Empowering Students to Empower Communities: Research Translation in Graduate and Undergraduate Engineering Education

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 Rojas
Casey Gibson, National Academy of Engineering

Casey Gibson, M.S., is an Associate Program Officer at the National Academy of Engineering (NAE) of U.S. National Academies of Science, Engineering, and Medicine. Gibson contributes to multiple NAE and cross-Academies initiatives, focusing primarily on the Cultural, Ethical, Social, and Environmental Responsibility in Engineering program. Gibson completed her M.S. from the Colorado School of Mines as a member of the inaugural cohort in Humanitarian Engineering and Science (HES). In the HES program, Gibson specialized in Environmental Engineering and conducted research under the NSF-funded ”Responsible Mining, Resilient Communities” project in Colombia. She was named Outstanding Graduate Student in HES. Gibson earned her B.S. in Biological/Agricultural Engineering and minor in Sustainability from the University of Arkansas, along with a B.A. in Spanish Language. In addition, Gibson served as a Fulbright-García Robles Scholar in Mexico.

Jaime Elizabeth Styer, Colorado School of Mines
Sofia Lara Schlezak, Colorado School of Mines

MS in Humanitarian Engineering and Science

©American Society for Engineering Education, 2024

Empowering students to empower communities: Research translation in graduate engineering research and undergraduate engineering education

Abstract

This paper shows how "research translation" (RT) can become an established practice in engineering education to provide necessary connections between graduate research and undergraduate learning and explicit social relevance of graduate research. RT has been defined by USAID as "a co-design process between academics and practitioners, where research is intentionally applied to a development challenge, and embedded in the research project from the beginning so that the result is a tested solution adapted for use as a product, practice, or policy." While the concept has a longer history in the health sciences and in commercialization of technology, RT remains undertheorized and underapplied in engineering, especially in engineering for community development programs. In this paper, we will review the literature on RT to identify barriers and opportunities for the development and implementation of RT in graduate engineering education, especially for those students interested in community development. Then we will present four case studies of graduate students in Humanitarian Engineering and Science (HES) at Colorado School of Mines (HES @ Mines) who have used RT to connect their research with undergraduate engineering education and with the communities they want to serve. The first case study will show how research on gold processing plants in ASGM has been translated to teach engineering students how engineering is ultimately a sociotechnical practice and how it can be disseminated so ASGM communities understand the power dimensions affecting their work. A second case-study will describe how RT can be used to teach engineering students community-based research methods and to empower communities at the intersection of ASGM and agriculture to evaluate environmental risks. A third case study will show how research on electrical and electronic waste (e-waste) recycling has been translated to teach students about engineering and community development and to empower communities to recycle e-waste in safer and more profitable conditions. A fourth case study will show how research on construction and demolition waste (C&DW) has been translated to teach freshmen engineering students about design for community and to empower communities near C&DW sites how to recycle these materials to diversify their incomes. The paper concludes with recommendations for how to begin making RT a more central feature of graduate engineering research.

Introduction

This paper has three purposes. First, we want to identify best practices in RT in community development and begin exploring how these can be translated into engineering education. Second, through four case studies, we show how graduate engineering students have, to some extent, followed these practices, where they fell short, and where they could improve. Third, we outline recommendations and begin exploring where and how these can be implemented in engineering education with the goal of creating a more socially just and responsible community-centered RT ecosystem. Given how RT challenges the status quo of academic research and how new this concept and its practices are in engineering, we have not been able to assess its widespread effectiveness. Hence, we do not have longitudinal data across time nor different institutions.

As described in [1], US graduate engineering research remains focused on preparing students for a shrinking pool of academic jobs and most students are dissatisfied by the lack of social relevance of their research. An article detailing the state of graduate education points out, "most graduate programs will, in fact, fail to deliver the training that students desire and society desperately needs. Graduate training remains focused on preparing students to address disciplinary knowledge gaps valued in a shrinking pool of faculty positions. While we invite students to apply for degrees based on their motivations to change the world, once they arrive, we do not prepare them to be successful change-makers. Current students report being discouraged from doing applied work, cut off from mentors who represent affected communities and constituencies, and given few opportunities to engage in the messy, value-laden contexts that await them upon graduation." [2]

This led some students in our Humanitarian Engineering and Science (HES) at Colorado School of Mines (HES @ Mines) to commit to RT and adopt USAID definition, aimed at bridging academic research with community development, which reads as follows: "a co-design process between academics and practitioners, where research is intentionally applied to a development challenge, and embedded in the research project from the beginning so that the result is a tested solution adapted for use as a product, practice, or policy." [3]. USAID defines 'adapted for use' as "a research product or set of research results that has been tailored for non-technical audiences with the intent of facilitating the application of the research. Research products translated for use include, but are not limited to policy briefs, policy recommendations, editorials, media, infographics, and blogs. Incorporation of research into a systematic review can also be considered translation for use. Workshops and workshop presentations designed for decision-makers and other non-technical audiences can also be considered a research product tailored for use." [3] Contrary to common definitions of RT, which view it as simply dissemination of research results after the research was defined, conducted, analyzed, and published by academics, we adopted a RT model that can bring the voices, needs, and desires of communities in the following stages:

1) definition of research questions and methodologies;
2) research process itself;
3) publication of the research results;
4) placing of research results in the context of other knowledge and sociocultural norms;
5) decision making and action taken by the research results; and
6) influence of future work.[4]

While our graduate students became aware of how this model can ostensibly promote more equitable power relations between engineering academics and the communities they want to serve, students were still embedded in academic structures and processes that made it difficult, if not impossible, to apply RT in all the places (1-6) outlined by the model. For example, most universities have already established and prescribed processes for graduate students to define research questions and methods with the advice, and sometimes full determination, of an academic faculty advisor and committee (often called thesis or dissertation proposal) often without any input from non-academic external stakeholders, let alone community perspectives that lack academic credentials. Similarly, the publication of results is often guided by the prestige

of academic journals (often measured by their Impact Factor) and the professional needs of academic advisors (e.g., promotion and tenure) than by the need for knowledge by communities. Furthermore, if a graduate student is funded by a federally funded research grant (e.g., NSF), s/he must comply with already structured research as stated in the grant proposal which rarely includes RT as defined and outlined above (NSF's Broader Impact criterion is not RT). In spite of these institutional, structural, and procedural constraints, the student co-authors in this paper developed a commitment to RT mainly due to the spaces that their HES graduate program opened to do so and the guidance of faculty committed to RT. Hence, as expected, their RT efforts had to be implemented somewhat haphazardly, often circumventing established academic practices but without placing themselves in trouble. Other students, while deeply committed to RT, found themselves prioritizing traditional academic writing, valued by academic mentors, while placing RT in the backburner. This conflict between academic structures, values, and processes, on one hand, and students' commitment to serve communities through a robust RT, on another, led us to examine RT best practices in the literature, assess how students' incidental RT efforts measure against best practices, and recommend structural and procedural changes to engineering research, especially that allegedly aimed at serving communities.

Literature review on RT best practices

As reported by [1], non-medical STEM fields have a recent and tenuous history of adopting RT, promoting forms of RT that privilege translation from basic research into for-profit commercialization [5] and educational research into pedagogical practices [6] while ignoring, almost completely, RT to underserved communities. As reported by [1], RT is beginning to make inroads into other STEM fields, like applied science and engineering, in large part due to a desire to make graduate student research socially relevant and to minimize the injustices of "extractive research" or helicopter research[1] [7] where the focus is to extract data and information from communities without providing much in return. While the "helicopter research" literature is a step in the right direction for explicitly pointing at the power inequalities between Global North researchers who benefit from data extraction for their academic products (papers, conferences, etc.) and Global South communities who serve as guides, translators, and data subjects, this literature has not provided explicit frameworks for what constitutes RT and how to do it right.

For this, we turn to the international development literature, in particular reports by USAID who has taken the lead in defining RT and beginning to assess best practices. RT has been defined by USAID as "a co-design process between academics and practitioners, where research is intentionally applied to a development challenge, and embedded in the research project from the beginning so that the result is a tested solution adapted for use as a product, practice, or policy."[3] Among USAID reports on RT, "Capacity Building for Research Translation" (CBRT) stands out as one of their most comprehensive systematic review of the RT literature, covering 16 performance reports, 21 peer-reviewed articles, 4 white papers, among others. [8] This report defines RT as "a dynamic and iterative process that includes synthesis, dissemination, exchange, and ethically sound application of knowledge to yield beneficial

[1] The complete definition provided by Minasny et al. (2020) states: "Helicopter research, parachute research, or neo-colonial research are synonymous terms which describe situation where researchers from wealthier countries (usually called global north, although Australia and New Zealand fit in this category), fly to a developing country (global south), collect data and specimens, fly out, analyze the data and specimens elsewhere, and publish the results with little involvement from local scientists."

outcomes for society. The ultimate objective of development research translation is to improve social outcomes." From a development perspective, the rationale for the CBRT report was to "identify existing evidence of effective research translation, best practices, and gaps for effective research translation… [and] include recommendations for strengthening research translation processes."[8] Next we will summarize the findings of the CBRT report along three main categories that provide a framework to assess how the RT efforts and experiences of our 4 graduate students fare with respect to these findings. We number the findings according to their categories to help us identify where and how the students found a barrier to RT, implemented an effective RT approach, and/or produced an appropriate RT product.

Findings

Category 1: Individual and Institutional Barriers to effective RT. While the [8] report is supposed to be about barriers to RT in the Global South, the findings apply to the Global North higher education as well. From our experiences, the **first finding (1.1)** is that practitioners (i.e., users of RT such as policymakers, local community developers, community members, etc.) lack time to read academic work and often find it too abstract to be applied in their specific contexts and needs.[9] Hence, academic research becomes non-useful and irrelevant to community development. The **second finding (1.2)** is that traditional indicators of academic research productivity (e.g., number of patents, peer-reviewed articles, number of grad students, etc.) are weak in the Global South.[10] And while these indicators might be stronger in the Global North, higher education reward systems in either geographic area are not aligned with the goals of RT. Hence academic researchers (mainly faculty and their graduate students) lack incentives from their employers, funding agencies, and professional peers to engage in RT. The **third finding (1.3)** is that if and when RT is done, it is mostly for policymakers and/or students while lay communities (developers, members, leaders, etc.) are not seen as potential users of RT. And since many policymakers and students have significant distance from communities (epistemic, geographic, socio-economic class, status, etc.), RT that might be accessible to policymakers and students does not necessarily reach communities. [11] The **fourth finding (1.4)** is that in the literature, there are no consistent definitions or frameworks for RT. Often RT is viewed as outreach and dissemination without clear indications of when, how, and for what effects these activities are done. A **fifth finding (1.5)** is that RT is not supported nor required by academic institutions, so most graduate research projects do not include RT activities. [12] Hence RT is considered only if there's a commitment (and availability) of the student to conduct RT activities on a voluntary basis, a situation that is not possible for many. When RT is present, it is often done at the very end of the research process, after the research has been concluded without any input from communities (not throughout stages 1-6 outlined above), so it becomes an exercise of "public science communication after the fact". [13]

Category 2: Effective approaches to RT. Aligned with USAID first definition of RT, the **first finding (2.1)** here is that "co-creation of research design, implementation, and translation with communities is key to designing research for better translation outcomes." [8][14] In short, co-creation with communities should be done in all stages 1-6 above. The **second finding (2.2)** is that when "research translation is built in from the beginning and through all phases of the research process—from identifying the research topic to disseminating the findings—instead of as a final step once results have been obtained and analyzed", RT is more effective for use by

policymakers and communities.[3], [8] The **third finding (2.3)** is that "effective community-level translation methods place an emphasis on using a variety of interactive and participatory strategies aimed at soliciting, valuing, and engaging with community." [8] These could go from authentic participatory action research (PAR) strategies in the planning of research, to community-owned workshops, to k-12 education modules to inform local teachers and students of the effects of research, to name a few. [15] Based on our experiences, the **fourth finding (2.4)** is that while RT-committed researchers might suffer from lack of trust from communities as result of actions by previous researchers not committed to RT, the former can re-establish trust if they show honest and robust commitment to RT and bring this to communities. Also from our experiences, a **fifth finding (2.5)** is that academic advisors can help students circumvent institutional barriers to RT, for example, by inviting community involvement throughout different stages of research (1-6 outlined above).

Category 3: Appropriate RT products for policymakers and practitioners. Not surprising, here the **first finding (3.1)** is that academic and scholarly research products (e.g., papers, conference presentations, seminars, etc.) are not the most effective RT products.[9], [16] The **second finding (3.2)** is that policy briefs, blogs and research disseminating events (e.g., workshops, field days, technology fairs, etc.) have found to be more effective.[9] Based on our experiences, a **third finding (3.3)** is that the development and deployment of appropriate RT products might take longer than the time available to one researcher so s/he would need to make plans for longer term deployment by training future researchers to do so. Based on our experiences, a **fourth finding (3.4)** is that RT that was initially done for students can be transformed into effective RT for communities if the students receive proper training on how to establish trust, understand, and value communities needs and desires related to the research in question.

Summary table of findings: CBRT report + Our Experiences

Findings	Cat 1: Individual/Institutional Barriers to effective RT	Cat 2: Effective approaches to RT	Cat 3: Appropriate RT products
1	1.1 RT practitioners lack time to read academic work	2.1 Co-creation of research design process with communities is key for RT outcomes	3.1 Academic research products not most effect RT products
2	1.2 Higher ed reward system not aligned with goals of RT	2.2 When RT is built from beginning of research process, RT will be more effective	3.2 Policy briefs, blogs, dissemination events are more effective
3	1.3 If and when RT is done, it is for policymakers and/or students	2.3 Effective RT use variety of interactive/ participatory strategies for engaging communities	3.3 Development/deployment of effective RT products take longer time than available to one researcher
4	1.4 There are no consistent and clear definitions of RT	2.4 Researchers can re-establish trust from communities if they show honest and robust commitment to RT	3.4 If RT is initially done for policymakers/students, it can be transformed into effective RT for communities
5	1.5 RT is not supported nor required by academic institutions	2.5 Academic advisors can help students circumvent institutional barriers to RT	

RT in Academic Research Program: Student Case Studies in HES @ Mines

As reported in our ASEE 2022 paper [1], graduate students' journey to RT begins with an in-depth process of formation which includes a self-reflection of their perspectives as historical and social agents, extensive critical readings of the history of engineering, development, and the role of engineers in development. Once they understand how their perspectives stand in relation to these histories then, and only then, they can do project scoping in topics and geographic areas and with communities that align with their personal, family, and professional histories and desires. Then, through a process of negotiation between students' perspectives, their academic committees, international partners who support their research abroad, and community liaisons, students settle on specific locations and problem areas which are then officially defined and documented in a thesis proposal. While RT is not a requirement in the thesis process, the four students (also co-authors of this paper) and their advisors made a commitment to RT once their thesis proposals were approved. We will indicate which category and findings these co-authors achieved (or got close to achieving) in their community-based research by including parenthetical references in the text as in (x.x). There is no statistically significant numerical data indicating the alignment between findings in the literature and students' experiences with RT. Gathering this kind of data across many students in different institutions via surveys could be a worthwhile endeavor once there is widespread agreement on how RT can live in academic engineering research.

RT in ASGM. Mateo Rojas' graduate research contributed novel dimensions to a sector that is characterized by both its importance as a rural livelihood and its harmful human and environmental health impacts: artisanal and small-scale gold mining (ASGM). The widespread use of mercury in this sector threatens the longevity of local populations and ecosystems, but the subsistence it provides to rural populations makes it a vital arena for community development. [17] This is especially true in the national context of Colombia, where an estimated 87% of the gold is produced by ASGM. [18] Instead of attempting to eradicate these activities, scholars and practitioners have long called for strategies that transform the gold processing practices that depend heavily on mercury use to offer miners a safer way to participate in ASGM. One strategy tried in Colombia has been the construction of communal gold processing plants, where miners could process their gold collectively using efficient and mercury-free technology. Unfortunately, the long-term success of these plants is rare. To better understand the difficulties behind the implementation of communal plants, Rojas carried out his research in two ASGM communities in the department of Antioquia, a region that produces approximately 65% of the country's gold. [19]

The multiple field trips Rojas took enabled him to consult with his research collaborators and consider RT strategies from the outset of his project. With financial support from an NSF-funded research project, Rojas visited Colombia three times before graduating and twice more after graduating, totaling about 30 weeks in the country. His co-advisor, a Colombian mining engineering and metallurgy professor at Universidad Nacional de Colombia (UNAL), connected him with community-based practitioners and researchers who either had experience working in ASGM or had connections to residents of his study sites. Taking these trips allowed Rojas to develop strong working relationships with his interlocutors in both of his study sites and identify potential outlets through which he could translate his research findings from the early stages of his research. **(2.1 and 2.2)**.

After graduating, Rojas returned to Colombia for 4 months to disseminate his findings and approach for academic audiences and translate his conclusions for groups beyond academia. His approach to RT involved a combination of both pre-planned engagements opportunities with both mining engineering students, who eventually will work with ASGM communities, and with mining communities **(1.3)** and serendipitous RT opportunities with government agencies and non-governmental organizations involved in ASGM. There were certain organizations and groups he identified during his fieldwork that he planned to present for, but he also took advantage of unforeseen opportunities presented to him that he found relevant to his RT objectives. His highest priority was returning to both ASGM towns he studied to share his findings with local mineworkers and demonstrate the value of community-based research to promote future partnerships between miners and university students. He also disseminated the efficacy of this approach with Colombian professors and students, delivering eight university presentations and one conference presentation to share his research strategy and findings **(1.3)**. The interdisciplinarity of his work also made it relevant for a variety of practitioners, leading him to share his findings with an engineering firm, a gold trading company, a small-scale gold mining consultancy, a lawyer specialized in small-scale gold mining, an NGO that empowers students to carry out community-development projects in vulnerable communities, and a number of national government agencies (the Colombian Defensoría del Pueblo, Agencia Nacional de Minería, Ministerio de Minas y Energía, and Servicio Nacional de Aprendizaje). **(2.3)**

Rojas' experiences translating his research for diverse audiences illuminated barriers for systematically integrating these practices into graduate research. The project that funded Rojas' research offered him the chance to spend almost seven months in Colombia to carry out his research and RT, providing him with far more freedom and resources to engage in RT than most graduate students. This freedom, combined with a lack of guidelines or requirements for translating research, gave Rojas the prerogative to decide when, where, and how to present his findings about the ASGM towns he studied. **(1.5)** While Rojas frequently consulted with the people he interacted with in his interviews, focus groups, and participant observation to collect their ideas for relevant RT mediums, these consultations were voluntary, and he and his co-advisors ultimately made the decisions about their RT activities **(2.5)**. Rojas' partial reliance on his advisor and co-advisor, both renowned academics, to find audiences for which he could present his research also influenced where his research was presented; out of the twenty presentations he delivered, eight were for universities. These university presentations undoubtedly helped promote community-centered engineering practice, but it is possible that Rojas' research collaborators would have preferred other outlets closer to communities if their desires had been equally prioritized in the RT approach from the outset of the project. **(1.3)** The imbalance of power between Rojas and his research participants reinforces how challenges related to research extractivism can hinder equitable RT practices and, even in attempts to include vulnerable communities' RT ideas, ultimately favor academic priorities. **(1.2)**

The primarily academic environment through which Rojas carried out his RT also failed to provide the same tools to comprehensively engage with practitioners as it did to extend his work through more traditional academic means. The result was that his RT with ASGM practitioners took place through one-time presentations, which was useful in translating the research to some, but was far from the longer partnerships or policy materials that LASER PULSE promotes in RT strategies. **(3.1)** Ultimately, Rojas decided that he was better prepared to focus on research

extension, which [1] describes as the creation of curricular opportunities for undergraduate students from graduate research. He carried out two community-based research workshops with primarily technically trained Colombian Mining Engineering and Metallurgy students to prepare them for a sociotechnical field trip to one of the ASGM towns he studied. **(3.1)** After the field trip, Rojas created a partnership between a group of interested UNAL students and miners from this community to provide the foundation for future community-centered collaborations. Rojas focused on creating this partnership between students and miners because he felt that in the limited time he had in Colombia, he was more likely to be successful in creating a university-based partnership with miners than in attempting to figure out the most effective ways to create materials for practitioners that most of his closest collaborators and mentors had little experience in developing **(3.3 and 3.4)**. Establishing a structure for traditionally trained Colombian engineering students to better engage with miners to understand their on-the-ground realities may have been a fruitful endeavor, but the fact Rojas felt he was better prepared to create a long-term partnership through academia than with practitioners underlines a barrier to implementing RT into graduate research. If RT is to reach beyond sharing findings and approaches in the "ivory tower" of academia, scholars of all levels will have to transcend their familiar methods and channels to create scholarly environments that offer tools to share knowledge across disciplines and sectors. **(1.1)**

RT at the nexus of agriculture and ASGM. Casey Gibson master's research in HES @ Mines focused on exploring the convergence between ASGM and agriculture in the municipality of Andes (Antioquia, Colombia). This is a region where coffee growing and ASGM co-exist, sometimes in conflict competing for water, land, labor, and state support. Her study identified common environmental challenges affecting and exacerbated by both sectors, including substantial impacts of climate change, mutual threats to water resources, and heightened risks of landslides. [20] Gibson adapted and implemented a modified ethnographic methodology to conduct interviews, focus groups, and site visits in rural areas of Andes, primarily basing the research approach on principles from a community-based research (CBR) course at Mines. [21] RT was not Gibson's intention from the onset of her project, yet there turned out to be several instances of employing RT in her work and considerable methodological and theoretical overlap with principles from CBR. **(1.5)** Gibson also describes the implementation of RT in her project. [21]

Gibson identified significant barriers to implementing RT in several phases outlined in the research translation model, specifically in the phases of "decision-making and actions taken from research results" and "influence on future work" [4] phases 5 and 6 listed above. These challenges are particularly pronounced within the constraints of a master's academic program. The relatively short duration of a master's program (usually two years) makes it extremely difficult to bring about tangible results in terms of policy, planning, or developments resulting from the research within that time frame. Decisions, influence, and actions may only materialize years later. Moreover, much of the RT that Gibson conducted happened during a follow-up trip to Andes which occurred after she had officially finished the M.S. program. This trip was only possible through unique circumstances–grant funding that could be extended to alumni and the privilege for Gibson to delay immediately starting a full-time job–that are uncommon for many graduate students. **(1.2, 1.5)**

Furthermore, Gibson experienced the academic structures and incentives which prioritized thesis writing, conference presentations, and journal publications over the production of policy reports or other materials that could incorporate RT for non-academic audiences. **(3.1)** In Gibson's case, despite her aspirations to create translated materials for Colombian governmental or general audiences, she was constrained by time limitations due to publication and graduation obligations. Therefore, while there may be intentions to translate research into formats that guide decision-making and influence future work, the academic context hinders immediate realization of these goals. **(1.2)**

Gibson was able to effectively employ research translation during "definition of research questions and methodologies" and "the research process itself" phases of her project, stages 1 and 2 above. [4] For Gibson, defining research questions/methodologies and the research process in the field were inseparable, typical of inductive community-based studies where questions emerge from the data. She also translated her research when "publishing research results" and "placing research results in the context of other knowledge and sociocultural norms" (phases 3 and 4 above) [4] **(2.1)**

To illustrate, problem definition for Gibson had two distinct phases. Initially, due to the COVID-19 pandemic, she interacted virtually with ASGM communities in Bajo Cauca, Antioquia, through virtual community capacity building workshops. This revealed the significant issue of food security among some mining communities, leading to research questions focused on the risks to local food production associated with environmental contamination from mining. In a summer internship, she developed and piloted "tool kit" consisting of interview and focus group templates to qualitatively assess preliminary risks of ASGM contamination in air, soil, and water to the local production of food for subsistence.

In the second year of the M.S. program, Gibson was able to conduct fieldwork in-person in Andes refining research questions through ethnographic interviews and focus groups. Two local research assistants in Andes played a crucial role in conducting the fieldwork. Quickly the team realized that the initial research questions were misaligned for the sociotechnical context in Andes–distinct from Bajo Cauca–prompting a shift towards research questions on perceived environmental threats at the agriculture-mining intersection. The act of translating the research questions, project scope, and anticipated products to community members during the interviews and visits (the "research itself"), while simultaneously employing contextual listening [22, p. 201] to understand local concerns and priorities, were instrumental in both the virtual and in-person problem definition phases and led directly to the evolution of the more appropriate research questions for each community. This type of RT also hinged upon Gibson's fluency in Spanish to be able to directly communicate with stakeholders **(2.1, 2.2).**

Gibson published and presented her work in various international academic contexts, engaging in extensive interdisciplinary RT for diverse academic audiences, including system engineers, engineering educators, socio-hydrologists, and scholars in anthropological studies of science and technology in the U.S. (including Puerto Rico), Colombia, and Mexico. This required familiarization with the jargon, literature, and research trends of each discipline and the expansion of her technical vocabulary in Spanish. She published 2 articles and one book chapter, attended 4 conferences, and gave 5 invited talks at 5 institutions in the U.S. and Colombia. She

also developed and led a workshop on her ethnographic research methodology for undergraduate engineering students. [21] **(1.3)** To get her manuscripts through the peer-review publishing process, Gibson had to dedicate significant time in the year(s) after her graduation while working full-time, further highlighting the challenge of time constraints in a master's program to engage in RT for diverse audiences, even academic ones **(1.2).**

Beyond academic dissemination, it was crucial for her and her team to bring the research findings back to Andes. A lack of RT and follow-up in the past by researchers had resulted in some community members distrusting academics and even refusing interviews with her team **(1.1).** To avoid making this same mistake, Gibson prioritized a research dissemination trip in the months following her graduation. She reconnected with key stakeholders and shared findings through a conversational approach inclusive of diverse levels of literacy. The in-person element was especially valuable in facilitating the trust-building/rapport process as well as for accommodating different levels of technological literacy and access. While community members were not surprised by the study's results, as they were already deeply familiar with the local context, they expressed gratitude for the act of returning to Andes, following up, and acknowledging that their narratives and challenges were heard by diverse audiences worldwide **(2.4).**

By integrating RT in distinct phases of the research process and her projects' outputs, Gibson was able to meet the required academic benchmarks, disseminate the findings to wide audiences, and contribute to a strengthened relationship with the community, while recognizing that this would not have been possible without certain privileges not afforded to many graduate researchers. Though the limitations of academia–namely time and academic incentives–were hindrances for immediately influencing decision-making and future actions, there are still many ways RT can be integrated into a project. Gibson found that RT–especially in the problem definition, research, and dissemination phases–had significant overlap with a community-based research approach and shows promise for integration with CBR approaches.

RT in Electronic Waste Recycling. The production and consumption of electrical and electronic equipment is growing annually by 2.5 million metric tons, generating one of the fastest-growing waste streams in the world, known as "e-waste" or "WEEE" [23], [24], [25], [26] This waste stream is becoming an important source of income for many vulnerable communities because of the value of its components. However, if e-waste is not properly managed, it represents a source of exposure to hazardous substances for them. [27] Seeing that very few projects and studies were focused on assisting low-income workers in Latin America to apply the best e-waste management practices with a simultaneous positive impact on their economies [27], [28], Sofia Schlezak investigated semi-formal and informal e-waste recycling settings in Buenos Aires (Argentina). Through her thesis, she proposed options for socio-technical interventions to reduce chemical risks in consideration of the socioeconomic development of the local workers. [29]

Targeting five main audiences (workers, governmental officials, scholars, professors, and students), Schlezak aimed at influencing academic research, partnerships, and policies for the development of environmentally sound and socially just interventions related to e-waste management and promoting safe working conditions in Argentina. At the global level, she

intended to motivate action towards occupational safety in the informal sector and call the attention of traditional mining and engineering professionals, scholars, and educators into future work in the field of urban mining.

The RT activities that this early-career researcher conducted were designed differently according to each target audience. *Public sector:* She partnered with two members of local governmental agencies in Buenos Aires, who helped her narrow down the scope of the thesis, formulate the research questions, and select methodologies suited to their interests. Moreover, she engaged one of these government officers as part of her Thesis Committee. The involvement of these key research participants could be considered her first approach to RT, which ended up being an effective way to align her research design and implementation with the needs and interests of the public sector. During her site visit in Buenos Aires, she presented the progress of her thesis to one of these agencies, pointing out some preliminary findings and concerns they addressed. After graduation, she also participated as an invited expert in an online official meeting organized by one of the local authorities in Buenos Aires. At this meeting, she shared some observations and input for future policies based on her research. **(1.3)**

E-waste workers and general public: In an attempt to popularizing "expert" knowledge -that is usually confined to governmental, scientific, and academic spaces- and respond to the e-waste workers' questions and interests, Schlezak developed workshops for them and gave lectures in academic courses. She addressed topics such as e-waste management, chemical risks, and prevention measures. During the development of the thesis, she presented in two different recycling facilities in Buenos Aires with more than 37 workers, and one in Bogotá (Colombia) with five workers. For these events, she presented slides and included interactive activities such as open questions and participatory mapping. After graduating, she presented content for 10 participants in a recycling facility in Rosario (Argentina), three national universities, and one national e-learning course for waste management workers, academics, and practitioners. For these audiences, she created presentations and short informative documents. **(2.2, 2.3)**

Students: Using the data generated and the literature analyzed for her thesis, Schlezak helped design the syllabus, developed content, and led some lectures for an undergraduate course in Engineering and Sustainable Community Development at Mines, where she performed as a Project Consultant. This exercise was part of an Independent Course that Schlezak took in one semester to learn teaching skills and put into practice RT. In partnership with a Colombian community engagement organization, the students spent two months meeting virtually with women from a Colombian waste recycling association dedicated to e-waste to co-define, ideate, and prototype solutions to the problems that these workers faced. Throughout this experience, she learned and applied different pedagogical strategies for the undergraduate students, including traditional lectures, videos, literature reviews, debates, quizzes, and group activities. **(2.3)**

Academic community: Student 3 also disseminated her findings and recommendations in academic platforms and events, including conferences and journals, to contribute to global conversations and the body of knowledge on e-waste. Academic papers and digital presentations were the tools that she preferred for this target audience. **(1.3, 2.3)**

The lack of systematic consideration of RT in academic research posed some barriers to Schlezak's work. For example, she was not able to formalize the participation of the Thesis Committee member who represented a governmental agency from Buenos Aires. While the expert was exceptionally influential for the thesis, this person could not be considered because their academic degree level did not fulfill the institutional requirements. This situation exemplifies how academic institutions still favor certified academic knowledge over experiential knowledge and other knowledges. **(1.2)** She sees these institutional requirements as barriers to overcome if research is aimed at responding to real-world needs. Key research participants from the targeted local groups should have the opportunity to become Thesis Committee members, as their views and input could be as relevant as any other member. Another barrier she found is related to the need for more allocation of time and resources for designing and implementing RT activities within graduate programs. Particularly in her MS program, she found support and motivation throughout her research and writing process, which was sufficient to include RT considerations before, during, and after the publication of her thesis. However, she noted that there is still much work ahead in terms of including concrete RT guidelines so students can prevent in advance any burden of work and needs for time and resources. Funding is also a significant issue when developing RT products because many of these tools require traveling, printing, translating, and other activities. Without an institutional willingness to support RT, graduate students could end up being overwhelmed and constrained to achieve their expectations and the expectations of their target audience. **(1.2)** Furthermore, engaging in RT demands a critical analysis of the audience's needs and the selection of the best means of implementation. Since these two steps are time-demanding, any support from the professors and the whole academic community is highly valuable. Making available guidelines for the design and implementation of presentations, workshops, and lectures and proposing spaces for developing pilot activities with peers are actions that Schlezak suggests being considered in graduate programs in order to promote high-quality and efficient RT activities. **(3.2)**

RT in Construction & Demolition Waste Recycling. For her master's thesis in HES, Jaime Styer researched how to contribute to empowering women and low-income communities in Colombia by recycling construction and demolition waste (C&DW). Throughout her preliminary literature review, Styer discovered that although many scholarly investigations conclude that the construction industry is a significant global contributor to environmental degradation, there is little research exploring community-owned C&DW management practices centering social justice, political autonomy, and self-determination as key project outcomes. In Colombia, the inadequate and unregulated disposal of C&DW and the increased illegal extraction of aggregate materials [30] experienced as a result of the expanding construction industry contributes to many environmental and social problems. Styer's aim was to collaborate with women and low income community members using a participatory, CBR approach to understand (1) the community's goals and aspirations for this project, (2) how value can be extracted from C&DW safely, (3) how the recycled materials can be made useful to their community, and (4) how to do all this in a way that enhances social cohesion in their community.

Throughout her research, she was given the opportunity to collaborate with international partners, local Colombian community members and leaders, as well as academics and practitioners spanning disciplines and international contexts to develop and implement solutions to empower low-income communities, with a specific focus on women. The main institutional

partner Styer collaborated with a Colombian university, Corporación Universitaria Minuto de Dios (Uniminuto). She utilized Uniminuto's five-phase community engagement framework, the Social Innovation Route or RUTA, to frame her research. [31] The five phases include Prepare, Understand & Analyze, Create, Implement, and Package and Scale. The Uniminuto team conducted the Prepare phase before she arrived in Colombia, and they identified a low-income community with the desire to work on this project. In the summer of 2022, she spent six weeks in Colombia conducting fieldwork with Uniminuto in Barzalosa, a community near Girardot, Colombia, for the Understand and Analyze phase of the project. During this time, she utilized participatory, CBR methods to understand more about the Barzalosa community, including their goals for this project, as well as important contextual information on the community (e.g. their values, beliefs, journeys, destinations, language, knowledge, and more). **(2.1)** During participant observations, unstructured conversations, and semi-structured interviews with the community members, Styer identified that a workshop was a relevant and empowering form of RT that the community preferred. Accordingly, during the next phase of her research she developed a community-based, participatory workshop in collaboration with Barzalosa community members, Colombian subject matter experts, and HES academics. **(3.2)**

In March 2023, the workshop was conducted with the Barzalosa community. Overall, thirteen participants received certificates of completion. To judge the effectiveness of the workshop, she and the research team took two approaches. The first approach was through the comparison of pre and post workshop surveys. The second approach, which was more reliable for her and the research team, was having the community members rate the workshop effectiveness using a focus group format. Overall, the feedback we received in the focus groups was overwhelmingly positive, almost all participants stated that the project was effective as they learned new ways, they could generate income by recycling construction and demolition waste. They community members also discussed their appreciation that the project was brought to fruition as many projects are started with their community but not many are finished. **(3.2)**

The main form of RT that Styer focused on throughout her research was in the format of a workshop targeted at the Barzalosa community; however, she also conducted alternative forms of RT intended for varying audiences, mainly in academia. She was given the opportunity to present her research findings at multiple universities in the US as well as academic conferences. She has also written at least six peer-reviewed journal manuscripts discussing her research. Many of these presentations and published papers were aimed at multiple disciplines, including the mining community, various engineering disciplines, engineering educators, development researchers, and scholars interested in gender equality and women's empowerment, thus Styer adjusted her RT approaches multiple times to tailor to diverse, interdisciplinary audiences. **(2.3, 3.4)**

Although meaningful RT was emphasized and implemented during every phase of the project, multiple notable barriers were encountered that often hindered the project. In agreement with Gibson above, timelines and academic incentives, including adhering to traditional indicators of academic productivity, are prominent barriers to engage in meaningful RT beyond academic dissemination. To finish her studies and conduct the second phase of her research including deploying the workshop, Styer delayed her graduation one semester as she was able to acquire the funding to do so, however, many graduate students are not granted this opportunity **(1.2, 1.5)**.

Additionally, power struggles and hierarchical tensions often created issues for RT throughout the project as well. Specifically, multiple community members became disoriented during the Understand and Analyze research phase as they were given conflicting information regarding project objectives from multiple people on the research team. **(1.4)** Additionally, the workshop became challenging to organize as a section of the research team chose not to participate, despite their expertise being necessary to accurately discuss certain specific technologies with the community. However, to resolve this, we were able to collaborate with subject matter experts from a different organization who could conduct RT regarding the technologies. **(2.4)**

Summary of how literature findings appear in students' RT case studies.

	Rojas	Gibson	Schlezak	Styer
1.1 RT practitioners lack time to read academic work	X	X		
1.2 Higher ed reward system not aligned with goals of RT	X	XXX	XX	X
1.3 If and when RT is done, it is for policymakers and/or students	XXX	X	XX	
1.4 There are no consistent and clear definitions of RT				X
1.5 RT is not supported nor required by academic institutions	X	XX		X
2.1 Co-creation of research design process with communities is key for RT outcomes	X	XX		X
2.2 When RT is built from beginning of research process, RT will be more effective	XX	X	X	
2.3 Effective RT use variety of interactive/ participatory strategies for engaging communities			XXX	X
2.4 Researchers can re-establish trust from communities if they show honest and robust commitment to RT		X		X
2.5 Academic advisors can help students circumvent institutional barriers to RT	X			
3.1 Academic research products not most effect RT products	XX	X		
3.2 Policy briefs, blogs, dissemination events are more effective			X	XX
3.3 Development/deployment of effective RT products take longer time than available to one researcher	X			
3.4 If RT is initially done for policymakers/students, it can be transformed into effective RT for communities	X			X

Each X indicates one occurrence of each finding in each student's narrative of their RT efforts

Conclusions and recommendations

We are using the USAID CBRT report [8] recommendations and the mapping of our own experiences with RT against CBRT findings to begin proposing specific recommendations for the effective integration of RT into the system of graduate engineering education and research.

Overcoming Individual and Institutional Barriers to effective RT

Before establishing a consistent RT framework. The emergence of new RT definitions and frameworks from agencies like USAID and the presence of long-standing RT practices in the health sciences (see below) present a great opportunity for academic engineering to learn from what other sectors and professions have done and begin institutionalizing a consistent RT framework in graduate engineering education and research practices. But prior to this institutionalization, engineering educators and students need to learn that all engineering research is inherently socially constructed and a sociotechnical endeavor [32] to accept that communities, for example, can co-define, along with engineers, research questions and methods, co-construct data gathering procedures, co-select research locations, and co-design solutions based on research findings. The governing bodies of the research enterprise (e.g., dean of research, graduate and research councils, graduate school, etc.) need to be brought on board to understand these realities to institutionalize RT throughout. The current mounting pressure on universities to show their social relevance to taxpayers and other constituents can make this reconceptualization of engineering as sociotechnical and socially constructed, which are necessary prior to the effective adoption of consistent RT frameworks, more plausible.

When establishing a consistent RT framework, graduate programs should define what RT is, what stages it encompass (like stages 1-6 above) and be willing to adopt a consistent framework that is appropriate to the research context. For any type of engineering related to development (large or small), the frameworks from USAID will be more useful. [3] For emergent fields of national importance that are being explicitly required more and more to have community engagement, like decarbonization of low-income housing or carbon capture and sequestration [33, p. 40], there will be a need to develop RT frameworks that are appropriate to these contexts, technologies used, and organizations involved. For biomedical/biosciences engineering research, or for engineering practices related to health and well-being of domestic communities, the frameworks from the health sciences might make more sense. The health sciences and clinical medical research have a longer history of RT as the institutions that fund this kind of research (e.g., NIH) have a pressing need to translate basic research quickly from the clinical lab into medical practices (e.g., diagnoses, prescriptions, therapies, etc.) to benefit the general public. Yet these forms of RT have not reached all groups of the general public equally, leaving some communities (e.g., low-income, multiethnic and language, rural) underserved by the benefits of research. This concern has led some RT researchers to develop criteria for RT decision-making in underserved community settings by creating "a list of criteria that can be used by researchers, in collaboration with community partners, to help evaluate intervention readiness for translation into community and/or organizational settings." [34]

Invest in understanding contextual barriers to RT. As Leydens and Lucena have shown [35], engineering educators and students who want to integrate social justice or sustainable community development into engineering first need to understand the engineering ideologies, mindsets, attitudes, and assumptions that get in the way of these integrations. Integrating RT in engineering research is no exception as the ideologies of meritocracy and depoliticization [36] and engineering mindsets [37] will get in the way. For example, the ideology of depoliticization, which creates a valuation of the technical over the social, will lead those under its influence to view RT processes and products of lesser value that those carried out through traditional engineering research. Meanwhile, adopting the engineering mindset of "positivism and the myth of objectivity" can lead to viewing RT with suspicion given its subjectivity by introducing

community perspectives in the various stages of the research process. Hence, as our graduate-student co-authors experienced in their education [1], there needs to be a preamble critical introspection of the ideologies and mindsets that underlie the reluctance to RT.

In the local settings where RT is deployed, there are also several contextual barriers. For example, paternalism often leads communities to expect most decisions, especially those related to knowledge creation, to come from those with academic credentials or those who have access to technologies (e.g., monitoring equipment), and/or leads local academics to adopt top-down attitudes towards communities when defining and carrying out research. All these contextual barriers deserve investigation and deployment of counter measures to minimize their obstruction to the deployment of RT. All our graduate-student co-authors were very aware of how paternalism could manifest in community interactions and took preventive measures during the RT activities. All of our students experienced heavily how the reward system in higher education is not aligned with the goals of RT (finding 1.2) yet they were able to implement RT in their theses, in large part due to their understanding of the contextual barriers to RT including how to counteract the ideologies and mindsets of engineering.

Improve understanding of gender equity and inclusion around RT. For the effective deployment of RT, we need to address literacy differences (e.g., people that do not know how to read and write) and language barriers beyond literacy (i.e. vocabulary terms used only in academia or discipline-specific jargon). We also need to be attentive to patriarchal practices that exclude women from participation. This is why RT best practices call for a diversity of formats to be used throughout to be inclusive of different forms and levels of literacies (e.g., acting skits, storytelling, visual art, photography, singing and rapping, etc.) and attentive to the power differentials between men and women so we might need women-only activities. Yet these formats deserve assessment and evaluation to determine effectiveness in different contexts. Our graduate students learned to be attentive to equity and inclusion in their field research and RT and to the best of their abilities were able to deploy RT practices, for example, that empowered women in male-dominated settings. Yet , as we see above, most of them found it easier to deploy RT for policymakers and students, audiences that use similar languages than they do.

Participation of multiple stakeholders in different parts of the system. The effective integration of RT in graduate engineering education will require proper training of faculty and students about specific RT needs of key stakeholders, differences in contexts, and an understanding of the heterogeneity and complexity within communities. This can be done by partnering with effective community-engagement organizations, like Diversa in Colombia (see diversa.co) who can translate community needs for RT to US faculty and students. [38] This can also be done in research seminars and/or research group meetings where stakeholder mapping can also include assessment of their different abilities to participate in the different stages of research and different needs for RT formats. In graduate engineering education, the notion, goals, and intended benefits of RT need to be integrated in other courses/requirements such as community-based research, communications/public speaking courses, etc. so RT integration does not become boxed in just one location in the graduate education system. For instance, RT could help meet ABET's student outcomes criteria such as "an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors." [39] And, as

shown above, two of our students found ways to transform RT that was initially done for policymakers/students into effective RT for communities (finding 3.4).

Develop and implement appropriate RT products for policymakers and practitioners. Target RT products directly to the needs and constraints of intended users and develop, deploy and assess the effectiveness of alternative publication formats/platforms, i.e. think pieces on Medium, policy brief, opinion pieces in local news or professional magazines NAE's The Bridge or ASCE's online magazine, Ted Talks, podcasts, and non-academic conferences, to name a few. While some of our students were able to develop and pilot different formats of RT, they were not able to assess their effectiveness. So as RT definitions and frameworks become implemented in graduate engineering, we also need to pay attention to the development, implementation, and assessment of different RT products.

References

[1] J. Lucena, E. Chapman, M. Rojas, S. Schlezak, and J. Styer, "Bringing it down from the ivory tower: Translating Engineering-for-Community-Development (ECD) graduate student research into community engagement and undergraduate student learning," in *ASEE 2022 Annual Conference*, Minneapolis, MN, USA: American Society for Engineering Education, Jun. 2022, pp. 1–30.

[2] B. Keeler, "Preparing Grad Students to Change the World," Inside Higher Ed. Accessed: Feb. 10, 2022. [Online]. Available: https://www.insidehighered.com/advice/2022/02/10/grad-students-want-make-societal-difference-opinion

[3] M. Fitzgerald, "Embedded Research Translation – LASER PULSE." Accessed: Feb. 08, 2022. [Online]. Available: https://laserpulse.org/embedded-research-translation/

[4] P. Sudsawad, "Introduction to Models, Strategies, and Measures," p. 44.

[5] J. Giordan, A. Shartrand, J. Steig, and P. Weilerstein, "Transforming the Practices and Rationale for Educational Programs to Aid Academic Researchers in Translating Research into Innovations and Ventures," presented at the 2011 ASEE Annual Conference & Exposition, Jun. 2011, p. 22.1547.1-22.1547.16. Accessed: Feb. 08, 2022. [Online]. Available: https://peer.asee.org/transforming-the-practices-and-rationale-for-educational-programs-to-aid-academic-researchers-in-translating-research-into-innovations-and-ventures

[6] S. W. Villachica, A. W. Marker, D. Plumlee, L. Huglin, and A. Chegash, "The Arrows in Our Backs: Lessons Learned Trying to Change the Engineering Curriculum," presented at the 2013 ASEE Annual Conference & Exposition, Jun. 2013, p. 23.1166.1-23.1166.18. Accessed: Feb. 08, 2022. [Online]. Available: https://peer.asee.org/the-arrows-in-our-backs-lessons-learned-trying-to-change-the-engineering-curriculum

[7] B. Minasny, D. Fiantis, B. Mulyanto, Y. Sulaeman, and W. Widyatmanti, "Global soil science research collaboration in the 21st century: Time to end helicopter research," *Geoderma*, vol. 373, p. 114299, Aug. 2020, doi: 10.1016/j.geoderma.2020.114299.

[8] Pulte Institute for Global Development, "CAPACITY BUILDING FOR RESEARCH TRANSLATION," University of Notre Dame, USAID Report, 2022.

[9] P. C. Avey, M. C. Desch, E. Parajon, S. Peterson, R. Powers, and M. J. Tierney, "Does Social Science Inform Foreign Policy? Evidence from a Survey of US National Security,

Trade, and Development Officials," *Int. Stud. Q.*, vol. 66, no. 1, p. sqab057, Mar. 2022, doi: 10.1093/isq/sqab057.
[10] L. Meek, "Higher education, research and innovation: changing dynamics; Report on the UNESCO Forum on Higher Education, Research and Knowledge, 2001-2009 - UNESCO Digital Library." Accessed: Feb. 07, 2024. [Online]. Available: https://unesdoc.unesco.org/ark:/48223/pf0000183071
[11] R. Delafield *et al.*, "A Community-Based Participatory Research Guided Model for the Dissemination of Evidence-Based Interventions," *Prog. Community Health Partnersh. Res. Educ. Action*, vol. 10, no. 4, pp. 585–595, 2016, doi: 10.1353/cpr.2016.0067.
[12] G. Harvey, R. J. Marshall, Z. Jordan, and A. L. Kitson, "Exploring the Hidden Barriers in Knowledge Translation: A Case Study Within an Academic Community," *Qual. Health Res.*, vol. 25, no. 11, pp. 1506–1517, Nov. 2015, doi: 10.1177/1049732315580300.
[13] A. M. Feldman, "Does Academic Culture Support Translational Research?," *Clin. Transl. Sci.*, vol. 1, no. 2, pp. 87–88, Sep. 2008, doi: 10.1111/j.1752-8062.2008.00046.x.
[14] S. Siron, C. Dagenais, and V. Ridde, "What research tells us about knowledge transfer strategies to improve public health in low-income countries: a scoping review," *Int. J. Public Health*, vol. 60, no. 7, pp. 849–863, Nov. 2015, doi: 10.1007/s00038-015-0716-5.
[15] D. Isobell, S. Lazarus, S. Suffla, and M. Seedat, "Research translation through participatory research: The case of two community-based projects in low-income African settings," *Action Res.*, vol. 14, no. 4, pp. 393–411, Dec. 2016, doi: 10.1177/1476750315626779.
[16] K. O'Grady, N. R. O. published on P. O. August 1, and 2016, "Linking academic research with the public and policy-makers," Policy Options. Accessed: Feb. 07, 2024. [Online]. Available: https://policyoptions.irpp.org/magazines/august-2016/linking-academic-research-with-the-public-and-policy-makers/
[17] Hilson G., "Small-scale mining, poverty and economic development in sub-Saharan Africa: An overview," *Resour. Policy*, vol. 34, no. 1–2, pp. 1–5, Mar. 2009, doi: 10.1016/j.resourpol.2008.12.001.
[18] V. Abierta, "'Barequeros' y 'chatarreros', entre criminales y la DIAN," VerdadAbierta.com. Accessed: Feb. 07, 2024. [Online]. Available: https://verdadabierta.com/barequeros-y-chatarreros-entre-criminales-y-la-dian/
[19] Ó. J. R. Baena and L. E. M. Mendoza, "Sustainability of the Artisanal and Small-Scale Gold Mining in Northeast Antioquia-Colombia," *Sustainability*, vol. 13, no. 16, Art. no. 16, Jan. 2021, doi: 10.3390/su13169345.
[20] C. Gibson, "THEORIZING THE 'SOCIAL' IN SOCIOTECHNICAL, COMMUNITY-BASED ENGINEERING: INCORPORATING A RAPID ASSESSMENT PROCEDURE IN EDUCATIONAL AND FIELD-BASED STUDIES ON COLOMBIAN ARTISANAL AND SMALL-SCALE GOLD MINING," Thesis, Colorado School of Mines, Golden, CO, 2022.
[21] C. Gibson, J. Smith, K. Smits, J. Lucena, and O. J. R. Baena, "Rapid Assessment Procedure as a Tool for Front-End Stakeholder Needs Analysis in Engineering Projects," *IEEE Open J. Syst. Eng.*, vol. 1, pp. 68–80, 2023, doi: 10.1109/OJSE.2023.3275379.
[22] J. Leydens and J. Lucena, "Listening as a missing dimension in humanitarian and sustainable community development efforts: The engineering curriculum as a potential learning inhibitor," *IEEE Trans. Prof. Commun.*, 2009.
[23] V. Forti, C. P. Balde, R. Kuehr, and G. Bel, *The Global E-waste Monitor 2020: Quantities, flows and the circular economy potential*. Bonn/Geneva/Rotterdam: United Nations

University (UNU)/United Nations Institute for Training and Research (UNITAR) – co-hosted SCYCLE Programme, International Telecommunication Union (ITU) & International Solid Waste Association (ISWA), 2020. Accessed: Aug. 16, 2023. [Online]. Available: https://collections.unu.edu/view/UNU:7737

[24] GDFEEW. Points of Consensus., "Global Dialogue Forum on Decent Work in the Management of Electrical and Electronic Waste (E-waste) (GDFEEW)," International Labour Organization (ILO), Geneva, Switzerland, Meeting Points of consensus No. GDFEEW/2019/7, Jan. 2019. Accessed: Feb. 06, 2024. [Online]. Available: http://www.ilo.org/sector/activities/sectoral-meetings/WCMS_666550/lang--en/index.htm

[25] K. Lundgren, *The Global Impact of E-Waste: Addressing the Challenge*. Geneva, Switzerland: International Labour Organization, 2012.

[26] M. Wagner, C. P. Baldé, V. Luda di Cortemiglia, I. Nnorom, R. Kuehr, and G. Iattoni, "Regional E-waste Monitor for Latin America: Results for the 13 countries participating in project UNIDO-GEF 5554," UNU/UNITAR, Bonn, Germany, 2022. Accessed: Aug. 16, 2023. [Online]. Available: http://collections.unu.edu/view/UNU:8704

[27] World Health Organization, *Children and digital dumpsites: e-waste exposure and child health*. Geneva: World Health Organization, 2021. Accessed: Nov. 19, 2021. [Online]. Available: https://apps.who.int/iris/handle/10665/341718

[28] A. L. Arain and R. L. Neitzel, "A Review of Biomarkers Used for Assessing Human Exposure to Metals from E-Waste," *Int. J. Environ. Res. Public. Health*, vol. 16, no. 10, Art. no. 10, Jan. 2019, doi: 10.3390/ijerph16101802.

[29] S. L. Schlezak, "Informal and semi-formal electrical and electronic waste (e-waste) management: a socio technical study of risks, perceptions, interventions, and educational opportunities," 2023, Accessed: Feb. 06, 2024. [Online]. Available: https://repository.mines.edu/handle/11124/178531

[30] A. M. Bravo-German, I. D. Bravo-Gomez, J. A. Mesa, and A. Maury-Ramirez, "Mechanical Properties of Concrete Using Recycled Aggregates Obtained from Old Paving Stones," 2021, doi: https://doi.org/10.3390/su13063044.

[31] J. F. Pacheco Duarte, E. S. Rodríguez Pupo, and S. F. Galindo Gómez, "Ruta de innovación social: Paso a paso para desarrollar innovaciones sociales," *UNIMINUTO-Parq. Científico Innov. Soc.*, Feb. 2021, Accessed: May 01, 2022. [Online]. Available: https://repository.uniminuto.edu/handle/10656/11502

[32] G. L. Downey and J. C. Lucena, "Engineering Studies," in *Handbook of Science, Technology, and Society*, S. Jasanoff, G. Markle, J. Petersen, and T. Pinch, Eds., Newbury Park: SAGE, 1994, pp. 167–188.

[33] "Justice40 Initiative | Environmental Justice," The White House. Accessed: Feb. 07, 2024. [Online]. Available: https://www.whitehouse.gov/environmentaljustice/justice40/

[34] M. E. Wende *et al.*, "Developing criteria for research translation decision-making in community settings: a systematic review and thematic analysis informed by the Knowledge to Action Framework and community input," *Implement. Sci. Commun.*, vol. 3, no. 1, p. 76, Jul. 2022, doi: 10.1186/s43058-022-00316-z.

[35] J. A. Leydens and J. C. Lucena, *Engineering Justice: Transforming Engineering Education and Practice*. John Wiley & Sons, 2017.

[36] E. A. Cech, "The (Mis)Framing of Social Justice: Why Ideologies of Depoliticization and Meritocracy Hinder Engineers' Ability to Think About Social Injustices," in *Engineering Education for Social Justice: Critical Explorations and Opportunities*, J. Lucena, Ed., in

Philosophy of Engineering and Technology. , Dordrecht: Springer Netherlands, 2013, pp. 67–84. doi: 10.1007/978-94-007-6350-0_4.
[37] D. Riley, *Engineering and social justice*. San Rafael, CA: Morgan and Claypool, 2008.
[38] J. Lucena, "'The Road Less Travelled': Engineering With Vulnerable Communities Through NGOs," in *2021 ASEE Virtual Annual Conference Content Access Proceedings*, Virtual Conference: ASEE Conferences, Jul. 2021, p. 36537. doi: 10.18260/1-2--36537.
[39] ABET, "2022-2023 Criteria for Accrediting engineering Programs," ABET, 2021. [Online]. Available: https://www.abet.org/wp-content/uploads/2022/01/2022-23-EAC-Criteria.pdf