
AC 2011-2701: THE UNIQUE VALUE OF HUMANITARIAN ENGINEERING

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The Unique Value of Humanitarian Engineering

Abstract

In this paper we explore the benefits and unique value that humanitarian engineering (HE)—the application of engineering skills or services for humanitarian aid purposes, such as disaster recovery or international development—brings to the engineering curriculum. We situate this work in several Accreditation Board for Engineering and Technology (ABET) Criteria 3 Program Outcomes that are frequently underrepresented in mainstream engineering courses: outcome H (the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context), outcome F (an understanding of professional and ethical responsibility), and the intangible constraints found in outcome C (an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability). Based on conceptual/theoretical considerations, we contribute a unique synthesis of the literature that illustrates how HE naturally provides a broader context than is found in mainstream engineering courses, and can thus improve coverage of ABET outcomes H, F, and C. More importantly, however, this paper reveals that, implicit to HE is an important dimension of ethics that is deficient in mainstream engineering education and thus even helps to shape the meaning of ABET F. This neglected dimension is care—an active, interpersonal compassion, empathy, or concern for the wellbeing of others—which we argue is not simply a nice thing for engineers to do in some cases, but, when properly invoked, makes a rich, meaningful, and needed contribution to the engineering education endeavor. The paper concludes with suggestions about how to integrate topics of humanitarian engineering, and the natural context for care that it brings, into the engineering curriculum.

What is Humanitarian Engineering?

Humanitarian engineering (HE) can be defined as the application of engineering skills or services for humanitarian aid purposes, such as disaster recovery or international development. The Humanitarian Engineering program at the Colorado School of Mines defines it as: "design under constraints to directly improve the wellbeing of underserved populations" ^[1], where constraints are not just physical and economic, but also environmental, legal, political, cultural, and ethical. As illustrated by Burnham ^[2], the emerging field of humanitarian engineering has great potential for addressing many of the world's problems, especially, we believe, if such work can be carried out sustainably in a way that fully engages the local people, considering them as potential resources (not problems), and recognizes their inherent nobility and worth. If the success of such organizations as Engineers Without Borders is any indication ^[3], the field of HE is sure to continue a rapid course of growth. Lucena & Leydens ^[4] provide an admirable collection of institutions and organizations that are actively engaged in, supporting and promoting humanitarian engineering.

As highlighted by VanderSteen ^[5], it is helpful to view HE not so much as a discipline of its own, but as a meta-discipline encapsulating potentially all of engineering. Such a sentiment is

echoed in Burnham ^[2] with his "systems approach" to humanitarian engineering. The cross-disciplinarity of HE becomes very apparent when considering the breadth of HE type projects currently under way at University of Washington (UW), as an example. Projects of the UW chapter of Engineers Without Borders (see <http://students.washington.edu/ewbuw/projects/>) include cook-stoves, roofs, roads, potable water and irrigation for farmers in rural Bolivia, while projects of the UW consortium of IT-related researchers known as Change (see <http://change.washington.edu/projects/>) includes a low-cost portable ultrasound system for village mid-wives in Uganda, a multi-player educational game for children in India, and a suite of open-source software tools to build information services for developing regions such as in Africa. Fields of study of the students and faculty involved include: civil & environmental engineering, mechanical engineering, electrical engineering, bioengineering, computer science & engineering, human centered design & engineering, informatics, public health, radiology. Other universities and colleges around the United States, both large and small, are likely to have similar levels of cross-disciplinarity represented in their HE efforts.

Limitations of Traditional Engineering Education

Leydens & Lucena ^[4] make the point that traditional engineering education is too narrowly focused and disciplinary to prepare students very well for most humanitarian engineering endeavors. While this shortcoming could conceivably be overcome in practice if effective multi-disciplinary teamwork were feasible, such teams are unlikely given typical HE project constraints. Leydens & Lucena also identify a number of other problems with traditional engineering education for HE. One of these problems is the existence of pervasive value hierarchies in the minds of engineers, such as valuing:

- 1) science over design,
- 2) high-tech over low-tech solutions, and
- 3) engineering over non-engineering (e.g., humanities and social sciences) work.

Another problem given in ^[4] is the pervasive use of the engineering problem solving method, which begins by presenting the students with the necessary information to solve the problem and then having them:

- 1) extract the relevant technical information,
- 2) create idealized abstractions (e.g., free-body diagrams),
- 3) make simplifying assumptions so the problems can be solved more efficiently,
- 4) identify and apply specific scientific principles (i.e., equations derived exclusively from the engineering sciences) to the problems,
- 5) deploy mathematical strategies to solve these equations,
- 6) produce a single "correct" solution on which they are graded,
- 7) reflect back on the answer and ask whether it makes sense in the physical world.

Students are rarely taught how to consider non-technical issues throughout this process: they may even learn that such issues are irrelevant and unimportant. Engineering students are thus taught a reductionist approach to design that deliberately limits problem scope to technical concerns and both excludes and devalues broader considerations ^[4]. Similarly, Moriarty ^[6, pp. 90] describes the modern engineer as functioning "in a pragmatic, efficient, productive manner that tries to elude the limitation of context as much as possible." These limitations in traditional

engineering education restrict its usefulness in preparing students to consider the broader design constraints and considerations found in most HE applications.

ABET H, F, C and Humanitarian Engineering

One motivation for this work is to address the "short shrift" typically given to ethics and broader societal impacts in engineering education (see ^{[7] [8] [9]}). We therefore situate this work in several Accreditation Board for Engineering and Technology (ABET) Criteria 3 Program Outcomes that are frequently underrepresented in mainstream engineering courses: outcome H, F, and the intangible design constraints found in C. These outcomes require students to attain ^[10]:

- (H) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context;
- (F) an understanding of professional and ethical responsibility;
- (C) an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability.

Many authors have noticed the connections between ethics and the broader societal impacts of engineering. For example, Devon ^[11] has pointed out the limitations of using moral dilemmas posed to the individual when teaching engineering ethics, and suggests we instead use a group-based ethical decision making process that reflects the consensus approach to technology development that actually occurs in industry. This consensus approach considers social relationships such as those among the engineering design group, the company, the client, and the government. Herkert ^[12] has explicitly highlighted the natural link between ABET H and F and very clearly advocates teaching them together. Pritchard ^[13], Haws ^[14], and Tsang & Pritchard ^[15] have all described the likelihood of effective ethics learning opportunities inherent in engineering service learning, which has a clear overlap with the practice of humanitarian engineering.

Humanitarian engineering itself has been recognized by several authors as having valuable potential for creating a new and meaningful approach to engineering education. Passino ^[16] shows how humanitarian engineering ethics is supported by the ethics of volunteerism, which, while prevalent in law and medicine, needs to be encouraged in engineering. Lucena et al ^[17] even go so far as to state that the focus of engineering ethics on individual and social responsibilities in the industrialized world has overlooked humanitarian engineering as "an important dimension of engineering practice that deserves clearer ethical articulation and curriculum development."

Finally, a compelling case for the integration of humanitarian engineering topics into technical communication courses for engineers has been made by Berndt & Paterson ^[18], who suggest that "incorporating humanitarian [case studies] into technical communication courses would promote higher levels of learning, student engagement, and the global citizenship that will be requisite for all engineers in the twenty-first century." As the above paragraphs show, HE clearly has unique characteristics that can be used to improve the training of engineers in the academic curriculum. Further articulating these characteristics and developing a systematic framework for understanding their impact on engineering education requires understanding HE in the context of engineering education both broadly and deeply. The question we seek to answer in this paper

then is: What specifically is it about humanitarian engineering that is beneficial to engineering education?

Humanitarian Engineering as a Microcosm

One advantage of HE that is particularly true in the developing world context is its ability to bring macro-ethical issues—those of large scale societal concern—down to a scale that is much more immediate, tangible, and tractable. When one has: 1) a specific location or people in mind; 2) involved those people in the design and decision making process; and 3) together reached a consensus on solutions that are in the people's best interest; one is much closer to the economic, environmental, global and societal issues and one can better understand their importance. For example, a faculty advisor of the UW EWB chapter has shared the following experience (adapted from a personal communication): a project was initiated in rural Bolivia to help villagers transport their crops and products to market more regularly during the rainy season when certain sections of road regularly wash out. Students working on this project are soon confronted with the realization that, while creating a reliable road that does not wash out every season will surely benefit the village with which they are working, it is also very likely to have unintended consequences, such as its likelihood of bringing traffic from the many other nearby villages whose main roads also seasonally wash out, thus introducing considerably more trash, noise, air pollution, and road maintenance requirements. Clearly, consideration of these consequences can and should feed back into 1) the design considerations, e.g., resulting in higher weight limits or design options to minimize maintenance needs, and 2) the decision-making process as the community decides whether a new road is worth the environmental cost and maintenance responsibility.

Such an advantageous level of context can also be simulated in classroom environments as demonstrated by the sample humanitarian engineering course materials presented by Berndt & Paterson^[18] and Passino^[16]. Our view of humanitarian engineering as presenting a microcosm of society is certainly a great pedagogical benefit. Broadening the engineer students' awareness of engineering's societal impacts (outcome H) naturally feeds back to encourage broader design considerations (outcome C), and by fully considering these outcomes, we very naturally pave the way for improving ethics (outcome F). However, what dimensions of ethics are the most significant in HE? We believe there is something essential with respect to ethics in humanitarian engineering that has not yet been articulated in the literature.

Care: A Neglected Dimension in Engineering Ethics

Building on the earlier work of John Piaget, psychologist Lawrence Kohlberg in the 1960's proposed a theoretical framework that posited discrete stages of moral development. Further, he developed, for the first time, an empirical means of assessing individual levels of moral development. This theory has inspired the most widely used and researched assessment tools for moral reasoning^[19], such as the Defining Issues Test (DIT) by James Rest^[20]. However, Kohlberg's theory has been criticized on several accounts, most notably by Carol Gilligan in the 1980's as containing an implicit gender bias^[21]. Emerging from Gilligan's work was the observation that Kohlberg's theory was founded on the deontological (duty-based) philosophy of Kant and thus focused on the issue of justice or fairness to the neglect or under-valuing of the

values of compassion and caring for others ^[22] ^[23]. While Gilligan's initial contention of gender differences in moral reasoning has not been resolved by empirical research ^[23, pp 560], her work has been seminal, founding a new ethical framework known as care ethics or the ethics of care ^[24] ^[25] ^[26]. Nair ^[27] describes the ethics of care as emphasizing "the importance of responsibility, concern, and relationship over consequences (utilitarianism) or rules (deontology)".

To date, only a small handful of authors advocating for the applicability of care ethics to engineering can be found in the literature. Pantazidou & Nair ^[22] and Nair ^[27] highlight the service oriented nature of engineering and illustrate its applicability to engineering design and problem solving methodologies by mapping these methodologies to Tronto's ^[25] five elements of care: attentiveness, responsibility, competence, responsiveness, and integrity. Kardon ^[28] conceptualizes care as a "standard of care" that essentially serves as a measure of being adequately careful in the exercise of the engineer's professional duties. These conceptualizations, however, are somewhat abstract and lack the interpersonal nature of care as an active, interpersonal compassion, empathy, or concern for the wellbeing of others. Moriarty ^[6] ^[29] provides an excellent introduction to care in engineering in an interpersonal sense through the use of virtue ethics. Tempering care with objectivity, he presents a balanced and appropriate conceptualization for both good engineering and the good engineer. What is lacking in the literature, however, is a concrete and more developmentally appropriate means to help engineering students or practicing engineers to understand and apply care ethics in engineering contexts.

Humanitarian Engineering as a Matrix for Care Ethics

Above, we have shown how care is essential to engineering education in a more abstract, philosophical sense, and like the authors cited in the previous section, we suggest that care has an important role to play in engineering. The contribution of this paper is to identify humanitarian engineering as providing an important pedagogical tool for improving engineering ethics and thereby engineering education. The problem that now remains is to integrate the grounded, interpersonal nature of care into engineering curricula. Pantazidou & Nair ^[22] report struggling to identify examples in traditional engineering that illustrate the applicability of the care ethic. Surely humanitarian engineering serves to epitomize the need for care in engineering.

We suggest that an ethic of care that draws specific attention to concern for the wellbeing of other people is essential to the success of any humanitarian engineering endeavor. It is this act of caring and the subsequent attention to the needs of others that humanitarian engineering stands to bring to engineering education. However, such consideration stands in stark contrast to the typical view of engineers as being cold, detached, rational, analytical problem solvers ^[30]. The need for engineers trained to be sensitive to and caring for others becomes clear when considering the important cautions and criticisms to humanitarian engineering posed by Schneider, Lucena, & Leydens ^[31], VanderSteen ^[5], and Vandersteen, Baillie & Hall ^[32]. These cautions and criticisms include issues of motivation, accountability, local history/context for development, and consideration of who benefits and who pays. Each of these is discussed briefly below (summarized with references from ^[31]):

Motivation of the humanitarian engineer:

It is important to be critical of motivations to help others and to maintain humility about abilities to do so ^[33, p.131]. Being invited to learn from and work together with a community or to help redress injustice involves a very different mindset from that of charity work, which may not even be desired by the recipient ^[34] and may imply a view that the recipient is "less-than" or inferior.

History and context for development projects in the area:

Long term evaluation and learning from past successes and failures is important. Engineers may be oblivious to the larger scale political, cultural, and economic contexts that have created the needs (real or perceived) they are stepping in to fill ^[35], but the communities they wish to help are likely to be aware of these contexts and of inequities that rich countries helped to create.

Who benefits and who pays:

Service learning has the potential to create exploitive relationships between privileged students and "developing" communities ^{[36] [35] [34]} whereby students gain experience, but communities end up with solutions that have short working lives ^{[37] [38]}.

Accountability:

There is presently little accountability in existing humanitarian engineering programs ^[35], and while there is evidence of self-reflection on problems due to technical, communication and cultural issues, there is little effort made toward understanding how systemic inequities may create patterns of failure across multiple projects.

From these cautions/criticisms one can see that care, as a genuine concern for the wellbeing of others, is essential to avoid the dangers of doing more harm than good. It is this compassion that provides an obvious motivation for those students and faculty already interested in humanitarian engineering. However, as Schneider, Lucena, & Leydens ^[31] point out, these altruistic motives must be transformed from mere sympathy to genuine empathy before any actions taken will be of lasting benefit. Teaching humanitarian engineering with an emphasis on the ethics of care is clearly necessary.

The Pedagogy of Integrating Care into Engineering Ethics

When viewed through an historical lens, we see that the justice-based ethics common in today's society, particularly in the areas of law and risk management from which engineering ethics often borrows, is based on the philosophies of utilitarianism and Kantian deontology ^[22]. These are views of morality that have come under much criticism in moral philosophy since the 1950's, and are challenged by a renaissance of virtue ethics ^{[39][40]}, which has historically been championed by such philosophers as Plato, Aristotle and later by Thomas Aquinas. Discussions of what virtue ethics might look like in engineering ethics education are found in Harris ^[41], Martin & Schinzinger ^[42], Seebauer & Barry ^[43], and Jordan ^[44], as well as a particularly care-oriented presentation in Moriarty ^{[6] [29]}. Virtue ethics is a framework in which both care-based and justice-based ethics can find expression, and through which care ethics can become an

explicit aspect of ethics instruction. Humanitarian engineering provides a natural context, as we described previously, in which to draw out and emphasize care in engineering.

Furthermore, virtue ethics is garnering empirical support from a new branch of psychology known as positive psychology. Positive psychology has grown out of the theoretical work of humanistic psychologist Abraham Maslow who sought to study the exemplary rather than the sick or dysfunctional^[40]. Recently, some conceptual work has been done to articulate a formal “positive ethics”^{[45][46]}, which appears to be very pluralistic and widely applicable. Ideas of positive ethics are starting to find their way into discourse on engineering ethics: see for example Michael Prichard's promotion of "moral exemplars"^[47]. The humanitarian engineering context naturally provides an arena for focusing on the positive, not only through the use of such moral exemplars as humanitarian engineer Fredrick Cuny (see^{[47][48]}), but more directly by providing opportunities for students to practice positive ethical decisions themselves through their design considerations, decisions, and interactions (real or hypothetical) with the people they wish to help.

To this end, Roeser^[30] provides a valuable starting point for the integration of "emotion" into engineering design. To help change the view of engineers as being cold, detached, rational, analytical problem solvers, humanitarian engineering topics provide a natural way of introducing emotion, appropriately applied, in engineering ethics instruction. While political, social or cultural design constraints may often appear silly or irrational to the engineering student, they are very important none-the-less. Indeed, in agreement with Moriarty^{[6][29]}, care ethics should be cultivated and encouraged in all engineering students to help them in becoming responsible professional engineers. Of course a focus on care ethics need not be exclusive to the traditional justice or fairness approach^[23] that underlies most engineering ethics instruction today; indeed they can and should be complementary.

Conclusions & Future Work

The work presented in this paper is part of a larger ongoing research study guided by the following overarching research questions:

- 1) What can humanitarian engineering bring to the engineering curriculum?
- 2) How do engineering students currently understand the broader (e.g., ethical, societal, environmental) contexts of engineering?
- 3) How can humanitarian engineering topics be integrated into traditional engineering courses?

A response to the first question was the primary focus of this paper, in which we showed that humanitarian engineering has the following strengths:

- i) it provides a rich and uncontrived context, as a microcosm of society, for understanding the ethical, economic, environmental, global and societal impacts of engineering as desired by ABET Program Outcomes H, F, and C;
- ii) it provides a natural pedagogical environment that legitimizes and applies the virtues of compassion and caring for others.

Furthermore, the amenability of humanitarian engineering with the ethic of care, we believe, makes it an attractive option to students that will serve to increase engineering student diversity in terms of gender, racial & ethnic background, and way of thinking.

Our efforts in response to the second and third research questions are currently underway. Having here performed some exploration of the value of humanitarian engineering, a logical next step toward any curricular effort to incorporate an HE context is to understand what engineering students bring to the table in terms of these two ABET outcomes and in terms of familiarity and interest in HE. Specifically, to address question 2, we are conducting an empirical mixed-methods study that involves both thematic analysis and rubric-based assessment of student work related to these broader contextual and ethical considerations. A self-report survey on ethics-related values is also under development (see ^[49]) and ethnographic-style classroom observation work is ongoing.

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