What is global preparedness? Arriving at answers in collaboration with student engineers working with underserved communities globally

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Abstract

Students have demonstrated increasing demand to use their engineering skills to address global societal problems. Also, the ABET criteria requires engineering programs to provide “the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context.” These two factors have raised fundamental questions about how to effectively prepare engineering students to engage with underserved communities globally. This paper uses a case study approach to document the experiences of students of a global engineering course. This course offered students the unique opportunity to address sanitation and hygiene issues by working with a community rather than for it. The paper highlights curricular innovations that ensured ethical, sustainable collaboration with the underserved community while building the global preparedness of the student engineers. This is followed by the experiences of the student co-authors who share what they have learned and how they have found these lessons useful outside of the context of the class. Based on an analysis of these case studies, the paper concludes by proposing the creation of a global preparedness efficacy construct as a possible way to evaluate global preparedness of undergraduate engineering students.

Introduction

Student engineers are becoming increasingly aware of global issues and are expressing their commitment to take on these challenges. The presence of student chapters of Engineers for a Sustainable World (ESW) and Engineers Without Borders (EWB) in numerous universities and colleges in the United States represents increasing student enthusiasm and demand for more courses, debates, discussions and modes of engagement on global issues and sustainable development. At the heart of these organizations is a desire to create an equitable, sustainable future by mobilizing engineers around the world.

In a Carnegie Foundation sponsored study on Educating Engineers: Designing for the Future of the Field, Sheppard, et. al. describe that “Because engineers’ work directly affects the world, engineers must be able and willing to think about their ethical responsibility for the consequences of their inventions in an increasingly interlinked world environment”. The need for engineering solutions to complex world issues has brought into focus the ability of engineering students to successfully engage with such problems and deliver responsible solutions.

Recent literature in the field of Engineering Education has highlighted the need for a change in engineering curricula. In the centennial issue of the Journal of Engineering Education (Jan 2011), an essay on how to engage future engineers suggests that “engineering education has a funny, maybe even neglectful relationship to people” and there is a call to re-imagine engineering education as something more “socio-technical”. This necessitates rigorous engineering education research to advance a fundamental
understanding of the nature of today’s increasingly socio-technical engineering work. Educators should translate this understanding into curricula that will better prepare student engineers to successfully and sustainably contribute solutions to global problems by taking into account both the social and technical challenges associated with complex issues.

Engineering Education research has evolved over time to focus on the needs of engineers in response to the techno-social changes in the profession. The global nature of engineering work has made it necessary for engineers to be skilled team players, have decision making abilities, display leadership skills and show openness to working in multi-cultural settings. These needs are now being taken up by the engineering education research community. A similar effort is needed to establish a curriculum aimed at building competency in student engineers that work with communities in developing countries.

Achieving sustainable solutions, ensuring student learning, and including the participating community as equal stakeholders poses a complex problem. Engineering curriculum currently focuses almost exclusively on technical expertise while ignoring the broader cultural, economic and socio-political context that the community is embedded in. What is required today is an imagination of a different approach of working with developing communities. Rather than undermining the community, this approach should build on the local context and expertise.

Description of the Global Engineers’ Education (GEE) course

The Global Engineers’ Education (GEE) curriculum is focused on the problem of sanitation and hygiene faced by an overwhelming part of humanity. Currently 2.6 billion people have no access to toilets. Most of these people are forced to defecate in the open, and lose their dignity and self-respect while making themselves vulnerable to violence and life threatening disease. Engaging with this issue in collaboration with a partner organization in India allows students to experience their role as engineers in context of the world they would like to change and improve and this program creates the opportunity for them, as well as for the underserved communities they wish to work with, to thrive.

This curriculum aims at educating student engineers to work with rather than for the underserved communities on the creation of shareable prosperity. The vision is to build capacity in the students and the underserved communities for sustained inquiry and collaboration with one another to live prosperous lives. This is achieved by enabling student engineers and underserved communities to experience the realities, knowledge, expertise and aspiration that they have for themselves and for one another by engaging in the act of working together.

The GEE course begins by forming and bringing together teams comprising of engineering students and members of an underserved community. These teams engage in a process modified from the Stanford University design process that begins with what
each student personally cares for about the challenges faced by the underserved community. This serves as the team’s point of view for the remainder of the design process. It becomes a method for balancing the need to provide immediate assistance with the ability to thoughtfully create breakthrough-engineering solutions collaboratively with the community that needs them.

The GEE course has the following learning components:

1. An overview of conventional paradigms of development for addressing complex global problems, academia-led engineering initiatives in underserved communities, and challenges of finding sustainable solutions to problems faced by underserved communities
2. Motivation, aims and research underpinnings of course curriculum
3. A review of the current state of the sanitation and hygiene problem globally, the history of how the problem evolved, and what is being done to address it. This course serves as an introduction to works of scholars and practitioners who are currently engaged in sanitation related work in underserved communities
4. A method for hands-on engagement in working with an underserved community
5. Reflection on the critical role of research in solving complex global problems and recognizing the contribution that the students have made as engineers and undergraduate research scholars to the underserved community

In addition to regular lecture hours and team meetings, the class invites field experts from the partnering NGO and community members in India as guest lecturers to the class. The class meets for Skype calls with the field site once a week for 6 weeks.

Past research has shown that working with underserved communities can be an overwhelming experience for students. A critical component of the class was active reflection. Encountering unfamiliar situations, cultural norms and social behaviors can lead to what Philip Zimbardo calls discontinuity as a result of violation of expectations. Zimbardo, in his description of the search process that follows the experience of discontinuities, says, “the ordinary person in the throes of dealing with a subjectively significant discontinuity does not have the training, the luxury of reflection time, nor the detached perspective of the scientist” (emphasis added)\(^{13, p. 355}\). He posits that reflection is one of the key aspects of preventing discontinuity-driven searches from becoming biased and leading to false conclusions, or, in extreme cases, resulting in phobias, self-doubt, and delusional behaviors.

John Dewey, the famous philosopher of education uses thinking and reflection interchangeably. He describes the significance of knowledge and belief in the following passage: “In discovery of the detailed connections of our activities and what happens in consequence, the thought implied in cut and dry experience is made explicit. Its quantity increases so that its proportionate value is very different. Hence the quality of the experience changes; the change is so significant that we may call this type of experience reflective – that is, reflective par excellence” (emphasis in original text)\(^{14, p. 170}\). For him, “[n]o experience having a meaning is possible without some element of thought”\(^{14, p. 169}\).
A learning experience will not have meaning if it is not reflected upon. Without thinking about the relationships between actions and their consequence, the effect of the knowledge creation and the ability for future action is lost. Sustainability of what has been learned comes from reflecting on learning experiences and establishing a continuum in learning.

Prior research has shown that journaling is an effective way of enabling students to reflect. Researchers trying to understand processes of reflection and the role of reflection as an educational practice have used it effectively. A case in point is the work done by Richardson and Maltby with nursing students doing summer internships. They found that “The experience of diary writing is seen to promote both the qualities required for reflection, i.e. open-mindedness and motivation, and also the skills, i.e. self-awareness, description and observation, critical analysis and problem-solving, synthesis and evaluation”15. By maintaining a daily reflection journal, students would have an account of the unfolding of their actions and the reactions they elicit.

Methods

The primary question guiding the research in this paper was to understand student experience of working with underserved communities. This inquiry was conducted by collaborating with the students to understand their experiences in their own words. The research plan was to author cases of student experiences of the class and determine what aspects (if anything) from the class were helpful outside the class context. The second part of the inquiry was added to identify if the class could satisfy ABET criteria 3h that requires that students “to understand the impact of engineering solutions in a global, economic, environmental, and societal context”16.

GEE has been offered twice so far (Spring Quarter 2013 and 2014). A total of 18 students have taken it so far. The course is open to all undergraduate engineering students but has also been taken by a few non-engineering students. The call to participate in this research was sent out to all students of the course. Four students responded that they would like to participate.

Cases were developed in two parts. The student experience of the course was recreated using individual students’ reflection journals and reflection papers in response to readings in the class. For the second part of the case study, the following prompt was sent by email:

Please discuss in about 500 words:

- What you have learned about care and what you care about through your participation in [the course]
- Please include whether or not what you learned in [the course] was useful/applicable outside the [course] context and if it was, please describe how
- Anecdotes /events/cases of how care or any other aspect of [the course] was useful in other courses/internships/life (!) will be most helpful.
After each case was written up, each student contributor had a chance to review it and ensure that it represented his or her experiences accurately. Finally, the complete paper was shared with all of the students to ensure that they were satisfied with the interpretation of their cases.

What follows are four cases from the student co-authors. From the cases, a general understanding of student experience is discerned and recommendations for future courses and their evaluation are made.

Cases

Case Study of Student 0114

Student 0114 came in the class as a senior student in mechanical engineering. In his final paper, he wrote, “Although I initially enrolled in this class as a ‘filler’ class, I was surprised to find myself becoming extremely intrigued by our exploration of human-centered design.” He initially entered the class with a very technical focus, and over time he began to place more emphasis on understanding the human complexities of the sanitation and hygiene issues. After reading a paper about existing interventions he reflected that, “Besides ideas for toilet designs, I also gained a lot of insight from this paper on how investment and supply must be balanced with demand-creation to ensure that the technology gets adopted.”

As the course progressed, he used his personal experiences to contextualize the complexity of the problem space. For example, he observes that “[h]aving traveled to India several times with my mother, I have observed that women are much better at banding together, communicating and helping each other in unfamiliar situations, such as the waiting room of an international airport, than men are. I would not be surprised at all to learn that similar behavior patterns could be observed in restrooms.” He goes on to wonder if “women be able to preserve their instinctive behavior and rapport in unisex bathrooms, where they might be forced to mingle with men?” Considering the many facets of the sanitation problem led him to further consider the importance of empathy in navigating difficult design scenarios. In his final reflection, he writes that, “I realized the importance of understanding and empathizing with the people I am designing for. I also came to grips with the somewhat harsh reality (from a designer’s point of view) that human-centered design can’t possibly be boiled down into a set of well-defined constraints, because every person or group of people will have a slightly different set of needs and circumstances.”

Through reflections about the nature of “engineering to help classes,” he described the importance of empathy and care in the role of the professional engineer. When confronted with the views of other disciplines on the field of engineering in his reflection paper, he was “taken aback by the picture they seemed to be painting of engineers and designers throughout the paper. An uneducated reader would imagine the engineer as a hermit locked inside a laboratory, receiving ‘problems’ in the form of papers slid under his door, and zealously working out solutions by distilling the information in the
problems into a set of constraints to be followed like a mathematical formula.” He further evaluates the importance of “the working with approach” as he articulates the role of the engineer in his reflection that “[e]ngineers are not hermits who solve problems in isolation. Indeed, design philosophy itself requires that designers empathize with their target audience before they start to ideate; only then will they feel a real motivation to develop a solution. But empathizing with nail-polish users is relatively easy, compared to empathizing with underserved communities in Third-World countries scattered around the world.”

The approach of designing with care expanded his belief in the capacity for people to aspire even in difficult circumstances. In his final report, he writes that “Having visited India several times, I have often been left with the impression that India is populated by a group of jaded, perpetually repressed people crammed together like sardines, who have simply stopped caring about improving their lot in life. But by reflecting on my own care statement and those of others, and by speaking to the folks from ESI, I have realized that everyone has an inner spark that inspires them to reach higher. Seeing that spark is simply a matter of giving it the right kindling -- something India probably doesn’t receive very often. I sincerely hope our work can contribute in some small way to ESI’s mission of fanning that spark into a flame of change in rural India.”

Response to prompt

As a senior Mechanical Engineering major, I believe my [course] experience was different from those of other students participating in the program. When I enrolled in the class I had already been through a rigorous four-year-long engineering curriculum, and had completed several complex mechanical design projects without ever consciously striving for “global preparedness”. By comparison, the freshmen and sophomores in the class would have the advantage of being able to apply the philosophy of “working with, not for, the community” in all their future endeavors. On the surface, I was a latecomer and felt out of place.

However, I soon realized that the program offered me a unique opportunity to re-evaluate my entire engineering experience through the lens of Care. As I was encouraged to think about my Care Statement while working with underserved communities in India, I applied the same thinking – in retrospect – to the design of the emergency brake mechanism for a solar car, and that of a vibration isolator for a high-resolution wafer scanning machine. By asking myself what my Care Statements for these past projects would have been, I came to the conclusion that my priorities as a mechanical engineer are centered on making my designs simple, robust and reliable. If a design becomes unusable or, even worse, creates additional problems for the user, it can spawn a general feeling of helplessness and distrust. Therefore, while brainstorming for my GEE project, I set myself the goal of producing an idea for a solution that would not lose functionality under the harshest of conditions: a design that a member of an underserved community could put their faith in.
Although our project still needed fine-tuning at the end of the academic term, and was far from satisfying this goal, participating in the course helped me approach subsequent design challenges with a clearer idea of what I wanted to achieve. Over the following summer, I worked as an intern at General Motors' Powertrain division. My supervisor was the leader of a quality-assurance team, which inspected engines with warranty claims. Over the course of three months, the team tore apart over 1300 engines and diagnosed each and every one of them. Many times, the failures were caused by customer abuse or lack of maintenance. However, instead of simply dismissing these failures, the team generated suggestions for improvements to the engine designs, which would make them more robust and durable. Rather than opt to save much-needed money by blaming the malfunction on the car's owner, the company did its best to build its customers' faith in its cars. Most importantly, each individual employee I met was personally committed to fulfilling that goal; every design engineer approached his/her job with the desire to create something that the average driver could rely on in any situation. My internship coincided with a time when General Motors was receiving a lot of negative exposure in the media; as a result, I arrived with many preconceived notions about the work environment and the prevalent engineering philosophy in the company. I was pleasantly surprised to have most, if not all, of them shattered.

Case Study of Student 0214

Student 214 came into the class having already worked with a non-profit organization and being aware of the challenges of working with underserved communities. After the first day of class she wrote, “Today’s session really got me thinking about what happiness is and what it means to ‘change the world’.” She was struck by learning about the conditions of community as expressed in the following quotes: “Hearing about the difficulties that women face on a day-to-day basis was heartbreaking to hear, and although I am grateful I have the opportunity to learn about the realities of some people’s situations, it still makes me very sad.” “[S]ometimes I feel almost guilty about how many comforts and rights I have compared to others because of fortune.” Over the duration of the course though the feeling of empathy for the community did not diminish, she expressed greater confidence in being able to contribute to their relief. She reflected that “I am a little frustrated and saddened by some of the things we heard about, but I know that in order to move forward, we need to know all of the facts in hopes of better understanding and hopefully improving quality of life.”

Student 214, like most other students in the class, found herself overwhelmed by the complexity of the problem space. In a journal entry after a Skype call with the field experts she wrote in her journal about the challenge of “how do we maintain a global and a local perspective and reconcile the differences in approaches is particularly interesting to me.” This insight led her to develop a more nuanced understanding of the various facets such as social justice, gender perspectives, and the public health dimensions of the problem experienced by the community as evidenced in the following quote: “One point I had not considered before is the plight of those who manually clean toilets that are not properly cleaned, maintained or built. Given the sometimes rigid social stratification in Indian society, improving public sanitation will also promote a better standard of living
for those who are most affected by pathogens and direct contact with excrement.” She concluded that “[c]ultural differences in toilet etiquette are very important to consider when benchmarking and ideating a design that will be culturally appropriate and useful” because “[t]he sociological implications of toilet in shaping gender, age, and cultural roles is something that will be important in relating to and identifying what multiple groups of the community care about.”

Over the duration of the course she began to use the designing with approach and the care discourse as means to navigate the complexity. Hearing from the alumni of the class speaking she noted in her journal that it: “reminded me of how complex and dynamic the sanitation problem is but it is still important to have hope and realize that even considering and caring about these issues in an educated and compassionate way has an impact beyond what we may immediately see.” This thought was further nuanced at the midpoint of the quarter where she wrote that “We obviously will not solve this very complex and often discouraging issue in 5 weeks, but at the same time, there is no need to sacrifice what we care about in order to produce something that is deliverable”.

The emphasis in class about the long-term nature of the problem and focusing on what the students care about allowed her to reconcile with the vastness of the problem space and her role in providing a solution. At the end of the course, she reflected, “Coming into this class, I expected that the focus would be on the technological aspects of solutions, but over time, I have learned and grown to appreciate how important it is to consider what it means to have purpose and to work to pursue that purpose. More than what technological solutions we will produce, it is the care and sense of purpose as well as the mutual learning between the members of ESI and within our class that will have impact.” It also made her reflect on what it in fact means to have an impact. At the start of the course, she wrote that, “Until recently, my goal was to create tangible change, but lately I have been questioning what constitutes a tangible change and the importance of always knowing the direct application of our actions.” Nearing the end of the quarter she had found a new understanding of the impact she could have on the world as reflected in the following quote. “Until now, I have focused my definition largely on taking action, but now I realize that ideas and innovative thinking are also ways to learn about and inform future decisions. In this class, we are only a small piece of the puzzle, and even if we do not produce a working solution by the end of the quarter, through our ideation and efforts, we will have made some sort of dent in this looming problem, and our ideas will serve as stepping blocks to future classes as well as guide our own future activities.”

As a freshman, Student 0214 was also curious about engineering as a profession and reflected on what it meant to be an engineer. In the first few weeks, she wrote, “I love how this class makes me question and think about the assumptions and values I have and how those relate to a pressing issue and engineering as a whole.” In working with her team comprised of two juniors and one senior (all mechanical engineers) she arrived at the following articulation. “It was interesting discussing more about how care ethics impact and influence our decisions in this class and beyond. The questions we discussed about the role and practice of engineering is interesting to me as I try to find my path and decide whether engineering is truly my passion.” After the final presentation she wrote,
“I feel honored and blessed to have been part of this class, and I think tonight was a good culmination of our efforts and I enjoyed getting to celebrate our efforts. Hopefully during my time at Stanford I can better learn how to use the mindset and ethics we learned to get from the “lab to the land,” but for now I am learning that even genuinely thinking and caring has an impact that we may not be able to quantify, but can have a huge impact in ways we cannot anticipate.”

Response to prompt

My experience in the program has helped me develop into a more independent and confident thinker. Ever since I was very young, I was terrified of becoming a parasite of the world; forever taking and never giving anything back. It soon got to the point where I would weigh every activity or class I would take with the question, “How can this activity, skill, or class help me bring about the most tangible change in the face of seemingly intractable issues?” I would agonize and over reflect on every decision. From my non-profit work experiences both in a global and local context, I felt overwhelmed by the scope of the problems I wanted to face and unsure about how to best meet the needs of communities with different values than my own. Learning about designing with care challenged my outlook by reminding me that what I cared about is a critical part in creating connections and collaborating. This perspective led me to view myself as an empowered individual who can articulate my own values while equally valuing the values of the communities I am working with. In a non-profit organization I am a director of, we were refining and reevaluating our mission statement after a few years of operation. I used care ethics as a way to lead the discussion to see what each member cared about and then we converged on a mission statement and philosophy that captured each of our individual cares in a way that enthused us and has helped take the organization to a new level. The working with approach has also significantly influenced my decision to decide to study engineering by portraying the potential for engineers to serve as agents of change and advocates for the needs of both the designers and the consumers.

I have been blessed with the opportunity to continue working at the KGC. In an extremely nurturing and thoughtful environment, I am able to use my own values to combine my cares in education, work with underserved communities, health and environment cohesively in a way that is meaningful to me. I am also grateful for the opportunity to give back to the program and I feel like my contributions and exchanges are valuable. My perception of a tangible change has broadened, and with that, I can find more peace with my work and celebrate my progress as well as my achievements more.

Case Study of Student 0814

Student 0814 came to the class a sophomore after declaring a Mechanical Engineering major. Through the course, he began discovering the complex nature of the sanitation and hygiene problem.
One aspect of the complexity that he became increasingly aware of was that different people experienced the same problem very differently. Priorities, cultural values and social norms made every instance of the problem unique. “Coming from the first Skype chat, what initially struck me about the article was the order of priorities for the Soshanguve women. Namely, a sanitation system that “reinforces their right to privacy and human dignity” ranks above housing as the more urgent priority. This perhaps reflects a different set of values than those of the Gujarati villagers, who, according to [name of field expert], place sanitation a bit further down their list of priorities.” He further reflected on how within the same community the possibility of differing and opposing needs could arise. “But what if the conflicting needs come from separate factions within the community? In discussing cultural and social factors, one may fall into the trap of thinking a village contains a homogenous culture or set of values.” He noted in response to reading and hearing about the plight of women that, “due to the grave issues of victimization and sexual harassment, it is a no-brainer to prioritize working with women. But what if the issue is not so clear-cut? How do we navigate “working with” a community when members of the community may not have each other’s’ best interests at heart? Where do we draw the line in prioritizing one group’s wants over another’s?”

Along with growing awareness and appreciation of the local context of global problem, he also started questioning the ethics of such initiatives. In particular, he mentioned that “This passage from the description of sanitation reform in post-colonial Nigeria struck me: “The sanitary inspector represented the intrusive agent of the colonial...The idea that white colonials could teach Africans how to be clean was frequently regarded as offensive” ([17], 104). Overall, this reinforces the necessity of adopting the “working with” approach over the “working for” approach. In building a better toilet and empowering our partners in the developing world, we must take care to be sensitive to their pride and culture—so as to not insult and offend, thus rendering everybody’s efforts useless.”

This inquiry continued even after the course was completed and he undertook a summer internship with the course instructor’s research group. He was examining the efficacy of persuasive technologies and approaches and found that he couldn’t reconcile the approaches of public shaming or imposing values that were not of the community on them. “However, there are also significant red-flags raised by some implementations of CLTS, chief among them is the conflict between sanitation reform and individual rights.” After reading, he was “[a]nticipating two arguments against persuasive tech[:] 1. Human freedom and [in] turn human dignity might be threatened when behavior is steered by technology. To paraphrase Verbeek [18], while freedom may be limited by technology this doesn’t mean it is an assault on human dignity. The legal system limits our freedom to murder and commit crime, but does that threaten human dignity? 2. Developing behavior-inducing technologies can be seen as an implicit propagation of a technocracy where problems are solved by technology rather than people. [M]ight there be a more democratic way of developing persuasive technologies?” This was consistent with his concern of the harm that could come from good intentions that were thoughtlessly implemented. “The women were not consulted in the planning and design
As such, he inquired into the designing with approach itself and tried to make meaning of how this approach enabled him to develop his own perspective on how to engage with underserved communities globally. Early on in the quarter he wrote, “How can we comply with a community’s requirements if it is steeped in masculine identities that may bring harm to women? And in neglecting this requirement, are we violating a tenet of “working with” and in turn alienating the community?” In the second half of the quarter he wrote, “I have learned about empathy and human-centered design approaches in a couple of my classes, but the approach taught by [this course] seem to take it a step further. The focus is not merely putting ourselves in the shoes of a client, but building rapport and friendships with our collaborators. [Name of field expert] summarized this philosophy poignantly during our first Skype chat: “I can make one hundred friends, toilets will follow.” In his final report while reflecting on the entirety of his experience he wrote, “Ultimately, working on this project has changed the way I approach problem-solving and working in teams--in life in general but especially with regards to the intersection of engineering and humanitarianism. The philosophy of keeping care and relationships at the center is something I will take with me to my future classes and beyond.”

Response to prompt:

The GEE class sparked my interest in sanitation and hygiene development. Specifically, the weekly readings on the sanitation situation in areas around South Asia and Africa compelled me to consider the multidisciplinary nature of the problem. As I learned more about sanitation and hygiene from readings and research leading up to the final GEE project, I grew more enthusiastic about doing further work in this sector. This was primarily due to the fact that we brought our own care—values, motivations, and aspirations—to the forefront of our work during the course. By the end of the class, my care within the area of sanitation was centered on the management and disposal of human waste. Yet upon further reflections, I’ve come to realize that implicit in this mental investment in sanitation and hygiene is a broader and somewhat vague care for “doing good” or creating “positive change.”

Beyond the class, GEE has had a major impact on my academic trajectory. I took the course during the spring quarter of my sophomore year—a formative year in my engineering education because I had just begun to break into the core curriculum for mechanical engineering yet was completely lost as to how I might want to apply it in the future. The course and continuing work with other GEE students at the KGC have stoked my own interest in global engineering and humanitarian work. Furthermore, the
multidisciplinary approach of GEE both in the classroom and in the office—have afforded me the confidence and opportunity to engage in academic interests beyond engineering. Namely, I am more motivated to study education.

Additionally, the focus on care has given me the opportunity and habit of being more metacognitive about my own education and life. Throughout my years of schooling, I’ve had a tendency to put my nose to the grindstone and shut out most thoughts that do not directly pertain to my coursework. After GEE, however, I am more wont to pause and consider how courses, work, actions, etc. relate to my values and what I care about—even if the latter are not entirely concrete yet. I will occasionally bring up the concept of care when I’m philosophizing and conversing with friends and family in order me to understand as well as nudge people to reflect on their values and goals. That is, as a result of GEE I have internalized the act of continuously synthesizing and articulating a life care statement as a way to frame my own thoughts, experiences, and aspirations.

Student 1014 Case Study

As a freshman in the mechanical engineering program, Student 1014 wanted to explore how he could apply the concepts he was learning in his class to working with communities. When reflecting on a class discussion about the ethics of “engineering to help,” he wrote: “I really like they mentioned that creativity is a big part of engineering! I know that may seem obvious, but it very often feels that the story is you learn math and physics and if you’re not good at these subjects you won’t succeed in engineering. Of course math and physics are necessary, but if you have all this knowledge and no cool way to apply it, then what was the real point of learning the fundamentals?” Speaking to alumni of the course encouraged him to reflect on tangible ways in which his engineering education could be applied. In his reflections, he wrote “Having just taken physics mechanics last quarter where a missing free body diagram would translate to missing points, I began to think how often I’d really need free body diagrams as an engineer with so many computing programs around that surely could do it for me. Yet, seeing them apply this concept to their schematic proved me wrong, and I’m glad it did.” He “embraced the idea that the life of an engineer shouldn’t be solely focused on math, science, and other facts, but there should also be a focus on the people who are affected by the project.”

Student 1014 grappled what it means to have an impact on future generations. After discussing Arjun Appadurai’s “Capacity to Aspire” paper [19], he reflected that “if a seemingly innocent action of his today results in the harm of someone in the future (someone who may not even exist yet) then he’s still responsible for what happened to that person. That’s a lot to handle...I feel that while we should definitely be aware of our current actions in order to leave behind a healthy world for the next generation, the sole purpose of our lives should not be to protect the people and things of the future. If that’s the case, then every little thing we do needs to be carefully analyzed and we are no longer living for (or caring for) ourselves and our own generation.” He initially arrives at the understanding that “[c]aring is important and we can try to do all that we can and
more to help those in the future, but after all, we’re only human and everything can’t be perfect.”

He was surprised by the scope of the social and technical aspects of the problem space. He described that reading about the role of the toilet in society is “mind-blowing in a way because I’m experiencing a totally new perception. The technology within a community is a good indicator of how well off the community is doing. For example, having a flush toilet or a laundry machine shows that the community has clean water in excess. So of course I’ve never had to think about the effects a toilet could have on culture, film, and literature because to me it was just that: a toilet. Both [chapters] [20] exemplified the effects toilets have on certain societies, and this point was broadened to encompass gender roles and expectations that are present within said society...The dichotomy of the toilet is ridiculous! It can be seen as a symbol of progress and power, but in a swift moment it can be viewed as a symbol of sexual aggression and violence among other things. I feel as if the point that is being made is that to those in privileged, well-off societies who take these things for granted, it must be understood that a toilet has the potential to be very complex both mechanically and anthropologically. I definitely agree. The sanitation and maintenance of toilets even branches into politics!” Reading about gender issues surrounding the toilet particularly affected him. He writes that “I think toilets and the societal and gender perceptions associated with them make a powerful statement on society and this is something I didn’t truly take into account before...The fact that boys declared the bushes unsafe due to snakes while girls thought it unsafe due to the possibility of rape illustrates how radically different the genders perceive their environment. It’s unfortunate and even angering how teachers or even those delegated to patrol and protect the environment still prove to be dangers in an environment dedicated to academic and personal growth. I guess this helps me think that when it comes to designing a toilet, I simply cannot assume that one design will be satisfactory for both genders.” He initially found it “extremely upsetting that a device meant to help caused much more harm than good” and then connects this failure in implementation by noting “I suppose whoever implemented the toilet failed to use the “working-with” approach.”

Although these issues moved him, he questioned what his role was in creating interventions. He wrote, “I’m now questioning more “for exactly who are our toilets for?” ‘Our’ being the collective work between our team and the village.” He reflects about “the thoughts I have surrounding the idea that even if you, the engineer, possess good intentions for helping others, are you doing it for the right reasons? Do the people want you there helping at all? By going out to help them, do you see them as some inferior region of the globe? All of these are great questions to check before deciding to act on a project that may potentially change lives for the worst.” He wondered, “Regardless of all the good collaboration we’re doing with ESI, [do] the people of Gujarat really want us to enter their lives and change their habits through toilets? If not, how do we go about helping them?” Reflecting on the designing with care approach helped him reconcile some of his doubts. For example, he writes “I thought back to the working-with approach and appreciated its basis. Working with the community is definitely something that alleviates if not totally dispenses of miscommunication or faulty misconceptions between those performing the service and those receiving it.” Ultimately
he expressed that “Working with my group, KGC and ESI has allowed to me to take part in something I’d consider bigger than myself, and recognizing that my work has a role to play in the bigger picture has helped me retain the focus and understanding surrounding my role in the project.”

By reflecting on the working with process he considered what the role of engineers were in engaging with issues in underserved communities. Care played a large role in his ability to navigate the problem space and reconcile the confusion he felt about his role in the project. In his final report, he reflects that “I’ve learned more about care and the importance of ‘working with’ those you are collaborating with so that both sides of the project don’t feel slighted or insulted. Care, I now realize, is a big part of the work one does because if I were to actually care about the device or service I’m crafting, then I’ll be more sure to make it fulfill the needs I’m looking to satisfy.” He describes his ideas on the practice of engineering in his report: “I’ve learned a lot of things through this class, but a new very important development is that engineering is not just math and science. It’s not even just analytical thinking and creativity. A major aspect of the engineering service is to acknowledge those who your devices affect. To be self-conscious about your actions and what they might mean to those around you illustrates the maturity of an engineer. I wouldn’t say I’m totally there yet, and I still have a lot to learn, but it’s good to know that I’m on the right path!” Using this perspective helped him contextualize his education and plan future action in a way that was sensitive to his new view of engineering practice.

Response to prompt

The most important element of “care” I’ve learned is it’s not simply a factor you take into account while designing a project, but it’s an essential foundation the entire project is built upon. As a Mechanical Engineering student, I believed my biggest concerns were comprised of my knowledge base in math and physics. This was before I applied to take the GEE. Instruction within the GEE course introduced me to the importance of care and how it not only matters for the empathy of design, but also for the designer to find an anchor in what truly matters to them. This added an entire new level to my perspective of engineering for others. It gave me the personal connection I was searching for in engineering fields and it’d be nice if other more technical classes in the engineering curriculum took these STEM principles and connected them to the fact what engineers make will have an impact on someone in the world.

I’m able to take what I learned in GEE and apply it to my life! It may sound a bit cliché, but it’s completely true. The trip to ESI in Ahmedabad, India may be grouped inside the course context, but I was able to enter the trip with a mind focused on what the people need as opposed to what I think the people want, a mindset I owe to the GEE class. Even when it comes to choosing classes at Stanford, I now ask myself if the material is something I care about and if it will help me achieve my goal in the future. I find this approach a lot better than taking a class because I feel I need to. Aside from care, I also learned how to work with a team in GEE. Granted care did play a part as the team came together and discussed how what we cared about would influence our product, but there
aren’t a ton of opportunities for team engineering projects as a freshman in college. I expect to work in teams a lot as an engineer in and out of college so GEE provided an opportunity to experience such work early on. There were high and low moments, but I learned a lot about myself and how I work with others. I’ll be sure to take these lessons and better myself as a team member because of them.

Currently, what I care about is playing a role in what summer internships I look into. Instead of applying for literally anything I see, I take into account if the job is a job I would enjoy doing. This isn’t necessarily an easy task, but it is important. It takes time to realize what I actually care about, but I know the time invested into figuring it out will benefit me in the long run.

Research findings

The four cases above describe student experiences of working with underserved communities. What is common between these 4 cases is that all the students were surprised by the reality, intricacy and local details of the problem space. They all describe situations that made them pause and think and then describe how they overcame these surprises and arrived at a meaningful way of engagement that they continued beyond the class.

The following stood out as common sources of pause and surprise and reflection:

1. **People have conflicting needs**: Despite the fact that access to sanitation and hygiene is a global problem, the nature of the problem was different for every community. There was no general rubric for what would solve the sanitation and hygiene problem for a community. In addition, within a single community, the needs and concerns differed based on gender, social roles and historical cultural practices.

2. **There is rarely access to perfect information**: Despite access to literature from multiple disciplinary perspectives and encouragement to search for more information on the web, the students found it difficult to obtain accurate information about the local conditions. Studies about the particular community that the students were collaborating with were scarce and the field partners had records of their own activities, but did not always have answers to questions that students had. In addition, most of the data from the field partners was in the form of anecdotes and it was difficult to ascertain how to quantify and infer requirements from this information.

3. **It is easy to lose sight of the realities of the situation**: After hearing first-hand accounts of some of the challenges faced in the field, students felt overwhelmed.
As a result, they sometimes fixated on relieving particular challenges that were described by the field partners, and lost sight of the big picture of the problem.

4. **It is challenging to navigate a culture or value system that is very different:**

   The students were unfamiliar with cultural norms of the partnering community, and found it was difficult to understand these values rationally because they came from deep-rooted belief systems. The course enables students to accept them and employ them as design constraints or requirements.

Implications of the findings

As observed in the four cases, students build competence from encountering a surprise, feeling unable to act immediately, reflecting on it, and then finding a suitable way to re-engage. The research findings identify criteria for a metric that measures the ability of curricula to prepare students for global work. Preparedness is a function of the student’s ability to navigate the complexity and novelty of the problem while creating solutions that are sensitive to the socio-economic, political and cultural realities. We propose the creation of a metric called *Global Preparedness Efficacy* (GPE).

The inspiration for GPE stems from Albert Bandura’s seminal work on self-efficacy. Bandura defines self-efficacy as “the conviction that one can successfully execute the behavior required to produce the outcomes” \(^{21}\). He posits that safely experiencing events that may appear to be “subjectively threatening” can result in enhancement of self-efficacy. He also concludes that the greater changes in self-efficacy result from consistent and realistic learning experiences.

Perceived self-efficacy influences the motivation and ability to engage in specific behavior as well as the pursuit of particular tasks \(^{22}\). As such, past efforts have investigated self-efficacy for particular tasks. The literature on creative self-efficacy defined as “beliefs that they can be creative in their work role” \(^{23}\) is a case in point. This study, published in the Academy of Management Journal, identified what factors influenced subject perception of creativity at their work as determinants of self-efficacy to be creative at work. This analysis went on to explore how job self-efficacy might moderate the effects of creative self-efficacy on creative performance. Using this method as a starting point, future research can begin by drawing on a theoretical understanding of student experience while working with underserved communities globally where students encounter complex and novel situations.

Conclusion and future work

This paper is a preliminary attempt to ascertain student experience of collaborating with underserved communities in a global context. This paper illuminates the challenges faced by students working in complex settings and highlights the tools that helped students overcome these challenges. It also describes the course, which served as the research setting where the students and members of an underserved community in India worked together on addressing the challenge of sanitation and hygiene faced by the community.
Finally the paper proposes a metric called *Global Preparedness Efficacy* that could be used to evaluate GEE and similar course offerings. Further research is necessary to develop this metric and examine the curricular features of the GEE courses that enabled students to overcome the challenges faced while working with their community partners.

The small sample size in this paper further reinforces the preliminary nature of this work. However, the findings are consistent with the extant literature about global engineering especially when working with underserved communities. However, the aim of future research is to expand the scale of the research and be able to collect data from other courses and at other institutions and develop a more robust understanding of the experiences of students engaged in engineering work with underserved communities.

Research is currently underway to develop a quantitative assessment of GPE. It uses a coding scheme that identifies discontinuities the students encounter in working with underserved communities globally and how many of these they are able to resolve. The student journals are currently the source of data. A preliminary definition of GPE is the ratio of resolved to total discontinuities encountered. The closer the GPE is to 1, indicates that the course is better at preparing students to navigate complex and novel situations that are likely to encounter in global engineering work especially with underserved communities.

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