Educating Engineers to Work Ethically with Global Marginalized Communities

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Abstract

Ethical reasoning is an important ability for engineers working with marginalized communities in global contexts. However, the ethical awareness and development that are critical for this work may not be included in traditional engineering education. This article presents faculty perspectives on the ethical and societal issues (ESI) that should be taught and the pedagogies that are used to prepare students for development engineering. Among 60 survey respondents who taught courses focused on global and/or development (GD) issues, the ESI topics that were particularly congruent included poverty, sustainability, social justice, and engineering decisions under uncertainty. Faculty interviews highlighted that GD should foreground the human side of engineering, respectful partnerships with communities grounded in an asset perspective, and considerations of historical elements. Discussions, case studies, design, and reflection are impactful pedagogies that can complement learning through service to achieve ESI educational goals.

Keywords: engineering education; ethics; humanities and social science; sustainable development

Introduction

There is a critical need for environmental engineers to apply their knowledge toward improving global conditions, including providing access to water and sanitation for all, contributing to responsible consumption and production, and supporting climate action (UN, 2015; Mihelcic et al., 2017). The inter-related nature of the UN Sustainable Development Goals (SDGs) links these areas to outcomes such as poverty, inequalities, and justice. Tackling these issues requires more than technical expertise, aligning with the National Academies’ ultimate challenge to prepare environmental engineers to address a new future (NASEM, 2018).

If engineers are to work effectively with marginalized communities locally and globally, they should be sensitized to a variety of ethical issues and have sophisticated ethical reasoning skills. This aligns with the NAE’s Environmental Engineering Grand Challenges report recommendation to “create opportunities to explore the ethical and social dimensions of environmental engineering challenges” (NASEM, 2018, p. 83). Ethics is defined broadly to include macroethical issues that pertain to the responsibility of the engineering profession to society and the environment, inclusive of ideas such as sustainability and social justice (SJ) (Barry and Herkert, 2014). This definition aligns with the current ABET criterion that engineering students should graduate with “an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts” (ABET, 2016). This criterion brings together what were formerly separate outcomes for ethics and societal issues (ESI) under the ABET EC2000 A to K criteria.

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†We refer readers to the Supplementary Materials for a definition of marginalized communities based on a number of theories and references.

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Correction added on March 29, 2021 after first online publication of November 23, 2020: The article reflects Open Access, with copyright transferring to the author(s), and a Creative Commons Attribution Noncommercial License (CC-BY-NC) added (http://creativecommons.org/licenses/by-nc/4.0/).
Giovanelli and Sandekian (2017) defined a global engineer as “someone who practices engineering:

(1) with forethought of its far-reaching consequences, both physical and social;
(2) with an appreciation of international colleagues and/or in international offices; and
(3) with cultural sensitivity, so that personal interactions are both pleasant and effective.”

These attributes are stated as prerequisites to achieve ethically sound solutions. Jesiek et al. (2014) also identified ethical issues among the three main contextual dimensions of global engineering competency.

A variety of ethical issues are related to engineering development work. Hersh (2015) calls attention to four core issues: serving needs before wants; respecting persons equally; respecting autonomy; and creating autonomy. SJ encompasses many of these considerations (Leydens and Lucena, 2014). Riley (2007) calls for enhanced ethics education in global development projects, which would resist neoliberalism. More concretely, Verharen et al. (2014) provide a series of 13 questions to evaluate appropriate technology projects and criteria for so-called survival ethics of projects (e.g., community solidarity, freedom or creativity, flourishing or happiness). There is, in fact, an entire field of “development ethics” that considers both large motivating issues (e.g., “What moral responsibility do affluent nations or those people in them have to the starving masses?” Crocker, 2008) and project-scale issues (e.g., To what extent does a project disrespect or weaken the agency of individuals in developing countries?).

There are a number of programs and courses that work to educate environmental engineers to work effectively in global development settings (Wright et al., 2008; Trotz et al., 2009; Duff et al., 2014; Sandekian et al., 2014). However, the specific ethical issues and teaching modalities for ethics in these courses are not clearly described. Other engineering service-oriented programs serve all disciplines (Colledge, 2012, 2014). For example, Purdue University’s EPICS program works with both local and global community partners and includes ethics and social context among eight course learning objectives (Zoltowski and Oakes, 2014). Students have reported ethical development due to participation in projects with marginalized communities globally that are facilitated through engineering-oriented, nongovernmental organizations (NGOs) such as Engineers Without Borders (EWB) (Jaeger and Larochele, 2009; Litchfield and Jennick-Will, 2014). However, sometimes these projects “inadvertently extend social injustices”, unintentionally inflict harm on communities, and/or fail to deliver long-term benefits (Nieuwma and Riley, 2010; Mazzurco and Jesiek, 2014). A combination of careful attention to the complex ethical issues embedded in development-oriented projects (e.g., Lucena, 2020), critical examination of past failures (e.g., EWB Canada), and intentional educational practices may help avoid some of these pitfalls.

Within two leading books focused on environmental engineering in global development contexts (Mihelcic et al., 2009; Laugesen et al., 2010), there is not a single explicit mention of ethics. Mihelcic et al. (2009) acknowledge civic responsibility in the preface and later describe respect for the community as an important element to “work effectively in the community”.

More equitable “participatory” models for development are presented in section 3.3 noting that “others believe development demands an explicit shift in the balance of power to the community and within the community.” The Laugesen et al. (2010) book on wastewater treatment in developing settings included little to no attention to social issues or participatory models. In contrast, Amadéi’s (2014) Engineering for Sustainable Human Development includes 20 mentions of “ethics/ethical” sprinkled throughout the book. The inclusion of ethics in the foundational early chapters in the book promotes a participatory approach with communities, including considerations of ethics, justice, equity, and social power. Ethics is identified among the important skills and considerations when educating engineers for development work.

Most engineering ethics textbooks fail to address global development issues in a substantive way. Unger (2017) briefly includes global development issues in case studies of the Panama Canal project and Ben Linder who worked on small-scale hydroelectric projects in Nicaragua. However, these cases do not portray the communities from an asset perspective. In contrast, Catalano’s (2006) ethics text examines poverty, underdevelopment, and sustainability issues in sophisticated and meaningful ways.

Despite the evidence that engineering education can bring together ideas of global development issues and ethics, it is unclear what practices faculty intentionally integrate into their teaching. More information in this regard can provide models for faculty to improve the education of students interested in participating in global development projects.

Two research questions were explored in this study:

(1) How prevalent are various ESI topics that are integrated into educating engineers to work in global development settings?
(2) What teaching practices are congruent with ESI education for work in global development settings?

The research questions seek to illuminate the current landscape of ESI education in the context of global development. Characterizing the exposure that students receive to these topics in their undergraduate education can inform an understanding of how to cultivate ethical awareness and ultimately ethical behavior. Current practices in ESI education can serve as examples and inspirations for engineering faculty looking to begin or extend their instruction on global development and work with marginalized communities.

Research Methods

This research used mixed methods and is embedded within a larger study on macroethics education in engineering. The study was reviewed and approved by the IRB as an exempt study with minimal risk level (Protocol #15–0326).

Quantitative

Surveys were used to gather data from a large number of engineering educators who teach students about the broader impacts of technology and ethical issues. At the time that the survey was administered, ethics and societal impacts were separate student outcomes under the ABET Engineering Accreditation Commission’s A to K criteria (ABET, 2016); therefore, “ethics and societal impact” was used in the
wording of the survey questions (referred to as ESI in this article). The survey questions and distribution methods have been previously described (Bielefeldt et al., 2018).

Notably, the current analysis combines responses from the largely-U.S. distribution (spring 2016) and a later Anglo/Western European distribution (summer 2018) (Polmear et al., 2019). Most relevant in this study is that invitations to participate in the survey were distributed in 2016 to the Ethics, Community Engagement, Liberal Education/Engineering & Society, and Educational Research and Methods divisions of the American Society for Engineering Education (ASEE) and faculty advisors of university chapters of EWB, Engineers for a Sustainable World (ESW), and Engineering World Health (EWH); and in 2018 to 1220 individual faculty identified as education program leaders at 116 institutions in Western European and non-U.S. Anglo countries.

The data set was limited to responses from those who indicated that they taught one or more ESI topics in their courses and described the teaching methods that they used in one or two courses (1,122 responses from 2016; 124 responses from 2018). The survey asked individuals to identify which among a list of 18 specific ESI topics plus “other” they taught in any of their undergraduate and/or graduate courses. For those that indicated any ESI topics, the survey asked them to identify the course they taught which they believed was the most effective for ESI education and then identify the teaching methods used for ESI in the course. Survey takers were then offered an option to describe a second course that they taught with ESI content. Based on the course titles supplied, there were 60 individuals who taught courses clearly focused on global issues and/or development; these will be called “GD courses.” In the few cases where individuals described two global and/or development (GD) courses, only the responses pertaining to their most effective GD course were analyzed. Common course titles included the terms sustainable community development (SCD), global service learning, humanitarian aid, and global perspectives. The majority of these courses were undergraduate electives (45), a few were required undergraduate courses (9), and others were graduate level (14).

Note that some courses fell under multiple categories (e.g., “Engineering and the Developing World” that was an elective cross-listed as an upper division undergraduate and a graduate level course). Additional course type descriptors for the undergraduate courses included 6 first-year engineering courses, 11 engineering science/engineering, 18 design-focused/senior capstone, 5 professional issues, 7 humanities and social science (HSS), and 7 other. These GD courses were taught by individuals at 36 different U.S. institutions and 12 international institutions (in the United Kingdom, Australia, New Zealand, Canada, Switzerland, Netherlands, and Hong Kong); 2 respondents did not identify their institution.

There were 141 individuals who indicated that they advised or mentored a cocurricular engineering service group (ESG)—such as EWB, EWH, ESW, or other—and did not obviously teach a GD course (among the 60 GD instructors, 27 mentored ESGs). Note that GD topics may have been embedded within their courses, but this was not obvious from the course titles that they provided in their survey responses. This group was broken out to represent individuals with a clear interest in GD issues.

The remaining 1,045 individuals taught one or more ESI topics in courses where they described their pedagogy. Statistical tests were used to compare the frequency of particular survey responses (e.g., ESI topics taught in courses) from among GD instructors, ESG advisors, and others who taught ESI in their courses (considered the “baseline”) using Fisher’s exact tests, with statistically significant differences inferred when the two-tailed p-values were 0.05 or less. When comparing count data (e.g., total number of ESI topics taught), nonparametric Kruskal–Wallis tests were first used to compare across the three

| Pseudonym | Instructional setting | Description |
|-----------|-----------------------|-------------|
| Chaney | E,GD | Global HSS course | Elective undergraduate course |
| Holt | E,GD | Global SL course | Two-semester international SL course focused on water, interdisciplinary |
| Humphries | E,GD | Eng SCD HSS course | Reading and writing intensive course, focused on case studies of development projects that failed |
| Odell | E,GD | Eng SCD HSS course | Reading and writing intensive course, focused on case studies of development projects that failed |
| Simms | E,G | Program Humanitarian Entrepreneurship | 5 courses in certificate: social entrepreneurship, seminar on design for developing communities, project-based humanitarian engineering, fieldwork, and reflection/dissemination |
| Sumner | Communication | elective in SCD minor | Humanitarian engineering minor includes a required design course sequence, required introductory HSS course, and two HSS electives from a menu completing projects in a long-term international partner and newer Native American community |
| Millhouse | E,GD | EWB student chapter | sends students to repair medical equipment and train locals in rural, international hospitals through summer program coordinated at the national level; trying to replicate training locally and partner on medical missions coordinated at their institution |

| Seymour | E,GD | EWH student chapter | |

*EPhD or MS in engineering.

*GD, global and/or development; ESG, engineering service group.

*Bachelor’s degree from institution located in a developing country.
instructor groups, followed by paired post hoc tests; these analyses were conducted using IBM SPSS software. (Comparisons between faculty teaching at United States vs. international institutions generally did not find statistically significant differences; results are included in the Supplementary Data).

Qualitative

From among the 2016 survey respondents, 37 were interviewed to learn more about their teaching practices. Three of these were instructors of GD courses, one discussed their communication course in the context of a program focused on humanitarian engineering, and two were advisors for student chapters of global ESGs. Two additional faculty interviews from the pilot phase of the study (Bielefeldt et al., 2016) were included due to their discussion of GD courses. Table 1 summarizes the characteristics of these eight interviews where GD educational settings were described; pseudonyms were assigned using a random name generator. Four of the faculty discussed HSS elective courses designed explicitly for engineering students. A majority of the faculty had personal GD experience. Those with engineering degrees spanned agricultural, civil, electrical, geological, and material disciplines.

Themes related to ESI, global issues, and/or serving marginalized populations within the interview transcripts and the open-ended responses on the survey were identified using deductive analysis. For example, “marginalized populations” was used as a guidepost in the analysis and included terms such as disadvantaged, developing communities, and impoverished. Quotes are provided in the words of the GD course instructors to provide richness to the results; these have been lightly edited to remove hesitation words (e.g., “um”) and repeated words to make the statements easier to read and understand.

Results and Discussion

The findings from the research are presented below, with discussion to place these ideas in the context of relevant literature. Additional quotes and course specifics are included in the Supplemental Data.

RQ1. ESI topics

A greater percentage of the respondents who taught GD courses integrated engineering and poverty, sustainability/sustainable development, societal impacts of engineering and technology, SJ, and engineering decisions under uncertainty into their courses, in comparison to the instructors of other courses (Table 2). ESG advisors more commonly taught poverty, sustainability, and environmental protection issues in their courses. Overall, individuals who taught GD courses integrated a similar total number of different ESI topics into their courses (average 7.83) in comparison to those who advised cocurricular ESGs (average 6.85), but significantly more than those who taught other courses (average 6.20); results are summarized in Table 3.

Table 2. Ethical And Societal Issue Topics Taught in Courses by Global and/or Development Course Instructors Compared to Other Survey Respondents

| ESI topic                              | GD course, % | Courses taught by ESG advisors, % | Other courses, % |
|---------------------------------------|--------------|----------------------------------|------------------|
| Engineering and poverty               | 75**         | 33**                             | 12               |
| Sustainability and/or sustainable development | 90**         | 66**                             | 46               |
| Societal impacts of engineering and technology | 90**         | 65                               | 57               |
| Social justice                        | 40**         | 23                               | 17               |
| Engineering decisions under uncertainty | 68**         | 59                               | 51               |
| Environmental protection issues       | 50*          | 52**                             | 36               |

Fisher’s exact test in comparison to individuals who taught other courses (n=1,045), two-tailed p<0.01**, p<0.05*. Fisher’s exact test comparing GD versus ESG, two-tailed p<0.01**, p<0.05+.

ESI topics not significantly different between groups (% among GD course instructors): professional practice issues (57), ethics in design (48), safety (47), risk and liability (45), ethical failures (43), engineering code of ethics (35), ethical theories (32), responsible conduct of research (32), privacy/civil liberties (10), war/peace/military issues (5), bioethics (3), nanotechnology (2), other (12). See comparisons in the Supplemental Data.

ESI, ethical and societal issues.

Table 3. Total Number of Ethical and Societal Issue Topics Taught in Courses by Different Groups of Faculty

| Parameter                           | GD (n=60) | ESG (n=141) | Other (n=1,045) |
|-------------------------------------|-----------|-------------|-----------------|
| Average                             | 7.83      | 6.85        | 6.20            |
| Standard deviation                  | 3.52      | 3.60        | 3.63            |
| Skewness                            | 0.075     | 0.44        | 0.582           |
| Kurtosis                            | -0.236    | -0.638      | -0.203          |
| Kruskal–Wallis asymptotic sig. (2-sided test) | 0.000     | NA          | 0.038/0.115     |
| Post hoc pairwise sig./adjusted sig. vs. ESG | 0.062/0.185 | NA         | 0.038/0.115     |
| Post hoc pairwise sig./adjusted sig. vs. Other | 0.000/0.001 | 0.038/0.115 | NA              |

NA, not applicable.
role in addressing it (Catalano, 2006, 2007). As evidence that individuals elect to teach poverty-related issues in what they feel are appropriate contexts, 65% of the ESG advisors indicated that poverty was a topic in those cocurricular settings, whereas only 33% indicated that poverty was integrated into the courses they taught.

Sustainability issues and the societal impacts of engineering and technology were topics taught by nearly all of the GD instructors. Sustainable development appears within the American Society of Civil Engineers (ASCE) Code of Ethics (2017). Sustainability goals are clearly aligned with global development, including future-oriented perspectives (Gagnon et al., 2009). There are myriad examples of well-meaning engineering projects that are littered around developing communities and not being used (e.g., 89 of 91 wastewater treatment plants in Malaysia are malfunctioning or inactive, Laugesen et al. 2010, vii). Sustainable development also encompasses elements of intergenerational equity and long-term ecological protection (WCED, 1987; Linnerud and Holden, 2016). The prominent role of sustainability is directly evident in the title of 15 of the GD courses (e.g., Investigating Sustainable International Development, Sustainable Design in the Developing World).

SJ was taught by only 17% of the ESI instructors of other courses, but was included by 40% of the GD course instructors. The term SJ was not used by the GD instructors during the interviews in reference to their course content, while Sumner talked extensively about SJ while describing the humanitarian engineering minor. Interestingly, SJ was taught in cocurricular service settings by 35% of the ESG advisors, higher than the 23% in their courses. Langhelle (2000) argues that “social justice is the primary development goal of sustainable development” (p. 299).

Engineering decisions under uncertainty was taught by more than half of the GD instructors. Global sustainable development includes the uncertainties of social issues outside one’s own culture and future environmental conditions (likely exacerbated by climate change). It is debatable whether engineering activities directed toward global development aims have higher uncertainties than “typical” engineering projects. In educational settings, traditional engineering projects are often taught in an overly simplistic manner that ignores inherent uncertainties, while these unknowns are much more obvious in development activities. Newberry (2010) explicitly characterizes lack of information among multiple macroethical issues. In the interview, Holt described this notion of design despite uncertainty in the context of a service-learning course:

So we go down [to our partner community] with the intent of gathering field data. Knowing full well that [the students are] going to really struggle with this because it’s such a shifting reality. For example, they couldn’t understand this year why I couldn’t tell them how many homes were in the community. And I said, “Well it’s somewhere between 25 and 60” and they’re like “well just count the homes.” And we went in January and they were walking with a guy from the village and they passed a house and they say, “is this in the village?” And the guy would say, “I don’t think so but it might be.” And they suddenly realize boundaries don’t make sense, that we’re judging these sort of things from our own notions of property ownership and boundaries. So a lot of actually what we do in January is dispelling all these notions of finally having all the data they need to do the design.

Odell also noted that “Calculations are easy. Getting coherent answers out of human beings is a lot harder.”

Environmental protection issues were taught by half of the instructors of GD courses. Because environmental protection is a component of sustainability (e.g., Hersh, 2015), it is somewhat surprising that more GD instructors did not teach it. Faculty may distinguish between sustainability and sustainable development. The pilot version of the survey instrument listed sustainable development and sustainability/sustainable engineering as separate topics, with two individuals who taught sustainable development (among 10) not also indicating that they taught sustainability/sustainable engineering (Bielefeldt et al., 2016).

Only one of the GD instructors, Chaney, talked about environmental issues explicitly in her interview, noting that her globally-focused HSS course included “a week on the environment, specifically global ecological problems and human rights issues.”

Beyond the broad ESI themes that were provided as multiple-choice options on the survey and are frequently associated with engineering ethics education, additional important topics for GD were identified from among the write-in comments on the survey and the interviews. These are presented below.

People. A key idea in most of the interviews was the sense that people are at the heart of the design process. Humphries gave the impression that the word “ethics” was not typically used in his class, but described a focus on the broader responsibility of engineering to serve people. Holt stated, “What I really like about this course is it’s kind of transformational because for a lot of our students it’s the first time they confront the fact that engineering has a human component. And recognizing that what they’re doing is solving people’s problems rather than solving problems.”

Chaney, a humanities instructor, explained:

So when it comes to teaching ethics, the larger picture for me is to make students aware of how complicated issues are and how many different players there are, how many different stakeholders…. One of the very short texts we read is somebody who says essentially “best for whom?” And it specifically uses the example of a labor saving device, which to most of us looks like a good idea until it’s your job they’ve just eliminated. And then suddenly it doesn’t look like such a good idea.

She also stated, “one of the foundations of having some kind of ethical sense is that you have to feel like there’s another person there. It’s not just some entity. And I think that’s important because I think the level of effort, the act, the level of activity and ethics is at the personal. I think it’s very rare that you feel that kind of abstract ethics.”

Asset view of communities. A key idea in a number of the interviews was the notion that engineers should view community partners from an asset perspective rather than a deficit model; this idea is also found in the literature (e.g., Lucena, 2013). Odell was the most explicit in communicating this idea:

I’m a big proponent of study abroad or go abroad or get abroad however you can. The valuable purpose is that it shows [our students] that there are other people in the world
who are fully formed people, who are not children, who are intelligent, who may not have graduated college—or even fourth grade in some cases—but might have quite sophisticated knowledge of ... development and the world and who have a lot to teach them. ... [community members] could teach us a lot.

Listening. As a supportive idea of respecting the community members and their expertise, listening was discussed in three interviews. In the communications course within the GD minor, the first phase in intercultural praxis involved inquiry, which Sumner described as: “you’re listening, you’re asking questions, you’re suspending judgment and trying to go in with an open mind, especially in another cultural context.” Listening to different stakeholders was also an important part of the first design course in the humanitarian engineering minor. He later described a case study they use in their courses:

The NGO wanted the engineers to go into this village in India and do a water and sanitation project, but the engineers who did this particular project were committed to listening and contextual listening and drawing out the perspectives of the community. So they did a community mapping session and from these discussions with different community members, what they realize is this community has no interest right now in a water and sanitation system.

Humphries noted in his SCD course, “I take this as an opportunity... to have the students start realizing that they need to kind of prop up their engineering skills with those professional skills such as communication and listening and just sort of an awareness of community priorities versus your own priorities.” He goes on to describe that these communication skills are important in all kinds of design projects, not just community development projects but also those for corporations and industry. “It’s possible to be working on things that are sort of a detriment to particular communities that are maybe marginalized, disadvantaged or not empowered to have a voice in any particular discussion of a project.”

Interestingly, the EWH advisor discussed listening in the context of his service-learning course that partners with nurses in local hospitals but not in the context of students engaging in EWH projects. He recognized issues of power and privilege between doctors and nurses, but when discussing the EWH training he focused more on language and the culture. [For example,] in Central America to not be impatient. I think our students are reminded that their values have to be modified... anybody who is going to be in a foreign country, simply has to be sensitive to know what they don’t know about the language and the culture. [For example,] in Central America culture is slower and our students have to get accommodated to not being impatient.... I think our students are reminded that their values have to be modified... I think students realize that rigid standards have to be reflected on if you are going to

In addition, listening is clearly needed for “genuine engagement with communities and stakeholders,” identified by the NAE as a key facet of environmental engineering practice to address complex challenges (NAEM, 2018, p. 79).

Humility. Engineers and engineering students should be humble when partnering with community members in development projects. On the survey a GD course instructor wrote:

Even a few weeks working on a project in Nicaragua, talking with locals, sleeping on floors, eating local food, observing the problems with infrastructure and transportation and power and justice—even that has a huge effect on receptive students. I’m more worried about the larger mass of students who never learn this basic lesson in humility.

The term humility was also used by the IEEE (2019) in its statement about stakeholder engagement.

Empathy. Was a clear theme in four of the interviews. Simms who led an entire program on global development noted,

[There is] a clear distinction between ethics education and ethical decision-making. And all my courses focused on ethical decision making, which is a very practical ethics education. What was most important was not the methodology which you can learn, but the emotional engagement. ... It was very easy for my program [] because we were completely focused on working with various stakeholders in developing countries, very heavily invested in making the technology venture successful. So the ethical component just came naturally and the empathy came naturally because they were invested in it.

Sumner indicated that the first design course in the humanitarian engineering minor “develops empathy skills and helps engineers define problems with but not for other people.” Holt describes how traveling to the partner community in the break between the two semesters of her service-learning development course helps students to “learn how to think more like the beneficiaries rather than themselves.”

One of the open-ended survey responses noted, “Modeling an ethical approach to international collaboration and exposing students to the power of a legacy of relationships built on trust and respect provides an example that may be more influential than a case study or lecture. A gentle analysis of the inherent ethical challenges of conventional engineering service projects helps students to develop the empathy that is necessary for ethical behavior.” Empathy has been previously identified as an important skill associated with global development work (e.g., Leydens and Lucena, 2014).

Local culture. A number of the GD instructors described that students need to gain awareness of cultural differences and similarities, both in general and with respect to ethics. Seymour described the in-country EWH experience that starts with training:

What they’re really doing is trying to provide some cultural sensitivity and enough language that the students can survive. ... anybody who is going to be in a foreign country, simply has to be sensitive to know what they don’t know about the language and the culture. [For example,] in Central America culture is slower and our students have to get accommodated to not being impatient.... I think our students are reminded that their values have to be modified... I think students realize that rigid standards have to be reflected on if you are going to
be an ethical person. What does that mean in this context? ...they [also] realize that there are ethical, almost universal principles that most people adhere to.

History. Was written in on the survey 19 times. This included respondents noting history among the ‘other’ ESI topics they taught, five courses with history in the title, and open-ended concluding thoughts that discussed historical issues. Three of the faculty interviews discussed historical elements in their HSS GD courses. Chaney summarized, so often students come in… thinking that the world was invented last week and thinking that the way you think right now is the way people have always thought… it’s the kind of class that makes students wake up in lots of ways they didn’t even know they were asleep. [At the end of the semester my students will say], ‘I’ve really learned to like history. I’ve really learned a lot about myself. I learned a lot about the world. I look at problems differently now. I assume that the obvious answer is not the full story. I’m much more critical about the way I think, about the way I approach problems, about the way I treat evidence.

Humphries noted, “engineering students [often] see all of that history and politics as separate from engineering. And there are few opportunities within their education to combine the two and to think about the two in any real way. So this class… it’s mostly a history class. But to have it with the engineering context, I think that’s really important for [students] to connect those.”

Sumner described historical context as an element of positionality: “if you come into a community that has had other designers come in and not do things that were culturally appropriate or not really listen to people or not engage the community in active ways or just engaged the mayor, but not the whole community, then you come in with some baggage that is invisible to you.” Sumner gave an example of “indigenous groups who don’t tend to trust nonindigenous groups due to American history.” Along similar lines, one of the international educators in their survey response noted, “Our students must understand the historical power dynamics that underlie our perspectives in order to approach future decision-making in a fair-minded and humane way.” Thus, understanding historical events and relationships is an important part of understanding the context of a community and working collaboratively toward engineering solutions that are respectful of the community (Riley, 2007; Lucena, 2013).

### RQ2. ESI teaching methods

In the GD courses a larger number of different methods were used to teach students about ESI (among the 15 choices on the survey, average 6.3 in GD courses versus 5.4 in courses taught by ESG advisors versus 5.0 for other courses with ESI integration, Table 4). The use of multiple pedagogies is appropriate given the complexity of ethical issues in GD contexts. The teaching method used by the highest percentage of GD educators was discussion, and those with the greatest differential use by GD educators overl ESG advisors and instructors of other courses were service-learning, guest lectures, and project based learning; see Table 5. These are primarily active and/or student-centered pedagogies, and any are congruent with teaching the themes associated with ESI in GD settings that were identified in RQ1.

The following paragraphs provide more description of the ESI teaching methods, based on the interviews with GD course instructors.

### Table 4. Number of Different Ethical And Societal Issue Teaching and Assessment Methods Used in Most Effective Course for Ethical And Societal Issue Instruction

| Parameter                          | GD     | ESG    | Other  |
|------------------------------------|--------|--------|--------|
| Average                            | 6.32   | 5.40   | 5.04   |
| Standard deviation                 | 3.34   | 2.85   | 2.58   |
| Skewness                           | 0.585  | 0.882  | 0.638  |
| Kurtosis                           | −0.116 | 0.548  | 0.198  |
| Kruskal–Wallis asymptotic sig. (2-sided test) | 0.011  |        |        |
| Pairwise sig./adj. sig. vs. ESG    | 0.063/0.189 | NA     | 0.291/0.873 |
| Pairwise sig./adj. sig. vs. Other  | 0.004/0.012 | 0.291/0.873 | NA     |

The survey presented 16 different teaching methods, including “other”. NA, not applicable.
Discussion. The ESI instruction method used in the largest percentage of GD courses (78%) was discussion. Humphries described:

> there’s writing and reflection and a lot of in-class discussion and small group discussion. And I think those small group discussions are probably the most valuable for this ethical development. They have to voice what their thinking is, their responsibility, and what they’re accountable for and who they’re accountable to, and kind of have that conversation. And figure it out a little bit on their own. They’re not just told this is how you do it. It’s more that these are the considerations you need to take into account. And it takes time and effort and it’s difficult. So it’s kind of messy. So I think as they go through and try to figure that out, they develop some more of these ethical considerations.

This description of discussion aligns with ideas of dialogic reflection (Hatton and Smith, 1995). Before in-class discussion in Chaney’s GD HSS elective course, students were assigned very short readings from Chaney’s course reader (see examples in Supplemental Data). For example, “instead of just reading about Newton, they actually have to read Isaac Newton. But… I zero in and make it so that the half page I’m giving them is really important.” This approach relied heavily on the instructor to facilitate a rich in-class discussion, unpacking lots of meaning from even a short paragraph. With the right probing, each carefully selected reading revealed insights to students and their own assumptions and biases that they brought to their interpretation. The discussion was often similar to think-pair-share, “Sometimes I give them an idea to think about. They talk to each other for a few minutes about it… there are multiple pairs or trios of students in a particular group. And then when they come back and report, there’s a larger field of comments, sort of sub conversations in reverse.” Discussion may be particularly well-suited to practicing listening skills, as well as building empathy.

Case Studies. Are commonly used in engineering ethics education in all settings, including in 65% of the GD courses. Case studies of development projects that failed were at the heart of Odell’s course, which “takes them apart, deconstructs them and looks at the sustainability, looks at the involvement of the community.” These same case studies of development projects could be used in any course.

Simms described that they developed a series of case studies that

> Hit on a number of topics, from self determination to indigenous knowledge to negotiating entry into a community. Corporate and business structure versus capitalism versus socialism of issues. It was really a broad spectrum of concepts that we brought to life through these cases, and these cases were all extremely, extremely real and most of them were specific situations encountered by our teams or something they could certainly relate to easily.

Other topics included the ethics of collaboration, equity and reciprocity, international research ethics, and issues of intellectual property. “[T]he cases were all about ABCD happened. What do you do next? It was about putting the students in the driver’s seat of what you do next as opposed to how should the world be. Because it doesn’t matter how the world should be, because you in no way control it. You have no influence over it. It’s all about effectuation.”

In the communications course within a GD minor, Sumner indicated that case studies were explored using the six phases of intercultural praxis to evaluate how well the people who conducted the engineering design enacted those phases. Case studies can also form the basis for discussion, indicating interplay among the pedagogies for ESI instruction. Case studies may be an ideal forum to provide examples of the importance of local culture, history, and asset views in GD settings.

Design. Half of the GD courses used design to teach ESI. Sumner described a three-course design sequence where the first course “position[s] users’ perspective prominently in the design process, especially when you’re defining the problem.” In the second course students attend to “what forms of societal well-being should result from the design… Who benefits in society and who does not benefit?” The third course was the two-semester capstone design course for all engineering majors, where some of the projects have community partners rather than industry clients. He noted, “there is a big difference between design for industry and design for community.”

The idea that different engineering design models are appropriate for GD is perhaps particularly relevant for disciplines like electrical engineering that rarely work directly with communities. Design projects are ideal settings to reinforce the integration of social and technical issues, centering people in the engineering process, and dealing with uncertainty. Sustainability and its component attributes can be explicitly included among design criteria. Sustainability was prominent within the humanitarian entrepreneurship program described by Simms, which integrated design in multiple courses.

Guest speakers. Examples of guest speakers include former Peace Corps volunteers and students who had gone on service trips. In the two-semester service-learning course, Holt described:

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**Table 5. Ethical and Societal Issues Teaching Methods More Prevalent Among Global and/or Development Courses Versus Other Courses**

| ESI teaching method       | GD course, % | Course taught by ESG advisor, % | Other courses, % |
|---------------------------|--------------|---------------------------------|------------------|
| In-class discussion       | 78*          | 67                              | 65               |
| Project based learning    | 60***        | 41                              | 37               |
| Guest lectures            | 58***        | 37*                             | 28               |
| Service learning          | 43***++      | 21++                            | 10               |
| Reflection                | 42*          | 32                              | 26               |
| In-class debates/role plays | 35*        | 25                              | 21               |
| Humanist readings         | 20**         | 9                               | 8                |

Fisher’s exact test in comparison to individuals who taught other courses (n = 1,045), two-tailed p < 0.01**, p < 0.05*. Fisher’s exact test comparing GD versus ESG, two-tailed p < 0.01***, p < 0.05**. Teaching methods in GD courses that did not differ versus other courses (% in GD courses): case studies (65), lectures (55), engineering design (50), examples of professional scenarios (45), videos/movie clips (32), think-pair-share (20), problem solving heuristics (12), other (10), moral exemplars (7).
Service Learning (SL). Showed the largest gap in application in GD courses versus other courses (43% vs. 10%, respectively). The use of service learning to prepare students for GD work aligns with a recommendation in the Environmental Engineering Grand Challenges report (NASEM, 2018, p. 84). ESG advisors may bring elements of their cocurricular projects into their courses, serving as sources of design projects (i.e., 56 of the 141 ESG instructors indicated that they taught design-focused undergraduate courses with ESI integration). Service learning in courses or learning through service in cocurricular settings may provide a rich environment for authentic student growth in ESI awareness and ethical reasoning. However, some of these community engagement experiences focus more on student learning than the community partner, an imbalance that is an ethical concern. In contrast, in Simms’ program “it was all about the quality of ventures…. My program did not really focus as much on the students and what they learned. …It was about what venture do we create that is independent and self-sustaining.” Thus the program prioritized the community over student learning, avoiding “things like hit and run research or parachuting into communities and trying to do something without proper equity and reciprocity.”

The advisors of EWH and EWB described that their programs attracted student participants with greater service motivation and intercultural awareness. These cocurricular settings appeared to have little direct instruction on ethics, but seemed to rely on the rich context to lead to growth in motivation and intercultural awareness. These cocurricular groups attracted student participants with greater service learning in courses or learning through service in cocurricular settings may provide a rich environment for authentic student growth in ESI awareness and ethical reasoning. However, some of these community engagement experiences focus more on student learning than the community partner, an imbalance that is an ethical concern. In contrast, in Simms’ program “it was all about the quality of ventures…. My program did not really focus as much on the students and what they learned. …It was about what venture do we create that is independent and self-sustaining.” Thus the program prioritized the community over student learning, avoiding “things like hit and run research or parachuting into communities and trying to do something without proper equity and reciprocity.”

The language of reflection was more commonly used in the interviews with instructors with an HSS background or teaching an HSS GD course.

Limitations

The primary limitation of this study is that the survey instrument and interviews were not specifically designed to probe instructional practices related to marginalized communities, but rather this was a post hoc analysis conducted on data from a large study on ESI education. A study intentionally focused on GD should distribute the survey invitation to individuals associated with the growing number of engineering programs focused on GD (Smith et al., 2020). Given the structure of the survey questions, the qualitative data do not explicitly identify the ESI topics in the GD courses, nor the teaching methods associated with individual ESI topics. In addition, the findings are based on individuals who chose to respond to an online survey focused on teaching engineering students to consider the broader impacts of engineering and technology, including ethics. The methodology by which ~6000 individuals were invited to participate in the survey cannot ensure that the results are fully representative of the spectrum of engineering instructors. Furthermore, the interviews only encompassed eight GD instructors, seven of whom were white, and therefore are unlikely to fully represent the diversity of opinions and approaches for ESI integration.

Summary

This research identified ESI topics and teaching practices that are congruent with preparing students for GD work. Although all of these ideas have been previously reported in the literature related to ethics or development work, this work revealed the perspectives of both U.S. and non-U.S. educators through the survey results, as well as individuals from an array of engineering disciplines and HSS backgrounds. Thus, a wide array of opinions is revealed in contrast to previous articles and books that represent the views of fewer individuals. The mixed-methods design also provides an aggregated baseline coupled with contextualized examples to illuminate instruction related to GD and marginalized communities. The data indicated the range of topics and pedagogies cited by GD instructors, both of which were greater than those noted by instructors who taught ESI in other communities that are maybe marginalized, disadvantaged or not empowered to have a voice in any particular discussion of a project.
courses. This finding acknowledges the important work that faculty are doing to teach engineering students about ESI and that engaging with communities necessitates a broad perspective on salient considerations. Exposure to ESI through courses and cocurricular activities can cultivate students’ awareness and thus support their ethical development and behavior. To fully prepare students for ethical GD work, best practices are programs that span multiple courses and terms and engage faculty with multiple perspectives (engineering, HSS). Courses should explicitly bring together social and technical issues, and students should authentically collaborate with marginalized communities. However, it can be challenging to create these programs in an ethical manner that honors the marginalized communities and delivers actual benefits to those communities. Honoring a marginalized community in an educational setting may include challenging decisions, such as prioritizing community needs over student learning; developing long-term partnerships; or engaging in projects that, in the end, may not need an engineering solution. The self-selected engineering students who seek out activities like EWB or elective courses focused on GD are generally already open to the idea that culture is a huge part of successful engineering development work. Because of this, GD topics may be an effective vehicle to draw students into key ethical considerations, which are beneficial not only in their work with marginalized communities but also can be critical as a foundation for traditional engineering work.

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Supplementary Material

Supplementary Data

References

ABET. (2016). Criteria for Accrediting Engineering Programs. Effective for Reviews During the 2017–2018 Cycle. Baltimore MD: Engineering Accreditation Commission, ABET.

Amadei, B. (2014). Engineering for Sustainable Human Development: A Guide to Successful Small-Scale Community Projects. Reston, VA: ASCE Press.

American Society of Civil Engineers (ASCE). (2017). Code of Ethics. Available at: www.asce.org/code-of-ethics/ (accessed June 18, 2020).

Barry, B.E., and Herkert, J.R. (2014). Engineering Ethics. In A. Johri and B.M. Olds, Eds., Cambridge Handbook of Engineering Education Research. New York, NY: Cambridge University Press.

Bielefeldt, A.R., Polmear, M., Canney, N., Swan, C., and Knight, D. (2018). Ethics education of undergraduate and graduate students in environmental engineering and related disciplines. Environ. Eng. Sci. 35, 684.

Bielefeldt, A.R., Canney, N.E., Swan, C., and Knight, D. (2016). Efficacy of Macroeconomics Education in Engineering. American Society for Engineering Education (ASEE) Annual Conference and Exposition Proceedings. Washington, DC: ASEE, p. 21. DOI 10.18260/p.26919.

Bielefeldt, A.R., Polmear, M., Canney, N.E., Swan, C., and Knight, D. (2020). Variations in Reflections as a Method for Teaching and Assessment of Engineering Ethics. American Society for Engineering Education (ASEE) Annual Conference. p. 16.

Catalano, G.D. (2007). Engineering, Poverty, and the Earth. San Rafael, CA: Morgan & Claypool Publishers.

Catalano, G.D. (2006). Engineering ethics: Peace, justice, and the Earth. San Rafael, CA: Morgan & Claypool Publishers.

Clarkeburn, H., and Kettula, K. (2012). Fairness and using reflective journals in assessment. Teach. Higher Educ. 17, 439.

Colledge, T. (2014). Special Issue: University engineering programs that impact communities: Critical Analyses and Reflection. International Journal for Service Learning in Engineering. Kingston, Canada: Queens University Library. p. 562.

Colledge, T.H. (2012). Convergence: Philosophies and Pedagogies for Developing the Next Generation of Humanitarian Engineers and Social Entrepreneurs. IJISLE and NCIIA.

Crockler, D.A. (2008). Ethics of Global Development: Agency, Capability, and Deliberative Democracy. NY: Cambridge University Press.

Colledge, T.H. (2012). Convergence: Philosophies and Pedagogies for Developing the Next Generation of Humanitarian Engineers and Social Entrepreneurs. IJISLE and NCIIA.

EWB Canada. Available at: www.ewb.ca/en/ Failure Reports. 2010–2017. (accessed September 18, 2020).

Gagnon, B., Leduc, R., and Savard, L. (2009). Sustainable development in engineering: A review of principles and definition of a conceptual framework. Environ. Eng. Sci. 26, 1459.

Giovannelli, L., and Sandekian, R. (2017). Global engineering: What do we mean by it and how are we preparing out students for it? American Society for Engineering Education (ASEE) Annual Conference and Exposition Proceedings, Paper ID #20023, 16 pp.

Hatton, N., and Smith, D. (1995). Reflection in teacher education: Towards definition and implementation. Teach. Teach. Educ. 11, 33.

Hersh, M. (2015). Ethical Engineering for International Development and Environmental Sustainability. London: Springer.

IEEE (2019). Ethically Aligned Design: A Vision for Prioritizing Human Well-Being with Autonomous and Intelligent Systems. Version 2. p. 266.

Jaeger, B., and LaRochelle, E. (2009). EWB^2 Engineers Without Borders: Educationally, A World of Benefits. American Society for Engineering Education Annual Conference & Exposition, Paper AC 2009–2740, p. 23. DOI: 10.18260/aisee.v0i0.5555.

EWW Canada. Available at: www.ewb.ca/en/ Failure Reports. 2010–2017. (accessed September 18, 2020).

Gagnon, B., Leduc, R., and Savard, L. (2009). Sustainable development in engineering: A review of principles and definition of a conceptual framework. Environ. Eng. Sci. 26, 1459.

Giovannelli, L., and Sandekian, R. (2017). Global engineering: What do we mean by it and how are we preparing out students for it? American Society for Engineering Education (ASEE) Annual Conference and Exposition Proceedings, Paper ID #20023, 16 pp.

Hatton, N., and Smith, D. (1995). Reflection in teacher education: Towards definition and implementation. Teach. Teach. Educ. 11, 33.

Hersh, M. (2015). Ethical Engineering for International Development and Environmental Sustainability. London: Springer.

IEEE (2019). Ethically Aligned Design: A Vision for Prioritizing Human Well-Being with Autonomous and Intelligent Systems. Version 2. p. 266.

Jaeger, B., and LaRochelle, E. (2009). EWB^2 Engineers Without Borders: Educationally, A World of Benefits. American Society for Engineering Education Annual Conference & Exposition, Paper AC 2009–2740, p. 23. DOI: 10.18260/aisee.v0i0.5555.

EWW Canada. Available at: www.ewb.ca/en/ Failure Reports. 2010–2017. (accessed September 18, 2020).

Gagnon, B., Leduc, R., and Savard, L. (2009). Sustainable development in engineering: A review of principles and definition of a conceptual framework. Environ. Eng. Sci. 26, 1459.

Giovannelli, L., and Sandekian, R. (2017). Global engineering: What do we mean by it and how are we preparing out students for it? American Society for Engineering Education (ASEE) Annual Conference and Exposition Proceedings, Paper ID #20023, 16 pp.

Hatton, N., and Smith, D. (1995). Reflection in teacher education: Towards definition and implementation. Teach. Teach. Educ. 11, 33.

Hersh, M. (2015). Ethical Engineering for International Development and Environmental Sustainability. London: Springer.

IEEE (2019). Ethically Aligned Design: A Vision for Prioritizing Human Well-Being with Autonomous and Intelligent Systems. Version 2. p. 266.

Jaeger, B., and LaRochelle, E. (2009). EWB^2 Engineers Without Borders: Educationally, A World of Benefits. American Society for Engineering Education Annual Conference & Exposition, Paper AC 2009–2740, p. 23. DOI: 10.18260/aisee.v0i0.5555.
Langhelle, O. (2000). Sustainable development and social justice: Expanding the Rawlsian framework of global justice. *Environ. Values*, 9, 295.

Laugesen, C., Fryd, O., Brix, H., and Kootatap, T. (2010). *Sustainable Wastewater Management in Developing Countries: New Paradigms and Case Studies from the Field*. Reston VA: ASCE.

Leydens, J.A., and Lucena, J.C. (2014). Social justice: A missing, unelaborated dimension in humanitarian engineering and learning through service. *Int. J. Serv. Learn. Eng.*, 9, 1.

Linnerud, K., and Holden, E. (2016). Five criteria for global sustainable development. *Int. J. Global Environ. Issues*, 15, 300.

Litchfield, K., and Javernick-Will, A. (2014). Investigating gains from EWB-USA involvement. *J. Prof. Issues Eng. Educ. Pract.*, 140, 9.

Lucena, J. (2013). Chapter 44: Engineers and Community: How sustainable engineering depends on engineers’ views of people. In J. Kauffman and K.-M. Lee, Eds., *Handbook of Sustainable Engineering*. Dordrecht: Springer, pp. 793–815.

Lucena, J. (2020). Can community development projects in engineering education be both responsible and sustainable? Theory, education, and praxis. *American Society for Engineering Education (ASEE) Virtual Annual Conference*. DOI: 10.18260/1-2–34254.

Mazzurco, A., and Jesiek, B.K. (2014). Learning from failure: Developing a typology to enhance global service-learning engineering projects. *American Society for Engineering Education Annual Conference & Exposition*. p. 12. DOI: 10.18260/1-2–20744.

Mihelcic, J.R., Fry, L.M., Myre, E.A., Phillips, L.D., and Barkdoll, B.D. (2009). *Field Guide to Environmental Engineering for Development Workers: Water, Sanitation, and Indoor Air*. Reston, VA: ASCE.

Mihelcic, J.R., Naughton, C.C., Verbyla, M.E., Zhang, Q., Schweitzer, R.W., Oakley, S.M., Wells, E.C., and Whiteford, L.M. (2017). The grandest challenge of all: The role of environmental engineering to achieve sustainability in the world’s developing regions. *Environ. Eng. Sci.*, 32, 16.

Miller, R.W. (2010). *Globalizing Justice: The Ethics of Poverty and Power*. Oxford: Oxford University Press.

National Academies of Science, Engineering, and Medicine (NASEM). (2018). *Environmental Engineering for the 21st Century: Addressing Grand Challenges*. Washington DC: National Academies Press.

Newberry, B. (2010). Katrina: Macro-ethical issues for engineers. *Sci. Eng. Ethics*, 16, 535.

Nievesma, D., and Riley, D. (2010). Designs on development: Engineering, globalization, and social justice. *Eng. Stud.*, 2, 29.

Polmear, M., Bielefeldt, A.R., Knight, D., Canney, N. and Swan, C. (2019). Analysis of Macroethics Teaching Practices and Perceptions in Engineering: A Cultural Comparison. *Eur. J. Eng. Educ.*, 44, 866.

Riley, D. (2007). Resisting neoliberalism in global development engineering. *American Society for Engineering Education Annual Conference & Exposition*, Paper AC 2007–2072, p. 16. DOI: 10.18260/1-2–2628.

Sandekian, R., Chinowsky, P., and Amadei, B. (2014). Engineering for developing communities at the University of Colorado Boulder: A ten year retrospective. *International Journal for Service Learning in Engineering*. pp. 62–77. DOI: 10.24908/ijsla.v0i0.5544.

Smith, J., Tran, A.L.H., and Compston, P. (2020). Review of humanitarian action and development engineering education programmes. *Eur. J. Eng. Educ.*, 45, 249.

Trotz, M., Stuart, A., Yeh, D., Muga, H., Phillips, L., and Mihelcic, J. (2009). Nontraditional university research partners that facilitate service learning and graduate research for sustainable development. *American Society for Engineering Education Annual Conference & Exposition*, Paper AC 2009–1393, p. 11. DOI: 10.18260/1-2–5327.

Unger, S.H. (2017). *Controlling technology: Ethics and the responsible engineer*. 3rd edition. Unger Media.

United Nations (U.N.) (2015). *Transforming our World: The 2030 Agenda for Sustainable Development*. United Nations.

Verharen, C., Tharakan, J., Bugarin, F., Fortunak, J., Kadoda, G. and Middendorf, G. (2014). Survival ethics in the real world: The research university and sustainable development. *Sci. Eng. Ethics*, 20, 135.

WCED – World Commission on Environment and Development of the United Nations. (1987). *Our Common Future*. Oxford, UK: Oxford University Press.

Wright, H., Phillips, L., and Mihelcic, J. (2008). International senior design: Assessing the impact on engineering students after graduation. *American Society for Engineering Education Annual Conference & Exposition*, Paper AC 2008–2562, p. 17. DOI: 10.18260/1-2–3367.

Zoliowski, C.B., and Oakes, W.C. (2014). Learning by doing: Reflections of the EPICS program. *International Journal for Service Learning in Engineering*, Special Issue, Fall, pp. 1–32. DOI: 10.24908/ijsla.v0i0.5540.