water, public health systems, and other essential resources [2], [3]. Meeting these growing needs is fundamental to ensuring a minimum standard of living for all individuals[4], [5].

In the Ecuadorian Amazon, these global challenges are further intensified by the expansion of illegal gold mining. Unregulated mining operations, particularly small-scale artisanal activities, have proliferated across provinces such as Napo, Orellana, Sucumbíos, and Zamora, leading to substantial deforestation and the release of toxic chemicals into freshwater systems [6], [7]. These activities have led to alarming levels of mercury contamination affecting aquatic life and threatening the health of Indigenous populations who depend on fish as a primary food source [8]. Addressing these complex socio-environmental dynamics requires not only technical solutions, but also culturally sensitive approaches that engage directly with local governance structures and environmental justice concerns.

In response, engineers are actively engaged in devising sustainable strategies to mitigate deficiencies in access to these vital services, implementing them in underserved communities across the globe. This approach aligns with the principle of Humanitarian Engineering (HE). Presently, HE is being integrated into modern engineering curricula, fostering a transformative perspective among faculty, students, and collaborators. It emphasizes the dual objective of academic development and real-world application, enabling students to refine their professional competencies while contributing meaningfully to community-based challenges [4].

Humanitarian Engineering (HE) initiatives demand strong technical competencies aimed at executing solutions that are sustainably conceived [9]. Nevertheless, community involvement plays a pivotal role. The degree to which a project succeeds is closely tied to the extent of community engagement and their availability to participate [10]. A thorough comprehension of the community's unique characteristics, including its social and cultural dynamics, is essential to foster trust and facilitate effective communication, both of which are critical for establishing meaningful collaboration and partnership. Alongside this contextual understanding, students and faculty mentors construct an operational framework grounded in ethical integrity and professional conduct, although such standards may not be universally applicable across all communities [9]. To ensure the initiative is contextually relevant and purpose-driven, it is vital that both students and faculty account for economic, social, environmental, and gender-related considerations [9]. Each community must be approached as a distinct and individual entity.

The proposed framework for collaborative design of this HE initiative is grounded in the five foundational principles outlined by Mazzurco and Jesiek. The primary aim of the project is to offer a structured approach for educators and professionals to co-develop engineering service-learning experiences in partnership with semi-rural communities in the Andean region. Student-led organizations such as Engineers Without Borders (EWB) and the Society of Women Engineers (SWE) will be involved in the initiative. This co-design model is intended to support both faculty and students in navigating the complexities of such projects, thereby enhancing their chances of success. Consequently, the HE intervention will not only respond to the specific needs identified within the community, but will also promote the development of essential competencies among students, including leadership, effective communication, critical thinking, and the practical application of technical knowledge in diverse real-world settings [9], [11], [12].

Background/Framework

The Ecuadorian Amazon is primarily composed of remote rural areas inhabited by Indigenous populations whose subsistence is closely tied to forest-based and small-scale agricultural activities [13]. These communities possess deeply rooted systems of environmental governance, with particular emphasis on the spiritual and cultural dimensions of water and land. Water is not merely a physical resource but is regarded as a sacred and life-giving element, linked to cosmologies that recognize rivers and springs as sentient beings [14]. As a result of these belief systems, limited emphasis has historically been placed on the development of centralized potable water systems. This worldview can lead to reduced awareness of waterborne contaminants and the health consequences of polluted water [15]. It is therefore critical to introduce hygiene and sanitation education tailored to the cultural frameworks of these communities, in order to mitigate disease risk and promote well-being.

In the Amazonian context, limited access to safe drinking water is closely linked to structural and culturally embedded challenges. In many communities, water is not viewed solely as a utilitarian resource, but rather as a symbolic element with spiritual and communal significance [16]. This worldview, combined with the limited coverage of treated water systems, contributes to a low perception of risk associated with water contamination [17].

Furthermore, traditional hygiene and sanitation practices often differ from institutional approaches promoted by external actors. In this context, environmental health interventions must consider not only technical infrastructure but also cultural practices, usage patterns, and local governance dynamics around water [18].

In this study, Humanitarian Engineering (HE) is defined as the process of designing within specific contextual constraints to directly enhance the living conditions of underserved populations in the Ecuadorian Amazon [19]. The literature underscores the potential pitfalls of insufficient community involvement in HE initiatives, particularly in culturally rich and ecologically sensitive regions such as the Amazon. Given that project success in these settings heavily relies on sustained local participation and long-term collaboration, it is essential that all involved actors align with the five principles outlined by Mazzurco and Jesiek. These principles provide a structural approach for facilitating meaningful engagement, participatory planning, and effective management. Accordingly, it is imperative to establish culturally appropriate strategies that foster constructive dialogue and cooperation between engineers and Indigenous or rural community members, thereby supporting the achievement of the project's goals. Scholarly work offers valuable frameworks that enable professionals, educators, and local stakeholders to engage more productively in co-creating context-specific engineering solutions.

Co-design involves developing solutions collaboratively with the people who will ultimately use or deliver them [20]. In Amazonian territories, this process requires continuous interaction between engineers and community members to ensure that proposed solutions align with local expectations and daily practices [21]. One of the main challenges is to define clear objectives that not only improve the technical performance of the intervention but also respect the social dynamics of the territory. In response to current humanitarian challenges and the complexity of working in culturally diverse and ecologically sensitive regions, many engineering programs have incorporated Humanitarian Engineering into their curricula [22]. These programs aim to prepare students to engage with real-life problems in ways that are both socially responsible and context-aware [23], [24], [25]. In the Amazon, where cultural beliefs, historical processes, and geographic isolation strongly influence local governance and access to services, engineers must critically assess these factors to adapt their interventions in respectful and sustainable ways [9], [26].

A comprehensive framework must be developed not only to strengthen engagement with community members, but also to incorporate educational and training dimensions by emphasizing essential competencies such as humility, self-reflection, intercultural sensitivity, and active listening. This study draws upon the work of Mazzurco and Jesiek [27], whose framework articulates practical approaches to promote meaningful community involvement in HE initiatives. Each of the five principles they propose outlines concrete methods for facilitating participation and highlights the risk associated with neglecting collaborative engagement, particularly in culturally diverse regions like the Ecuadorian Amazon. These principles may be interpreted as sequential steps that support the inclusion of local stakeholders, leverage community-based knowledge and resources, embed ethical considerations, cultivate trust, and foster the development of effective multidisciplinary or interdisciplinary teams. As such, these principles serve not only as ethical and relational guidelines but also as strategic tools for addressing technical challenges within complex socio-environmental contexts. Figure 1 below presents Mazzurco and Jesiek's five guiding principles designed to strengthen community collaboration in HE projects.

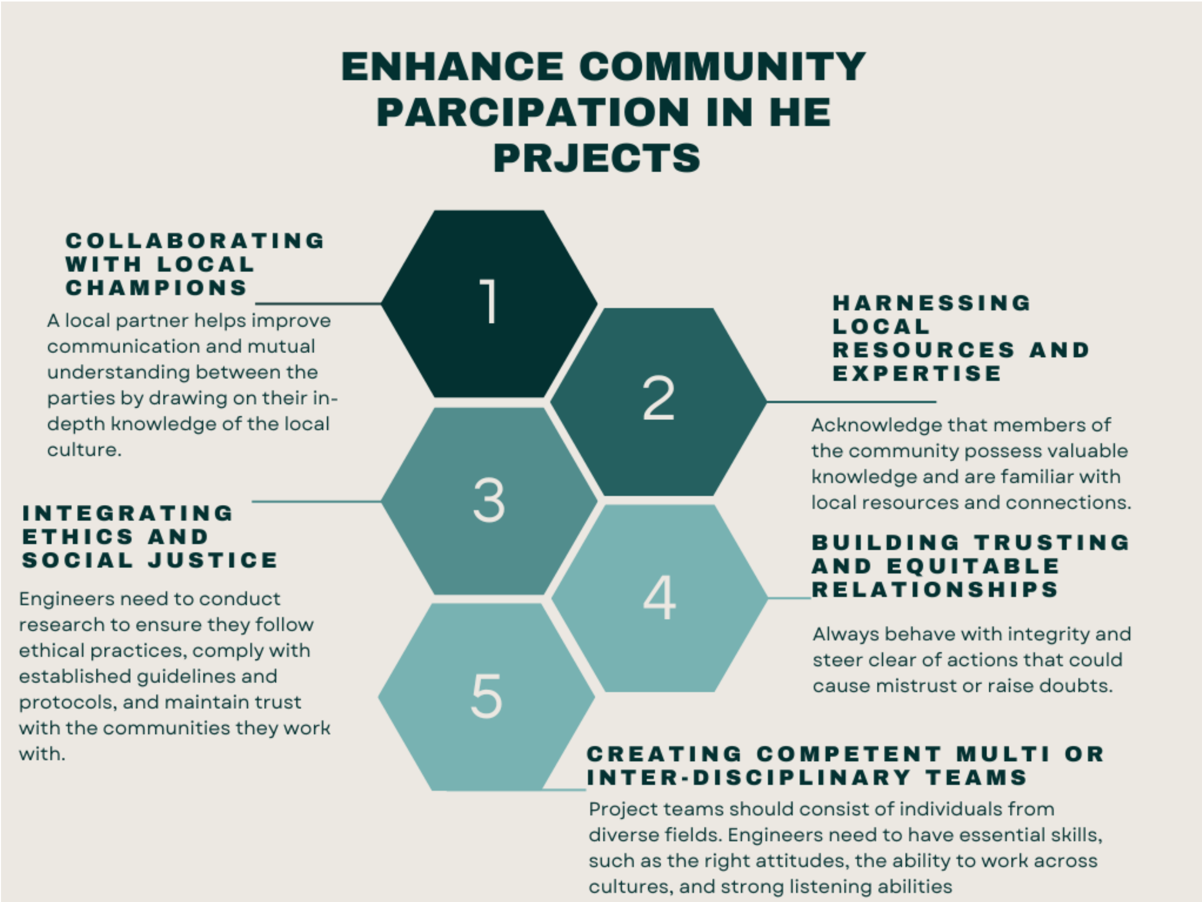

Figure 1. Mazzurco & Jessiek's 5 guiding principles to enhance community participation.

The first principle consists of collaborating with local champions, such as community-based organizations or NGOs with long-standing involvement in the Amazon region [27]. These actors must demonstrate a genuine commitment to both the well-being of the community and the objectives of the project. The second principle focuses on harnessing local resources and knowledge. In the Amazonian context, this includes physical resources such as terrain, water sources, and biodiversity, as well as the participation of community members through their labor, traditional skills, and ecological knowledge. Utilizing these local assets enhances the potential for long-term, sustainable outcomes. The third principle is integrating ethics and social justice. In collaboration with communities in remote and often marginalized Amazonian areas, it is essential to consider ethical dimensions such as cultural respect, inclusivity, and equitable participation. The program's goal must promote human rights, expand local capacities, and facilitate cooperation between engineers and community members based on mutual respect and fairness [27].

The fourth principle focuses on fostering equitable and trust-based relationships, emphasizing the need to cultivate mutual trust between engineers and community members to ensure that resources and project activities are allocated fairly and in alignment with shared expectations. Recognizing the value of distributed leadership and cooperative task delegation is essential for effective collaboration. In this regard, engineers are encouraged to adopt a posture of humility and align their approaches with the community's worldview, thereby supporting participatory processes and reinforcing collective engagement [27]. The fifth principle centers on the formation of competent multidisciplinary teams. This involves promoting attitudes grounded in empathy, cultural humility, and openness toward diverse forms of knowledge. The initiative should prioritize meaningful interaction with local stakeholders while actively working to bridge potential divides between technical experts, community members, and other collaborators involved in the project [27].

Recognizing that Humanitarian Engineering (HE) projects should aim to empower communities establishes a foundational criterion for effective co-design between engineers and local actors in Amazonian territories. These projects must go beyond simply delivering technical solutions; they should also foster personal development in engineers, enabling them to build interpersonal relationships, understand local belief systems, and integrate meaningfully into the community and the initiative itself. Both engineers and community members should collaborate toward shared goals. In addition to identifying and addressing local challenges, HE programs offer valuable educational benefits: students gain essential soft skills such as communication, adaptability, and cultural sensitivity [28]. Their involvement in Humanitarian Engineering not only enhances their motivation but also contributes to the development of professional competencies and helps them envision potential career pathways [29].

Ultimately, research suggests that a lack of humility among project participants may jeopardize the success of the initiative. To strengthen collaboration between engineering professionals and community, members particularly in culturally diverse settings such as the Ecuadorian Amazon, it is essential to recognize and address specific barriers and competencies that influence interpersonal dynamics. While the five guiding principles provide a consistent ethical and operational foundation, they must be thoughtfully adapted to the unique circumstances of each Humanitarian Engineering (HE) project. Although all interventions are rooted in the same conceptual framework, their implementation should remain flexible and responsive to the social, environmental, and cultural specificities of the context in which they are applied.

Methods

The students from the interdisciplinary team at Universidad San Francisco de Quito (USFQ) applied the Five Guiding Principles by Mazzurco & Jesiek to co-design a Humanitarian Engineering project in several Amazonian communities sharing similar characteristics. The objective was to guide the students through structured steps that would enhance their involvement with the communities and ensure the success of the project. The first stage involved meeting with 25 students to assess their interest in participating in the humanitarian engineering initiative. Informational sessions were conducted with members of the EWB and SWE student chapters, alongside faculty advisors. After presenting the installation of water purification systems as the main goal, a leadership team was selected to coordinate activities among student volunteers, community members, faculty, and experienced student leaders who had previously worked on similar interventions.

The students were assigned to different tasks according to Five Guiding Principles. One group was responsible for selecting the community and identifying a local leader to serve as a liaison. After selecting the community, the students collected information about the local beliefs, customs, and culture. Preparatory meetings were held with students, faculty, the community leader, and the local champion to plan and organize the intervention schedule for the installation day. The activities extended beyond the technical work; the initial focus was on engaging with the community through interactive spaces to foster dialogue, trust, and mutual understanding. During these exchanges, students prepared a presentation to educate the community on the importance of safe water, its proper usage, and the maintenance of the purification system to ensure its ongoing functionality.

For future support, students established communication with the designated community water leader to provide periodic technical assistance. The project evaluation involved measuring community participation and willingness to engage. Students documented attendance at each activity and conducted informal interviews to identify potential barriers or challenges. These conversations addressed topics such as collaboration, participation in community events, inter-community relations, socioeconomic, religious, and ethnic diversity, interactions with government authorities at different levels, access to legal services, and connections with service and volunteer organizations. All responses were recorded, transcribed, and analyzed to assess the project's outcomes and overall effectiveness.

Results

The co-design pedagogy implemented in this project was structured around the Five Guiding Principles proposed by Mazzurco and Jesiek, which include collaboration with local leaders, mobilization of community-based knowledge and resources, integration of ethical reflection and social justice, cultivation of trust-based relationships, and the development of capable interdisciplinary teams. By adhering to these principles, students were able to confront technical challenges while maintaining active engagement with members of the Amazonian community. Additionally, they designed context-specific activities aligned with each principle to facilitate successful implementation throughout the different stages of the project.

Students held meetings with several local champions-organizations or individuals already active in different Amazonian communities and discussed their potential involvement during weekly planning sessions. Each local champion had ties to distinct territories, which required students to assess which partnership aligned best with the project's objectives. Key factors considered in this evaluation included the geographic location of the community, estimated travel time, population size, and the feasibility of supplying treated water using chlorinator systems. After selecting the most suitable community, students established contact through the identified NGO, whose local knowledge proved essential in helping them better understand the context. The initial step involved confirming the community's interest in the intervention via the local champion. If no interest was expressed, the process would restart with another community. Securing community willingness and availability was crucial before advancing to subsequent phases of the project.

In alignment with the second guiding principle, students began by conducting a self-assessment to identify their individual competencies, allowing for effective time and resource management. A coordination board was established, and responsibilities were distributed among subgroups, each tasked with a specific component of the project. These included assembling the technical water chlorinator system, recruiting local volunteers, organizing participatory activities with the community, facilitating co-design sessions, and developing technical training materials. This structured organization enabled students to deliver a coherent and effective presentation to the community. Furthermore, project activities were introduced to local leaders, who in turn helped identify community members with relevant expertise. Once the community had a clear understanding of the initiative, working groups were formed. It was essential that both students and community participants felt ownership of the project, and that they contributed within areas that matched their interests and abilities. Beyond project execution, additional elements such as capacity-building sessions were incorporated to ensure correct operation of water chlorinators. These efforts were aligned with the project's overarching goal of securing safe and sustainable access to potable water, including provisions for system maintenance and long-term use.

In applying the third principle-integrating ethics and social justice, students were required to conduct preliminary research about the selected Amazonian community. Coordination with the local NGO played a key role in facilitating this process, offering insights into cultural norms, sensitivities, and potential barriers. This preparation was essential to avoid misunderstandings or distrust between the technical team and the community. A critical aspect of this stage was acknowledging the authority of appropriate local leaders, in recognition of the community's hierarchical structures and governance. Understanding and respecting local protocols helped foster cooperation and encouraged active participation from community members throughout the intervention.

Once students had developed a comprehensive understanding of the community's cultural norms and modes of collaboration, they prioritized the establishment of trust-based relationships, a process that, although formally associated with the Fourth Guiding Principle, was intentionally sustained throughout the entire duration of the project. Building trust was critical to fostering an environment in which community members felt comfortable sharing their perspectives on the project's goals and contributing constructive feedback. This relational foundation facilitated equitable task distribution and fostered meaningful contributions from all participants. To support this dynamic, students were encouraged to engage with open-mindedness and respectful communication, demonstrating a genuine willingness to accommodate community input and to adapt project components accordingly. Importantly, students needed to remain flexible, recognizing that some of their initial plans might require revision in response to the evolving needs and preferences of the local context.

Lastly, the creation of competent multidisciplinary teams was essential to overcome barriers related to cultural, linguistic, and value-based differences commonly encountered in Amazonian contexts. Students were encouraged to approach these differences with openness, actively adapting to the community's worldview and social norms. This principle plays a crucial role in ensuring genuine community participation and preventing miscommunication during the project. To work effectively with non-technical community members, students needed to cultivate empathy, humanity, and respect for local expertise. Faculty advisors, recognizing the importance of alignment between students and the community, could recommend that students step back from the project if they are unwilling or unable to engage respectfully with the local culture, beliefs, or values. These types of experiences are intended to shape both the professional and personal development of future engineers through meaningful intercultural engagement.

Throughout the implementation phase, students encountered several challenges that affected the project's progress. One significant barrier was the limited technical knowledge among community members regarding the operation, maintenance, and resupply of the water chlorinator system. Another obstacle involved issues of gender dynamics and interpersonal trust. Students observed that engaging with women in the community posed particular difficulties, potentially due to the composition of the student team, which had a predominantly male presence. Additionally, broader cultural norms and belief systems presented constraints to implementation, particularly in the absence of external institutional support. In response to these limitations, the community had previously established a local water board to self-manage water-related concerns, which became a crucial actor in navigating project coordination and sustaining efforts toward improved water access.

Discussion

The results underscore a persistent gap between engineering practitioners and community members, rooted in divergences of culture, values, belief systems, and language [27]. Although the project was carried out within the same national region as the students, its implementation required careful attention to a range of sociocultural and contextual factors. These findings highlight the necessity for HE programs to integrate interdisciplinary perspectives. Doing so not only enables more effective responses to technical challenges, but also fosters the development of alternative design approaches that can better align with local realities and enhance the overall impact of the project [30].

Although Humanitarian Engineering (HE) projects rely on interdisciplinary collaboration, both faculty advisors and students must recognize that each discipline brings its own methods and perspectives for addressing problems, which can lead to coordination challenges and potential delays in implementation [31], [32], [33], [34].In this sense, HE programs should incorporate guiding principles not only for engaging with communities, but also for structuring collaboration among the project team itself. Achieving effective integration among disciplines is key to project success-particularly in the Amazon, where complex socio-environmental realities demand holistic approaches. In this process, active ownership and long-term commitment are essential to achieving lasting impact [4], [19], [22].

Humanitarian Engineering programs must incorporate a diversity of perspectives, beginning with those of students and faculty advisors [12], [31]. The value of these programs extends beyond the provision of sustainable solutions for underserved communities; they also offer students critical experiential learning opportunities and broaden their understanding of professional practice. HE initiatives are intentionally structured to allow students to apply their academic knowledge within real-world settings while simultaneously cultivating competencies that are not typically acquired through traditional classroom instruction. These experiences contribute holistically to students' professional formation. The framework proposed by Mazzurco and Jesiek serves as a practical guide to help students navigate project tasks and meet key objectives. Nevertheless, future interventions must account for specific social, cultural, and environmental characteristics of the target communities, as well as broader challenges inherent to the humanitarian context.

Conclusions

A common cause of failure in Humanitarian Engineering (HE) projects is the lack of meaningful community involvement from the initial stages of planning. The co-design approach presented here offers a structured methodology for engineering students to engage with local populations and address community-identified needs, while fostering inclusive participation. Each of the guiding principles functions as progressive step within the project cycle, yet successful implementation requires preliminary attention to contextual factors such as cultural norms, belief systems, and traditional modes of organization. In the Amazonian context, as in other Indigenous territories, recognizing community leadership and ensuring mutual respect are fundamental for successful collaboration. Acknowledging and integrating these dimensions is essential for fostering effective collaboration. Future efforts will focus on developing a lessons-learned manual based on this intervention, which will be incorporated into the planning and implementation phases of subsequent water chlorination projects. These insights are expected to enhance the sensitivity of student teams to sociocultural differences and improve the overall quality of co-design processes in future initiatives.

Looking ahead, Humanitarian Engineering (HE) projects in Amazonian communities should incorporate long-term strategies to ensure the appropriate use and sustainability of the services or technologies delivered. For example, periodic visits throughout the year should allow for the monitoring of the operational status of installed systems, such as water chlorinators in this case- while also providing opportunities for maintenance and reinforcing proper hygiene practices through ongoing dialogue with the community. It is essential that students develop plans that promote continued engagement beyond the initial installation phase. The ultimate goal should not be limited to service delivery, but should focus on how the community adopts, maintains, and benefits from the solution over time. Moreover, HE initiatives should be developed in collaboration with professionals from other fields such as medicine, education, and psychology, in order to reach vulnerable populations such as children, women, and the elderly. In culturally sensitive matters-like those related to women’s health and hygiene, it may be more appropriate for medical or psychosocial professionals to lead discussions, as engineers may not have the training or rapport to navigate those topics effectively.

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