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Beyond uncritical blindness: How critical thinking about engineering for community development could lead to socially responsible and sustainable projects

Dr. Juan C. Lucena, Colorado School of Mines

Juan Lucena is Professor and Director of Humanitarian Engineering Undergraduate Programs at the Colorado School of Mines (CSM). Juan obtained a Ph.D. in Science and Technology Studies (STS) from Virginia Tech and a MS in STS and BS in Mechanical and Aeronautical Engineering fro

Mateo F. Rojas, Colorado School of Mines
Sofia Lara Schlezak, Colorado School of Mines

MS in Humanitarian Engineering and Science

Emma Chapman, Colorado School of Mines

Emma Chapman holds a B.S. in Mechanical Engineering from Newberg, Oregon's George Fox University, where she participated in the Grand Challenge Scholar Program focusing on making solar energy economical and providing access to clean water. She is currently in Colorado School of Mines' Humanitarian Engineering Master's program concentrating in Environmental Engineering. Her Master's thesis is on the water accessibility, prioritization, and treatment methods employed by the unhoused communities in her hometown of Portland, Oregon, and her previous research endeavors include biosand filtration and residential scale agrivoltaics.

Beyond Uncritical Blindness: How critical praxis about engineering for community development could lead to socially responsible and just projects

Abstract

This paper explores how using concepts and frameworks from Science and Technology Studies (STS) to think and practice critically about engineering for community development (ECD) is a necessary precondition and preparation if engineering educators hope to instill socially responsible behavior in our students and social justice in their community projects. With the significant surge of community engagement projects in US engineering programs, there is a growing need for developing critical lenses for engineering students involved in community development, so they do not continue reproducing unfair neo-colonial practices and assumptions of past development practices. Here we explore how STS concepts have served engineering students to develop critical praxis, a more robust and responsible understanding of the relationships between engineering faculty, students, and communities, and the material and social worlds in which they are embedded, using community development projects related to artisanal gold mining, inclusive management of electronic waste, and water access for underserved communities as examples.

Background

As shown in our 2022 ASEE paper [1], pedagogies of formation are explorations that implicate the self in questioning "what engineering is for" and how answers to these questions begin to show students the "whys" and "hows" of the communities they want to serve. These explorations lead graduate students in our Humanitarian Engineering and Science (HES) Program to crave for understanding complex relationships among knowledge, power, technology, and society, domains that, thus far, they have learned to see as separate in large part due to effects of mindsets and ideologies in engineering education and how these shape the organization of curricula. For example, many students beginning to work on engineering for community development (ECD) crave understanding of how knowledges and technologies can be transferred across different places to be used by communities addressing a similar problem to gain power in front of more powerful actors (e.g., how can gold processing knowledge and technologies used by artisanal mining communities in Peru be used by communities in Colombia to minimize exploitation from large-scale mining). Or students want to understand how expert and lay knowledges enter into productive negotiations in problem definition and solution in community development projects while considering the power differentials between these two kinds of knowledges. Or students long for understandings of how communities can socially construct knowledge and technologies that will be accepted by more powerful entities like the state, corporations, and academia. These cravings open opportunities for learning STS concepts and frameworks[1] that critically question complex topics like: the reasons behind the separation among knowledge/technology/power/society in ECD when in fact they are deeply interrelated; the knowledge and technology unidirectional flows from North to South as forms

[1] The content of STS programs include scholarship from a wide array of humanities and social sciences, including anthropology, design studies, economics, history, philosophy, political science, sociology, etc. and, of course, STS now constituted as a field with its own journals, book series, encyclopedias, and conferences. Hence, in this article, we define STS content accordingly.

of post-colonial imperialism; the superiority of expert knowledge over lay knowledge; and the apparent passive reception of technology by users, to name a few.

Helping students realize that community problems cannot be solved through technological or sociological deterministic solutions, STS can also provide students with an understanding on how to avoid projects that prioritize the cultural enrichment of students from the Global North at the expense of the empowerment of less-powerful groups, and how to disrupt unjust structural forces that result in the advantage of some groups at the expense of the less-powerful. But this positioning of STS, as scholarship that can provide many critical insights, raises the following questions: How should this knowledge be shared with students? What kind of theoretical and pedagogical framework should guide STS-knowledge exchange between faculty and students, so it does not become an exercise of irrelevant theorizing (i.e., academic navel gazing) but a way to inform the practice of ECD in ways that empowers both students and communities? [2]. To answer these questions, we propose a framework for critical praxis in engineering research for ECD.

What is critical praxis in engineering research for community development?

Engineering faculty often enact the ideology of depoliticization [3] in the ways they construct, organize, and deliver curricula and how by valuing the technical over the social dimensions of engineering, they create a "culture of disengagement" [4]. Faculty divide the world between the technical and social dimensions, privilege and give more value to the former over the latter dimension [5], and, when challenged by students to demonstrate the relevance of content, provide a celebratory effect of technology on society often enacting the "ethics of material provisioning" in the classroom (e.g., without large-scale mineral extraction there would be no progress) [6] **.** When ECD topics or projects make their way into engineering curricula, or into student life in the form of Engineers Without Borders (EWB) projects, they are not exempt of the encroachments of depoliticization. Motivated by a desire to help and seldom accompanied by critical thinking, engineering students in these student-led projects often continue to divide the world between the technical and social, value the former over the latter in problematic ways, as when methods and assumptions made in design for industry are used uncritically in ECD, and then assume that technology will have a positive impact on community yet rarely prove that this is actually the case [7]. These technocentric approaches in ECD tend to exacerbate social injustices [8]. Humanities and Social Sciences (HUSS) faculty who teach undergraduates might not be exempt from depoliticization either. They just do the opposite in their courses, still separating the social from the technical, privileging the former over the latter, often providing examples of the negative effects of technology on society (e.g., Chernobyl, Space Shuttle). With engineering faculty as technological optimists on one side, and HUSS faculty often as technological pessimists on the other, yet both invoking the ideology of depoliticization and technological or sociological determinisms, students are left in the middle without effective options to better understand how technology and society interact and how this interaction could be put into practice in ways to empower the communities they want to serve [9][2].

One antidote for this dichotomy is critical praxis in engineering research for community development informed by STS. Adopting Paolo Freire's concept of praxis in some courses in our Humanitarian Engineering and Science (HES) program at Colorado School of Mines, we define this type of critical praxis as the processes by which the theories, lessons, and practices of ECD are enacted, embodied, or realized through dialogue, action, and critical reflection to transform reality [11], [12]. The realities that we seek to transform through critical praxis are primarily those of communities historically underserved by engineering, of students who want alternative pathways to serve people through engineering, and of faculty who want to move beyond the constraints of depoliticization and who want their work to have more impact on students and communities.

The people involved in this praxis generally fall in three groups: 1) Faculty as teacher-student; 2) Students as student-teachers; and 3) Community Members as both teachers and students of faculty and students and as validators of the processes and outcomes of ECD. As the name implies, *teacher-students* are faculty who possess certain expert knowledge in a subject matter (e.g., mechanical engineering, engineering education, STS) yet remain open to learn from both students and communities. *Student-teachers* are novice engineers in training who have the capacity to teach both faculty and community members. *Community Members* are both teachers and students who have the final say (validate) on problem definition, solutions, operations and long-term viability and sustainability of ECD projects. (see Fig. 1)

Figure 1. Ideally, faculty, students, and community members enter into relationships of teaching and learning in each of the main dimensions of praxis. Source: authors

[2] Albert Teich's book *Technology and the Future* (with more than 9 editions) divides the debates on technology impact on society between enthusiasts and pessimists, reflecting a larger cultural debate between these opposites that continues to go on to this date. While not constructive in our understandings of technology-society interactions, these ongoing debates show the power of the ideology of depoliticization in US higher education [10].

As scholars of Paolo Freire have pointed out, Freire's concept of praxis is extremely complicated as it is disseminated throughout his massive ouvre [13]–[15], has many intellectual influences (e.g., Gramsci, Marx, Nyerere)[16], has been applied mainly to education and also to other human domains [17] , and yet, it is highly misused and misconceived in the literature [11]. To help us navigate through the complexity of Freire's concept of praxis, which is a the center of his philosophical and political work, Peter Mayo, one of Freire's premier scholars, distills praxis around its most important elements: 1. Theory, transformation, reflection; 2. Critical distancing; 3. The material basis of consciousness; 4. The concept of concientizaçao or acquiring consciousness; 5. Critical literacy; 6. Reconciling the contradictions of opposites; 7. Authentic dialogue; 8. The collective dimensions of learning; and 9. The contextual basis of praxis. Using these elements of praxis in our HES Program at Mines, mainly in an introductory course called Advanced Engineering for Sustainable Community Development*,* we show in this paper how our faculty, students, and the communities we serve engage in critical praxis in engineering research for ECD, how STS scholarship contributes (or could contribute) to each element, and how students (co-authors in this paper) have experienced these elements in both the introductory course and their research in artisanal gold mining, inclusive management of electronic waste, and water access for underserved communities.

Theory, transformation, reflection. According to Freire, *action* on its own is mindless activism, and *reflection*, divorced from action, constitutes empty theorizing. And *theory*, divorced from action and reflection, becomes abstract navel gazing. So these three elements should be interdependent in a dialectical manner, that is contributing to each other while keeping each other in check, if we hope to transform reality (see Fig. 1). In our HES Program, graduate research theses have a theoretical grounding leading to action, which we call research translation [1], that then leads to reflection, through dialogue with peers, communities, and literature, that then leads to refining the initial theoretical framework and so on. For Theory, STS scholarship has contributed with theories and concepts of sociotechnical systems, change, and transfer [18][19]. For Transformation, STS provides concepts of knowledge transfer to aid research translation [20], [21] and a sociotechnical framework that has allowed us to transform existing concepts like global competencies into global *sociotechnical* competencies in humanitarian engineers [22]. For Reflection, STS provides students with the understanding that knowledge is socially constructed and reconstructed and hence how theories can be challenged, evolved, and changed for new ones. How did the students experience this dialectical interdependence between theory, transformation, and reflection?

Not all experiences in this dialectical cycle (see Fig. 1) begin with theorizing. For Mateo, a HES student and co-author of this paper, his experience began learning about the disastrous environmental and human health effects of large-scale gold mining pollution while on a volunteer visit in Peru with Amigos de las Américas. Deeply touched by this experience and already enrolled in the HES Program program, his theorizing started with learning about the history and criticism of development [23], [24] including, according to him, "as learning about the seemingly altruistic rhetoric used by development institutions to justify expanding the American presence in countries in the Global South. While the purported purpose of this presence was to improve the well-being of these countries, it resulted in creating or exacerbating dependencies on an increasingly globalized international economy and rarely had a focus on strengthening the sovereignty or capacities of what President Truman coined as 'underdeveloped areas'". Wanting to transform this form of developmentalism, he adopted one of our program's central frameworks -- Engineering for Sustainable Community Development criteria (see below)—and began reflecting on how to apply it to his area of research: the transformation of artisanal and small-scale gold mining (ASGM) processes to empower the less-powerful groups of ASGM miners in Latin America and reduce the use of toxic mercury in gold processing. Committed now to improve the livelihoods of ASGM miners, he went back to theory by drawing from the capability approach framework [25] [26] [27] to understand what "nations, international organizations and agreements, multinational corporations, NGOs, and individuals have a duty to protect" and to the application of this framework for designing for the world's poor populations to empower them to "live the lives that they have reason to value."

For Sofia, another HES student and co-author of this paper, her experience began with the realization that government agencies do not usually represent the interests of the group of people that she wants to serve as an engineer: informal recoverers (recuperadores) of electrical and electronic waste in low-income communities from Buenos Aires, Argentina. Wanting to understand how to reduce chemical risks involved in this form of waste management, she learned from STS scholars that, to avoid reducing poverty and social exclusion from defining a technical problem and providing solutions, the search for technological alternatives that activate inclusive development processes should include users from the moment the problem is set [28]. Thus, she was set on the quest to understand how recyclers have essential knowledge of their practice and the risks involved that must be also considered from the outset, as they *"are producers of knowledge and reality"* [29]. Putting this theorizing into action in her own field research, she interviewed e-waste cooperative members, conducted participatory observation in local neighborhoods, and organized two workshops with recoverers in Buenos Aires. Wanting to minimize the risks associated with open burning of e-waste, she engaged recyclers in a first prototyping stage of a wire stripper to prevent their exposure to hazardous chemicals. The participants had the opportunity to discuss its feasibility, advantages, and disadvantages in comparison with existing practices. She then reflected on this experience to realize the local e-waste workers have relevant levels of awareness about the risks of their activities, the time associated with open burning, local trade routes, and the local resource limitations that serve as key insights for future efforts for the construction of the proposed wire stripper.

For Emma, a third HES student and co-author of this paper, her experience began through her family ties and involvement in serving the unhoused community in her hometown of Portland, Oregon. There she witnessed the need of unhoused populations to secure water regardless of season, weather, gender, income, or living situation. Enrolled in the HES program and the ESCD class, she realized that she needed to research where water is available to unhoused communities, how it is used when there is access to it, and how unclean water is treated, if at all. Yet, not wanting to embody the problematic stereotype of the engineer as a top-down planner and solver of people's problems, she set on the quest to understand how to "decolonize my mind as Shrestha proposes in her paper [30]. That is the ability to humble myself and come from a mindset of collaboration rather than omnipotence like many of our predecessors." Also, drawing on STS histories of engineers doing community development in the 1960s [31], she "liked the idea of Volunteers in Technical Assistance (VITA) having no Cold War political agenda when they distributed tools and applications of engineering techniques to aid communities who reached out to them. This made their work more accessible to anyone who needed it although they fed straight into the concept of depoliticization." Having theorized a new attitude to research water access among unhoused populations, and like Mateo and Sofia above, realizing that people in the field have essential knowledge and are producers of knowledge, she was set to begin interviewing outreach workers who have deep knowledge of operation at access water points or water storage techniques within tents, etc.

Critical distancing. This element of praxis calls for educators and students to spend time in communities co-researching, gathering data and information, and sharing these with communities. All three actors need to obtain a *critical distancing from data*, especially that which is probably familiar to communities, e.g., that an abandoned gold processing plant is no longer operational, or that e-waste recyclers are burning cables to extract copper. According to Mayo, this is "to help people view the familiar from a different vantage point" [11]. Our HES students learn to analyze and codify field research data and then share it with faculty and communities throughout the research process and later during research translation strategies (e.g., workshops) so all make sense of the data in new ways. From STS, our students learn concepts related to the subjectivity and politics of data gathering, interpretation and dissemination [32-33] and how traditional practices of development attempt to cloud this subjectivity and politics under the veil of objectivity in ways that benefit the status quo [23].

For Mateo, the process of critical distancing began with a preliminary research trip to Colombia, where he engaged with ASGM miners, owners of gold processing plants, government officials, mining engineers, and mining engineering students to understand why and how communal gold processing plants have failed so he could propose better ways to design and build them in the future. Learning from STS-informed fieldwork, he achieved further critical distancing by not "[invoking] (a priori) theoretical categories, often those sacred to the core of a particular discipline, to characterize events and settings" to avoid producing "a radical decontextualization and destruction of local meanings" [citing 34, p. 111-112]. This critical distancing allowed him to compare data from two different mining communities and began making sense of the difference between the material and social conditions that gave rise to certain processing practices in ways that would make sense to all. In one site, a large-scale mining company restructured the gold processing arrangement which resulted in a system where miners have little to no say in how their gold is processed. In a second site, an attempt to improve the gold processing practices failed because a development agency did not fully account for the way miners use ancestral technologies, leading the miners to not have an incentive to use the plant. This plant now sits idle. Mateo is now committed to translate his research for non-academic audiences, including ASGM communities, government officials, NGOs supporting sustainable mining, and gold trading companies interested in building communal gold processing plants or improving the processing practices used in ASGM contexts.

For Sofia, critical distancing began with the STS lesson that the generation and dissemination of knowledge and data are processes not isolated from culture, history, and sociopolitical contexts. This realization has allowed her to interpret data from government, international organizations, e-waste cooperatives, and local communities in their proper contexts. For example, in her research on e-waste management in Argentina, she realized how some government agencies produce data to meet numerical objectives that are often part of their political agendas, simplifying structural problems and complex socio-environmental dynamics to isolated actions that serve to complete checklists. On the other hand, international organizations, which lose sight of local context and delegate to external "experts" the gathering and analysis of data, often misrepresent local specific situations. Even within the cooperatives and local communities, actors interpret data differently according to their position and interests. For instance, she explains that "even if cooperatives grow under a more democratic and socially just framework of doing business (the social economy), cooperative managers and workers do not have the same knowledge about the market, the legal framework, interinstitutional relationships, etc. This asymmetry could lead to power imbalance when it comes to risk management decision making". Committed to help different stakeholders understand each other's interpretations of the risks involved in e-waste management, she will translate her research to different audiences to promote an harmonized baseline of knowledge that will be fundamental in future co-designed interventions to reduce chemical risks in e-waste recycling.

Material basis of consciousness. Influenced by Marxist philosophy, Freire understood that people's material surroundings and social relations shape (and provide basis for) their consciousness of themselves in (and of) the world [11-12]. Taking this dialectical materialism as a starting point, our HES students engage in self-reflection of their material and social condition through perspective mapping [1], positioning their perspective in relation to the material (actual projects) and social dimensions (institutions and practices) in the history of engineering, development, and modernization [24, 35, 36], and, given the constraints and opportunities placed by the material and social dimensions of engineering and development, beginning to ask, what kind of ECD can I do that serves the communities that I care about? In [1] we described the process of student formation, first by helping students' map their perspectives (including their location, knowledge, desires) and then by connecting these to the histories of engineering and development. To understand how the material and social dimensions of engineering and development stand in relation to their perspectives and relate to their own education and practice, we engage students through critical reading, reflection and writing of STS works. Students, for example, learn how what constitutes engineering – i.e., who gets in, who is kept out, what problems are worthy of engineering analysis, who defines these problem spaces, etc.—is a political process where certain material conditions of capitalist exchange, and actors and institutions, often with sexist, racist, classist motives, decide how to construct and maintain the boundaries of engineering [37–43]. Through these examples, students learn the relationship between agency and structure in engineering boundary setting, how material and social dimensions shape knowledge acquisition and practice in science and engineering, and how they, through their own agency, can engage in boundary redefinition by carving spaces for humanitarian engineering projects.

Mateo became aware of the social and material basis of consciousness, first by engaging in self-reflection of his own material and social conditions and, after reading the STS-informed histories of engineering and development, learning to see the residues of these histories in his interactions with mining engineers, petroleum engineers, and geologists at his university. Many of these students are funded by or work for oil and gas companies and yet are unaware of how the material and social conditions at their institution shape their outlook and work. These readings, self-reflection and interactions prepared him to understand how the material and social conditions behind communal gold processing plants in Colombia have led to their failure since most communal plants have been designed with economic efficiency (higher gold recovery) as the main objective, with little to no consideration for how these plants could serve as a force of empowerment for ASGM communities. Rojas is now committed to advocate for a vision for communal gold processing systems that supports the sustainable community development of ASGM communities by employing miners' existing empirical knowledge, reducing dependencies on external or more powerful actors such as multinational mining companies, and strengthening the autonomy of these communities.

Like Mateo, Emma engaged in self-reflection, readings, and interactions with people to realize the material basis of her consciousness, namely that of living and experiencing housing as a securely housed individual throughout her life. She understood that the interests, privileges, and geographical locations of the housed population set, to a large extent, what is possible for the unhoused to do by dictating city ordinances, regulations, police enforcement, availability of food kitchens, etc. Realizing these constraints, she is now committed, for example, to highlight the close relationship between food and water insecurity by voicing the requests made in her survey such as the creation of 24-hour bottle-filling stations with small outdoor kitchens in uptown spaces.

Conscientizaçao. This element of praxis is about "the development of the awakening of critical awareness in a critical evolutionary process that is permanently unfinished, whose openness enlivens our dialectical relationship with the world and beckons us towards emancipatory futures" [44]. After self-reflection on the material basis of consciousness (see above), our HES students begin developing critical awareness of what they can and cannot do to change the material conditions and social relations in communities they want to serve. From STS, they study case studies of "positive deviants" who have challenged the dominant structures and ideologies of S&E and development [31, 45]. First, students learn about the histories and present forms and practices of the engineering mindsets [46], the ideologies of depoliticization and meritocracy [3], the culture of disengagement in engineering education [4], and how these can present specific challenges for the kinds of engineers they want to be, and for the kind of ECD they hope to achieve. These realizations, leaves them wanting for ways to counteract mindsets, ideologies and disengagement. STS literature can provide insights on how to counteract the mindsets of uncritical acceptance of authority and positivism and myth of objectivity and the ideology of depoliticization, for example, by reading how engineering is always political [47–50], the social dimensions of objectivity and positivism [32, 51], and how engineers have resisted authority [31, 45, 52]. Within these histories, students learn about “positive deviants” who have tried to resist dominance of the military-industrial-academic complex to put engineering at the service of alternative goals [48], or those who have tied to make the boundaries of engineering more inclusive for women, low-income persons, LGBTQ+, among others [53–55].

For Emma, for example, this awakening of critical awareness included questioning the many problematic viewpoints taught to her, explicitly and subliminally (hidden curriculum) in her undergraduate engineering major, the most significant of which was depoliticization. She came to question the portrayal of engineers as neutral and objective parties for, as preached by her professors, if they are applying math and science, they cannot be morally “right” or “wrong”. Her undergraduate curriculum never mentioned the role that engineers played in the history of colonization and oppression, nor provided guidance on how projects should not harm communities, while reinforcing the notion that engineers should keep their heads down and not question project outcomes beyond efficiency and cost. Identifying those traits within herself, she is now committed to overcome them and advocate for change in engineering at large.

Sofia began this process of critical awareness as a high school student when she visited mountain communities in Argentina where she observed communities facing difficulties when using solar panels designed for them by engineers who did not consider the local context and availability of spare parts and maintenance. During her education as a chemical engineer, she experienced a curriculum that focused exclusively on processes and products, leaving out discussions about users, the environment, and sustainable development. Her STS readings in the HES Program have allowed her to become critically aware that the technologies that engineers deploy reciprocally interact with politics [56], that ideologies of depoliticization and meritocracy shape the content and reward structure of her undergraduate curriculum [3], and the ways in which development is sold as progress [23] in the context of the growing global climate change consciousness materialized in the high-tech renewable energies expansion, though resulting in solar panels that do not work for some communities.

Critical literacy. This form of literacy transcends functional literacy (e.g., reading, writing, math) and includes reading the power dynamics of reality, unveiling contradictions in a particular context, and learning how ideology resides in language and practice [11]. Our students engage in critical reading, writing and reflection on the promises and ideologies behind development, and the roles of science and engineering in it, and on the power dynamics that has been established by old and new forms of development. From STS, our students learn to understand the power of technological determinism in justifying the colonizing missions of development and post-development ideologies and practices [57-58]. Students also learn about the history of the making and practice of international development, the ideology of modernization and the institutions that came to embody it (e.g., World Bank, USAID, Peace Corps, etc.), the assumptions about “others” that circulate and are reinforced through these institutions like Third World, underdeveloped, etc. [23], how international development became central to US foreign policy against communism during the Cold War, and later to the expansion of neoliberalism [35], and how new forms of post-colonial development now make part of the volunteering and higher education landscapes, including engineering practice education [59-60]. Using an STS lens, students learn how the construction of development knowledge relates to the political desires of those in power and how this relationship between knowledge and power in development is maintained through ideologies and institutions [23, 61]. They get to see, for example, how STS concepts like epistemic and technological determinism are useful to understand existing practices in development aid [62].

For Mateo, critical literacy manifested, for example, by learning to map development organizations, to see how the histories of development continue to materialize in these organizations, questioning new forms of post-colonial development, and identifying those forms and organizations that could lead to a different kind of development that includes local economic and political autonomy, protection of local ecosystem and social justice (See ESCD criteria above). These insights also allowed him to identify how these histories continue to influence the pedagogy of educational institutions training students how to practice "engineering for good." Mateo was able to see that many of these programs emphasized understanding the local context by engaging with members of their partner communities, only to take this information back to their team of engineers or professionals to create a solution for the problem. This approach, which does not teach students to necessarily include community members in all phases of the project, reproduces neocolonial pedagogies of "help" that value engineering knowledge and expertise over the capacities of the communities that engineers seek to serve.

Sofia learned from Argentinian STSers to critically question projects focused on the development of technology for social inclusion as these often fail or create more inequality because they tend to reduce poverty and social exclusion to a technical problem and become top-down, pro-poor intervention strategies and research efforts aimed to find 'appropriate technologies' [28]. Through her research, she is committed to go beyond technological development by developing other alternatives of socio-technical interventions that acknowledge the intricate relationships between materials, processes, and actors related to the e-waste management in Buenos Aires.

Authentic dialogue. This element of praxis calls for "allow[ing] for the interaction of different meanings emerging from all those involved…for grater circulation of different reflections…[and] for these reflections to be challenged from which new perspectives can emerge" [11]. We also define here the related element, **collective dimension of** learning which refers to how "people learn in a manner which connects the self to the rest of the social…Overcoming misconceptions and fixed ideas…occurs in settings where one is challenged by alternative perspectives" [11]. For both of these elements, our HES students engage in dialogues in the form of student-centered pedagogies in classroom settings, in lunch and learns between faculty and students, and in ongoing dialogue with communities before, during, after field research. In our classes, they learn how to apply the socially responsible engineering (SRE) framework, which emphasizes "contextual listening" [63] and identification of opportunities to create value with stakeholders so they can empathically engage communities before, during and after their field research [64]. Through specific coursework assignments, they explore and reflect with others on the reasons for being in HES and for wanting to do sustainable community development, to explore the constraints, opportunities, and pathways placed in front of them by the histories of their families, of engineering, of development, and by the multiple dimensions of their identity (gender, race, ethnicity, national origin, sexual orientation, etc.). Then collaboratively, they map the actors, activities (projects, organizations), the location of these activities, and the methods/processes involved in HES areas of interest (e.g., WASH- water, sanitation, and health) to begin establishing their own area of potential research or practice (e.g., water access for unhoused populations). In these course assignments, students learn to apply STS core lessons like that knowledge is socially constructed and reconstructed through dialogue and interactions, and concepts like "interpretive flexibility" and "object world" to help them understand how technological design and artifacts are understood, appropriated, and used differently by different actors [18, 65].

For Mateo, these elements of praxis have been vital in developing a diverse and nuanced understanding of humanitarian engineering and science and of his thesis topic. For example, authentic dialogue allowed him to identify situations in ASGM communities that reflected the harmful effects of developmentalism and, together with faculty, student peers, and community members, seeking alternatives to provide more autonomy and social justice for the communities he wants to serve. While in Colombia, his conversations with miners in two ASGM communities elucidated that the foreign actors that have carried out projects to improve their gold mining or processing practices have rarely sought to include miners' perspectives or knowledge in these projects. His conversations with engineering students and faculty provided a clearer picture of the hierarchy of knowledge and power that exists between technicians and mining engineers and the uncritical bias towards large-scale mining (LSM) at the expense of ASGM. This picture now helps him understand the priorities of engineers in regional- or national-level mining agencies and LSM companies and how these priorities constrain possibilities for the design and construction of communal gold processing plants and other projects seeking to improve gold mining or processing in ASGM contexts

Sofia took these elements of praxis to heart during the design and delivery of workshops with e-waste recoverers. Going beyond than just gathering data from the community, her research team built spaces for workers to share questions and concerns about the negative health and environmental effects related to the e-waste management and to evaluate the feasibility of the proposed device for wire stripping.

Emma engaged in these elements of praxis before starting her research, given her personal and family involvement with the unhoused community and outreach organizations in Portland. During her research, she invoked both elements of praxis to learn, for example, that different actors in this space have different views about what perpetuates the cycle of housing insecurity, whether it be a lack of access to food/water that exacerbates sickness, addiction, mental health crises, the housing market, or the economy. Despite these different views and that not all actors view water insecurity as an essential issue, Emma learned that actors in the outreach community share a desire to improve housing numbers and decrease the number of families on the street regardless of the metric they find most pertinent.

Solving the contradiction of opposites. According to Peter Mayo, "Praxis helps us view a situation critically, with a view to developing a vision that transcends the present power framework." But in this process we risk dehumanizing the oppressed and disenfranchised, i.e., those who we are trying to serve. So, the oppressed (e.g., communities as recipients of aid, students as learners) must be allowed to humanize the oppressor (e.g., communities to humanize students as community developers; students to humanize faculty as teachers) to end relations of oppression [11]. Our HES students learn to be attentive to these forms of oppression by developing empathy and epistemic humility that allows the oppressed (students, communities) to teach the oppressor (faculty, students as community developers) to counteract relations of oppression in teaching/learning and community development. Our students are introduced to two STS-informed frameworks aimed at counteracting forms of oppression brought by the power of institutions, practices and ideologies of engineering and development. First, the Socially Responsible Engineering (SRE) criteria is a normative framework for how students, as future engineers in ECD and other domains, should engage communities, especially those that lack power in the practices of international development or those that have to face corporate power. These criteria help students see 1) how power, agency, and structure relate to each other in the practice of ECD; 2) how technology as inherently political, hence how ECD projects will legislate human relations and behavior after they are deployed; 3) how to listen to all stakeholders contextually by paying attention to the past and present of their struggles; 4) being more attentive to those who are marginalized, to grasp their needs, desires and fears surrounding a specific ECD project so decision making can be more inclusive; and, 4) how it is possible to adapt engineering decision-making to promote economic, social and environmental shared values, acknowledging situations in which this is not possible and engineering projects should not move forward [64].

Next, students are introduced to Engineering for Sustainable Community Development (ESCD) criteria which have their origins in rural sociology [66] and we have modified them to be applicable to ECD projects and practice. These criteria are 1) Enhancing local economic diversity; 2) Enhancing political autonomy and self-determination of communities; 3) Reducing use of materials and energy; 4) Protecting local ecosystems by responsible stewardship of natural resources; and 5) Enhancing social justice [67]. Each ESCD criterion is historicized to show how specific actors and institutions, and relations of power/knowledge, created the problems behind each of these criteria in the first place. For example, many of the problems behind the lack of economic diversity and self-determination of communities can be traced back to the practices of international development and its main ideology: modernization. As fully documented in the histories of development, modernization is the main ideology behind the idea and practice of international development [68]. Yet often viewed as an outdated ideology of development, modernization has left legacies and many of its manifestations are still alive and well in many parts of the world, including agricultural monoculture (which leads to lack of economic diversity), technocracy (which brings reduction in political autonomy of communities), mass consumption touted as the highest state of modernization (which increases the use of materials and energy and leads to ecological devastation), and, in some cases, the authoritarianism of high modernism (which brings social injustice) [68-70]. After exploring the historical roots of each of the problems outlined above, we then motivate students to mobilize their agency and recognize how to mobilize the agency of others. They learn about potential interventions to counteract the harmful effects of modernization that include creating capacity-strengthening methods to increase local economic diversity; working with associative corporations to increase political autonomy of communities; focusing on circular economies and decentralized power generation to reduce energy and material consumption; and enhancing human capabilities as the goal of engineering for social justice.

While there are many strategies that our students learn to “humanize the oppressor”, whether students as community developers or government officials as regulators, we will focus here on two strategies: research translation and research extension [1]. In her research on socio-technical interventions to reduce chemical risk in informal e-waste management settings, Sofia will develop different research translation tools (e.g., short briefs with the key findings and suggestions, graphic and non-high-level technical flyers and posters) to allow e-waste workers to learn yet contest her research findings, and government regulators to become aware of the human dimensions of e-waste management behind reporting metrics that the government cares about. She has also engaged in research extension by participating in undergraduate design courses to bring students closer to the realities of e-waste management in Buenos Aires and Bogota while encouraging them to research and develop recycling machines and tools to be applied in informal contexts. In three different engineering design courses, she has mentored students to building empathic community engagement processes and being aware of power differentials while pursuing the reduction of risks and harms among recyclers, their families, and the environment.

Conclusion

In sum, our HES students learn that, like their own personal perspectives, the practices of engineering and development are historically situated, maintained and legitimized by knowledge/power relations that are socially constructed (and hence can be contested and transformed), and shaped by political desires. Like their own histories, the histories of engineering and development have material and social basis that have shaped their boundaries, allowing certain groups of people and problems in while keeping others out. Like their own knowledge, knowledge creation and dissemination in engineering and development have origins, personal and institutional interests and both visible and hidden connections to power. Like their own desires, the history of political projects in engineering and development have been shaped by visions of what engineering and development should be. Yet all of these can be theorized, reflected upon, and transformed through a critical praxis in engineering research for community development with STS scholarship as the main content for this process. As shown above, this praxis can be enacted as the pedagogy of the oppressed in both the classroom and ECD projects with the help of STS scholarship in the proper theorizing about knowledge, technology and power relations, the understanding of the material basis of consciousness and the acquisition of critical literacy and consciousness, and the transformation of relationships of oppression in both education and community development.

To expand this critical praxis to other domains of engineering education, especially undergraduate curricula, we recognize the challenges but also the opportunities. For example, while not all engineering programs have faculty trained in STS and/or students ready to embrace STS scholarship, there are opportunities for graduate students to insert their STS-informed research into undergraduate design courses and, even in small ways, begin infusing attention to critical literacy and material and social basis of consciousness as two of our students have done in first-, third- and fourth-year engineering design courses. Engineering faculty also can incorporate the rewrite of engineering problems to include attention to inequalities of power, resources, and opportunities as proposed in [9].

Faculty members in a particular institution interested in integrating critical praxis in their curriculum can organize workshops to explore where and how there are opportunities to integrate different the different elements outlined above in specific courses, projects, homework assignments, etc. For example, the material basis of consciousness can begin to be explored in an Intro to Engineering class by teaching students, using NSF data on the funding of engineering R&D and workforce allocations, how military and corporate interests dominate the profession, its workforce, and problem-area allocations.

We also recognize that there is a growing number of Engineering to Help (ETH) programs [60] that could benefit from incorporating some elements of *critical praxis* to help them reflect critically on their good intentions, the North-South power relationships, the use of "contextualization as virtue" [71], and, in some cases, the (mis)use of "social entrepreneurship" which often create new exposures to an increasingly unequal globalized economy, instead of developing projects that strengthen communities' autonomy from more powerful actors. As ETH programs grow, it will be essential to challenge the educational structures that deter engineering professors and students from engaging in these difficult questions as they seek to use their engineering abilities for "good." We will develop a framework for critical praxis of these programs in future papers.

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