Developing curriculum to prepare student engineers to engage with problems faced by underserved communities globally

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Abstract:

This paper addresses the need to develop pedagogy that will enable engineering students to work with underserved communities globally on problems that the communities face in their everyday lives. There are many parameters that are influential in creating a learning interaction between students and underserved communities such as building trust with the community, mutual respect, regular communication, technology for communication, overcoming cultural and language barriers to name a few. This paper focuses on the inclusion of interdisciplinary literature as a means of creating a more comprehensive understanding and expansion of the problem space without overwhelming the students. Drawing on data from student experience in a course called Global Engineers Education at Stanford University, this paper looks at the role of care as a means to both, work with the underserved community and include the knowledge from multiple disciplines in the design process.

Introduction

The world continues to be plagued by serious and complex humanitarian issues despite exponential technological advancement. Unprecedented prosperity creation has been unable to eradicate chronic poverty, malnutrition, deadly diseases and widespread political conflicts. According to the United Nations Millennium Development Goals\(^1\), 920 million people will be below the international poverty line (estimated at $1.25/day) in the year 2015. Half the population in the developing regions of the world is likely to have no access to clean drinking water and about a billion people are expected to suffer from malnutrition\(^2\).

Thanks to technologically mediated social networks, it has become difficult to remain ignorant of the realities experienced by people across the globe\(^3\). This social connectivity has also made it easier for like-minded people to act on problems that they find compelling simultaneously making the need and the motivation to act more apparent and urgent.

The engineering community has responded to this call as evidenced in the emergence of groups such as Engineers for a Sustainable World (ESW)\(^4\), Engineers Without Borders (EWB)\(^5\) and Engineers Against Poverty\(^6\). At the heart of these organizations is a desire to create an equitable, sustainable future by mobilizing engineers around the world to make meaningful contributions to complex, global problems.

Evidence from a number of academic institutions that students are increasingly demanding more courses, debates, discussions and modes of engagement on global issues and sustainable development\(^7\) demonstrates a growing awareness of global issues. The presence of student chapters of ESW and EWB in numerous universities and colleges in the United States is a testament to students’ enthusiasm and concern. 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. Sheppard, et. al. in their Carnegie Foundation sponsored study on Educating
Engineers: Designing for the Future of the Field convey it succinctly: “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”\textsuperscript{5}.

In the centennial issue of the Journal of Engineering Education (Jan 2011), an essay on how to engage future engineers suggests, “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”\textsuperscript{6}. Rigorous engineering education research is needed to advance fundamental understanding of the nature of today’s increasingly socio-technical engineering work, as well as translating this understanding into curriculum. Recent literature in the field of Engineering Education has highlighted the need for change in engineering curriculum to 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 them.

Several attempts have been made to systematically understand what global engineering is\textsuperscript{7}, what purpose it serves, case studies of its implementation and questions about community involvement, participation and ethics. However, very little literature exists on identifying parameters on how to develop curriculum that would in fact enable students to feel that they are making meaningful contributions to challenges faced by underserved communities globally.

Working with underserved communities poses its own unique challenges. Attempting to make a dent in any of the problems such as access to clean water, interpersonal violence, and poverty is a Big Hairy Audacious Goal\textsuperscript{8}. Complicating matter further, it is also hard to immediately think of these as engineering problems. They have so long been studied by, seen as the domain of other disciplines (humanities and social sciences) that it takes a whole new mindset to think of them as anything but that. On the other hand reducing the problem to a purely technological one is also a shortsighted approach. To ignore what other disciplines and research have learned is foolhardy. The question therefore is how to include the knowledge from other disciplines as part of the design process. This aspect of how to include the knowledge from other fields not merely as an inclusion of facts but as an important step in the design process thereby making it uniquely adapted to working with underserved communities is the thrust of this paper.

What follows is the description of a course developed at the Kozmetsky Global Collaboratory at Stanford University called Global Engineers’ Education (GEE) in response to the needs stated above and how interdisciplinary literature was effectively included in it. The GEE course is described, along with a glimpse of the designing with approach followed by the critical role of articulation of care. This sets the context for how interdisciplinary literature was included and student response to it.
Global Engineers' Education Introduction:

GEE provides methods for engineering students to realize where and how their expertise as engineers is relevant and critical to creating a prosperous life for all. It allows students to experience themselves as engineers in context of the world they would like to change and improve. GEE also creates the opportunity for them, as well as for the underserved communities they wish to work with, to thrive.

Engineering for underserved communities has largely followed a one-sided approach. This approach focuses on the transfer of technology and frequently imposes solutions that have proved successful in prosperous countries but fail to have the desired impact on impoverished communities. Local conditions, both environmental and cultural, have an impact on the solutions and their efficacy. Attempts to solve problems that do not incorporate local support nor take into account the aspirations of the local community do not sustain. They last as long as outsiders (NGOs, researchers or governmental agencies) are present in the field. When they leave the ongoing attempts to address the community’s problems come to a complete stop usually because they are not representative of the local community’s aspiration for their future.¹⁰,¹¹

GEE addresses this challenge by blurring the distinction between the student engineers in their role as solution providers and the underserved community in their role as consumers of the engineering solution. The engineering students are as much consumers as the underserved community members are designers and architects of the solution and the experience of creating it together. In doing so lies the opportunity for manifesting something together with ingenuity and creativity.

GEE therefore, 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.

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 are forced to defecate in the open, losing their dignity and self-respect, making themselves vulnerable to violence and life threatening disease. Given the global nature of the problem and the impact it has on health, safety, dignity, education and overall well-being of individuals and communities, the challenge of sanitation and hygiene will be the focus for the course. This is one of the most systemic, complex and existential problems faced by underserved communities globally. Over the duration of the course students learn how to work with the community by prototyping technologies to address some component of the problem. They will do so through engagement and contribution to an ongoing project, starting with field sites in rural India, that focuses on addressing issues of education, safety, and dignity while enabling better hygiene and health monitoring by
making the toilet desirable, affordable and the preferred alternative to open defecation. The long-term duration of the project and the regular interaction with the community made the students realize their responsibility of creating solutions that could be further improved by future cohorts of students and also be worked upon by the community members as seen by the following quote “I think that designing with a community motivates me further to work. Having a relationship and an interdependence between us and the community, even time zones apart, inspired me to be more involved with the process and held me more accountable than working for a community would” [Student 6, Final Report 2013].

It also created a sense of continuity and made the students more sensitive to realizing the importance of both the history and the future of the project. “We knew that the people in India already liked the original prototype so working on it was crucial to us in designing with the community rather than for them. As we moved forward from here, we really took some time to think about what we cared about in life and how that related to what we cared about in class and in the design. This consideration for us was also important to be designing with rather than for. We knew that if we found something that we were passionate about and cared about then we would enjoy doing the work” [Student 3, Final Report 2013].

Articulating Care:

GEE begins by bringing together teams comprising of engineering students and members of an underserved community. Over the course duration of 10 weeks, the students attend weekly lectures, meet with their teams, and the class as a whole meets with the community via visual communication technology (such as Skype or Facetime). Throughout the duration of the course, each student was required to maintain a reflection journal to be updated whenever the class and the teams met. At the end of the course, the student teams produce a prototype, a poster and a final report. So far, 13 undergraduate students from mechanical engineering, civil engineering and product design have participated in the prototype.

The designing with process is inspired by the Gandhian quote “Who can say what sores might be healed, what hurts solved were the doings of each half of the world’s inhabitants understood and appreciated by the other?”12 Too often the approach to working with underserved communities has been to divide the work – listen deeply, empathize and collect data about needs from the customer/client in this case the community. Under the circumstance, the students respond to the anecdotes and worries shared with them by the members of the community that they interact with. From the following quote from a student’s final report, it would appear as if what the students may know about the global nature of the problem has somehow become irrelevant or unnecessary. “The work between the different project members must be a real collaboration. Every participant advances hand in hand with the others. However, I realized during the last call that this explanation is still incomplete. The opposite risk is also possible. Indian's points of views may also substitute to ours opinions. Due to the difference of cultures, our feeling of being a stranger, it can lead to a situation “designing for”. It is not “designing at the
place of”, but it means that the collaboration is not effective anymore. Indian members become conductors and their points of view are seen as truth. So it is “designing for” in the sense that we put our efforts at the service of 2 villagers” [Student 2, Final Report 2012]. Another student echoed the sentiment reflecting “that it is important to know what designing with means before any interaction with the community. Sometimes, I found myself losing my stand in the face of the participants from India, but I had to remind myself that they are not clients but my team members. As a team member, I had the right to assert my needs in the design” [Student 1, Final Report 2012]. Leaving this unchecked proves detrimental to the creative process undermining the possibilities of building long lasting, culturally appropriate, effective solutions.

The GEE process closely resembles the [University Name] design process with the following steps:

1. Needfinding
2. Benchmarking
3. Ideation/Brainstorming
4. Rapid/Rough Prototyping
5. Material Selection
6. Analysis/Dimensioning
7. Manufacturing
8. User Testing

What differentiates it is that before commencing the designing itself, the GEE team members reflect on and articulate what each of them personally cares for about the challenges faced by the underserved community. This serves as their 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 as evidenced in this reflection in one of the student journals, "Importantly, I also noted the differences in our backgrounds. [Student team mate] and I are engineering students and we wanted to design. However, [Community team mates] are community leaders. Their role is to educate and reach out to the villagers, and they believe in direct interaction with the villagers and educating them, rather than a better design. It is important to understand these differences in our backgrounds and to work on a design that appeals to all the team members” [Student 1, Final Report 2012].

The articulated care statements are individually created as a combination of visuals and text and then shared within the ecology. The process does not require building consensus or arriving at one point that the GEE team collectively cares about. Rather individual members of the ecology are responsible for ensuring that what they care about is represented in their design solution. The ecology collectively agrees to create a solution that does in fact embody what each one of the ecology members cares about.

This approach ensures that the community continues to stay engaged in the process. Further it prevents from reducing the input received from the community to mere facts. Rather, it ensures continuity of community engagement as they continue to share what
they care about and why. By sharing stories and their lived experiences they contribute to coming up with design requirements, design constraints and design ideas.

Figure 1: The top image shows the white board captured during Skype call (2012) to share care statements, with an easier to read rewritten version below it

For students, the articulation of care enables them to explore their own motivation to work in the global context and with underserved communities. It also helps take a very
large complex problem and find a piece of it that is more manageable even in its complexity. It therefore serves as a realistic problem that challenges them without becoming overwhelming simply because of its magnitude and multitude of dimensions, each competing for attention, as they appear equally important and urgent.

Figure 2: White board illustration of how the students visualized the problem space, gradually adding layers of complexity as depicted by the different colors.

**Working with other disciplines:**

Given the students limited understanding of underserved communities, development efforts or the specific challenge of sanitation and hygiene, the students were provided with literature from several different disciplines such as economics, sociology and gender studies [Complete Reading List in Appendix A]. The students were guided to read the papers not only to learn facts but also look beyond and discuss what they felt the authors of these papers cared about and why. Class discussions focused on discerning the methods followed, the theories that the papers built on and most importantly how the insights from the papers reshaped or affected the problem space. Through the readings, the students were encouraged to add more detail and gradually expand the complexity of the problem space. Three cases of how different disciplinary inputs were processed and
became part of the students’ understanding of the problem space and the designing with process are described below.

Case 1: The first is the reaction students had to a paper on future ethics entitled “Future ethics: risk, care and non-reciprocal responsibility” by Christopher Groves. Below is a student’s summary of the paper:

“The first part of the article basically laid the framework for the type of future ethics that is in place right now and looked at how some situations of future impacts could be left out or would be unaddressed in the current approaches. Groves then discussed the idea of basing ethics off of care and really focusing in on the diverse personal things that different people care about. One of the big concerns with this second approach is that the broad, general problems in the future might not be addressed in how we live today. However, Groves makes the argument though that if we are really planning for the future with the things individual people really care about, then we will be forced to consider the things that affect these personal interests. Then, this will eventually lead to addressing the big issues, but almost with more of a passion than the indifferent approach because we are then aware of the impact that the broad future issue might have on the present smaller issue we care about.” [Student 3, Weekly Paper 2013]

Majority of the students struggled with this philosophical paper. It however, made for excellent class discussion and below are excerpts of how the Grove’s article was included in thinking about the sanitation and hygiene challenge that the students were working on.

“I was able to relate to some of the points that Groves brought up. At first, I was not overly excited about reading about future ethics. In the past, I have found myself more focused on how things are impacting people today... this article helped me to see that if we do not come up with solutions for today that have tomorrow in mind, then we might just be making even more problems for tomorrow than we have today, which is negative progress... Based on the current future ethics, and even the approach that I just mentioned, it appears that finding a solution is more about conquering an issue than it is about the people that are facing the issue. The care approach, though, would seem to put more emphasis on really caring about the fact that there is a child in India that has serious illness related to poor sanitation and hygiene practices, rather than just trying to build an innovative toilet”. [Student 3, Journal Entry 2013]

Case 2: The second paper which was quite popular with the class was from Sociology titled “The Capacity to Aspire: Culture and Terms of Recognition” by Arjun Appadurai. The paper as per the reflections of one student was “an interesting reprieve from the recent focus on sanitation and engineering in recent weeks. Instead it focused on the greater issues of how community aspirations are representative of culture, how culture should be observed in light of the future as much as in the past, and of how nurturing a community’s “voice” is a fundamental step in the development process” [Student 5, Weekly Paper 2013].

A view that was shared by many in the class in response to this paper is well represented in the following quote “I learned that the cultural differences are actually more
important than I thought. Instead of being a big barrier that we have to push our way through in order to help these people, it is actually they key to how we will help them” [Student 6, Final Report 2013]. This view was further built upon and applied to the problem at hand as expressed by the reflection piece of another student, “In the Aspire paper, he argues that culture not only is relevant to the past, but most importantly to the future and development. This is something that is not believed right now in the world. Today we think that culture opposes development, because of keywords like tradition, which opposes change. People have tended to blame economists for having a closed mind and trying to change culture by introducing new technologies, etc. I really liked paper on culture. This was a big theme in the class, how the most effective way to advance a society is with respect for the culture, designing with them, so that their ideas are the ideas of the future. These are the most sustainable solutions” [Student 5, Journal Entry 2013]


The summary of the paper is succinctly captured in the following quote, “In one important paper entitled, “Geographies of Danger,” researcher Claudia Mitchell conducted a research experiment in which he asked young women to take photographs of places they felt unsafe. A common response from women of all ages was the latrine, where they often feel harassed or are even abused, often sexually” [Student 7, Weekly Paper 2013] This paper from gender studies met with the most surprise. The fact that toilets could be seen as unsafe came as quite a shock to most of the class. In addition the methodology in the paper and its emphasis on the meaning of safety from a gender perspective lead to a very lively discussion. This paper was most readily incorporated into the design process as seen in the following quotes.

“Integrating safety as a guiding principle into the design process will be a necessity if the end user is to have a good experience using our prototype.” [Student 7, Final Report 2013]

“The Geographies of Danger article was about how gender is viewed in sub-Saharan Africa. For example, girls are treated horribly in schools, and the bathroom is a very dangerous place for them… This brought another need to our attention, which is the need for a safer bathroom space, one where everyone will feel comfortable physically and mentally just entering the bathroom at all to be able to use a toilet” [Student 5, Weekly Paper 2013]

“I hope that if the toilet space is clean, children, especially young girls will feel safer using it. I was especially touched when I learned that toilets are seen as unsafe spaces in schools, and I immediately realized the critical need for a safe space” [Student 6, Final Report, 2013]

The inclusion of multiple and assorted points of view introduced the students to the complex nature of the challenge of sanitation and hygiene. However, by employing what
they care about as the lenses to make meaning of literature from fields they were completely unfamiliar with allowed them to appreciate the complexity of the problem without getting overwhelmed by it. Instead they were able to incorporate the readings to reflect in their care statements and create questions that they could more readily answer as seen in the following quote. “Reading the paper on future care, I tried to focus on an individual without access to proper sanitation, and how I could change that. In addition, drawing upon the readings that we did on taboo, I started to think, would it be possible to impart some sort of value to waste, such that it is less of a taboo?” [Student 4, Final Report 2013]

Engineers and engineering as part of a larger context:

As the students were exposed to research and literature from multiple disciplines and to an underserved community directly, what emerged was that the students were able to better understand their role as engineers in contributing solutions to problems faced by underserved communities globally.

“I really wanted to see what engineering was all about. After taking two quarters of initial “engineering” math and science classes, I was feeling at a loss at what all this theory really meant in practice. We always learn about the “ideal situation” where everything is perfect. However, time and time again, we are reminded that the world isn’t – that there are always things we have to account for, expected and unexpected... After reading various works relating to toilets, sanitation, and the taboo, I was fascinated that a good chunk of humanity is dealing with problems I have never thought twice of. We were now given the opportunity to work with real people in a real-life setting. It was the perfect chance for us to use all these skills we have acquired throughout our schoolings to create a technology with a community, something that they can use!” [Student 8, Final Report 2013]

It enabled them to contextualize the contributions they were making while being fully mindful of the complex structure they were working within and appreciating the impact that their solutions could have. It gave them a method to see the larger picture painted by the multitude of disciplines and appreciate their methods and insights by framing them as what the authors care about.

“Why I care about this project is firstly because I wanted to challenge myself and explore a topic that has a huge social dimension to it, but still apply my skills as an engineer. My Pre-Major Advisor has taught me that a discipline is in a sense, a lens, tool, and way of interpreting and understanding the world. What I sought, then, through this project, was a way of reconciling my interest in social change with the way engineering is often taught in college. Therefore, I was attracted to the fact that the problem space provided a means of interacting with the world” [Student 4, Journal Entry 2013]
Conclusion:

The preliminary analysis of the data collected about the student experience in this course showed that introducing interdisciplinary literature in the context of an engineering problem allowed them to understand the methods and points of view employed in other disciplines and make meaning of the insights that these fields offer. The role of articulating what the students care about in the problem space was particularly effective in them being able to see the readings from humanities and social sciences as relevant to engineering. They began to look into the insight to create a more thorough and vivid picture of the context that their engineering problem is embedded in. The articulation of care also allowed the students to have a language that created continuity for them between the design process that they were familiar with and the research in humanities and social sciences that they were beginning to explore. These outcomes are encouraging and point towards a possible new approach to educate engineering students about their role in the global, economic, environmental, and societal context.

Future offerings of GEE will continue to explore the impact and use of interdisciplinary literature in promoting student understanding of the complexity of the problem space. Based on student feedback on the various readings, changes will be made to the course to bring more relevant, up to date and varied disciplinary inputs. Particular attention will be paid to the translation of insights the students gain from these readings into the prototypes that they generate. This data will be collected indirectly through their journals and reports and also directly through interviews. Similarly, another interest would be to track alumni of the course through the remainder of their undergraduate careers and see if exposure to these readings encourages them to take more classes in humanities and social sciences.

What this paper demonstrates is that creating a course where student engineers understand the relevance and importance of research in other disciplines to their engineering problem makes them more receptive to interdisciplinary readings. The articulation of care allows them to create their own meaning and narrative, which in turn enables them to better understand and appreciate interdisciplinary content and provides the necessary impetus to actively engage with interdisciplinary research. The first offering of GEE was a modest beginning to creating engineers who can have a holistic view of the problems that they are working on and benefit from the vast knowledge that the academic community has to offer. Future offerings will be studied for efficacy and sustainability of this approach.

John Dewey, the famous pragmatic philosopher of education wrote, “Given imagination, courage and the desire to experiment and to learn from its results, there is a push toward, a momentum for creative work”16. The students of GEE found that they could fulfill their desires to serve underserved communities by being engineers and through their engineering. It helped them understand that engineering was part of a larger world and was impacted by the current global context while simultaneously reshaping the world itself. It helped them contextualize the role they as engineers can play in the global, socio-economic context. Finally it made the students realize that engineering with care is not simply something to do with underserved communities. It is a capacity that can be
extended to all aspects of their own lives. “I realized that with any project, I have to find what I truly care about in relation to my work. This quarter, I did not work to just fill requirements of a project. When I cared for the people using my work, I was really proud of what I made. I was also more focused in my other classes when I could relate what I was learning to what I cared about. Finding what I care about is essential for me to be excited about my work and to be proud of my accomplishments” [Student 6, Final Report 2013]. Future research will show how the alumni of the GEE course continue to nurture their sense of care and bring together the best of what academia, irrespective of discipline has to offer to and employ their engineering prowess to create safer, healthier and happier world for all of us.

References:


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a ESW was formed in 2001. The vision of the organization is to ”improve both the quality of life and the condition of the planet” (http://www.eswusa.org)

b Several Non Profit Organizations use EWB across the globe to describe their engineering activities in service to international development. The first such organization was created in France in the 1980. The first US based group was established in 2001 (http://www.ewb-usa.org)

c EAP is an NGO founded by the Royal Academy of Engineering and the Department for Inter-national Development in UK. Established in 1998, the group has focused on eliminating poverty and promoting sustainable development (http://www.engineersagainstpoverty.org)

d Data for this paper comes from materials produced by the students in the form of journal entries, reflection papers written once a week and final reports produced at the end of 10 weeks.