Engineering Empathy: A Multidisciplinary Approach Combining Engineering, Peace Studies, and Drones

Prof. Gordon D. Hoople, University of San Diego

Dr. Gordon D. Hoople is an assistant professor of general engineering at the University of San Diego. His research interests lie in microfluidics, rapid prototyping, genomics, engineering ethics, and engineering education. He earned his MS and PhD in mechanical engineering from University of California, Berkeley and a BS in engineering from Harvey Mudd College.

Dr. Austin Choi-Fitzpatrick, University of San Diego

Engineering Empathy: A Multidisciplinary Approach Combining Engineering, Peace Studies, and New Technology

Abstract

As educators we train our students to view the world using a particular disciplinary lens. In engineering this means helping our students to "think" like engineers. We teach them to categorize and solve problems using a technically focused mindset. For instance, they learn the importance of using hard data to quantify success or failure. Other disciplines, especially in the social sciences, focus additional attention on normative and substantive issues. Students are taught the importance of developing contextual understanding and of recognizing that lived experiences generate different perceptions of reality. This variety in discipline specific thinking gives rise to a rich diversity of ways to interpret the world. These mindsets, however, can also act like silos that prevent the exchange of information. For example, while engineers share a common language, they often find it difficult to explain to a non-specialist how they reached a particular decision. As teams are rarely composed of individuals from a single discipline, this presents a fundamental challenge. How do teams collaborate effectively across disciplinary boundaries?

To prepare our students for this challenge, we are developing a multidisciplinary, team based course that will bring students together from two disparate disciplinary fields on our campus: the school of engineering and the school of peace studies. The course will be co-taught, with GDH representing engineering and ACF representing peace studies. The semester will be spent on a single project, designing a drone for social good. Drones come with an ideal combination of technical and ethical challenges that will force students from both schools to wrestle together with unfamiliar questions. One of our primary learning outcomes will be for this struggle to cultivate individual empathy across disciplinary boundaries. Put more practically, we want the students to understand how using alternative disciplinary frameworks changes their understanding of problems. During the semester small teams (4-6 students) will each 1) build a quadcopter drone using the open source technology platform ardupilot, and 2) design and build a unique payload for the drone. The course assignments involve designing and building the device (a clear engineering challenge) with the more conceptual work of planning for its integration into pro-social organizational processes (a clear peace and justice challenge). To facilitate this exploration, we have designed the course to minimize lectures and instead use class time for conversations and collaboration. This will be done through a combination of group discussions, team exercises, and collaborative workshops.

This paper, submitted as a work-in-progress, presents the current state of our course development. We discuss our learning outcomes, describe our pedagogical approaches, and

identify areas of concern associated with this approach to multidisciplinary engineering education. By providing a detailed framework of the class as currently designed, we hope to solicit meaningful feedback from the multidisciplinary engineering community before teaching the course in the fall of 2017.

Introduction

The University of San Diego Shiley-Marcos School of Engineering (USD SMSE) was awarded a NSF Revolutionizing Engineering Departments (RED) grant in 2015. One way we are attempting to revolutionize engineering education is by contextualizing courses with themes from social justice, peace, and humanitarian advancement. In this paper we report on the development of multidisciplinary course that is attempting to realize this vision. The course will be co-taught by a faculty member from engineering and a faculty member from peace studies.

Are we really talking about empathy?

At its heart, the course we are developing is focused on building empathy across disciplinary boundaries. The idea of "a little more empathy" as a panacea has become something of a cliche. From Mark Zuckerberg to Glenn Beck, the word has been bandied about in the media as the obvious solution to heal our deepest societal rifts.[1] So what is empathy? And why should we as engineers care about it?

One definition for empathy, from Oxley's *The Moral Dimensions of Empathy*, is "feeling a congruent emotion with another person, in virtue of perceiving her emotion with some mental process such as imitation, simulation, projection, or imagination."[2] This definition highlights the ways that empathy is both affective -- the transference of emotions from person to person -- and cognitive -- the development of an understanding of how others see the world. This is, however, far from the only definition of empathy. Batson, a social psychologist, has identified eight distinct phenomena that have been called empathy.[3] These phenomena range from "Adopting the Posture or Matching the Neural Responses of an Observed Other" to "Feeling for Another Person Who Is Suffering." As noted by Decety and Ickes, editors of *The Social Neuroscience of Empathy*, research into empathy "has blossomed into a vibrant, multidisciplinary field of study."[4]

In engineering, when it is discussed at all, empathy is usually found in the design context. Tim Brown, CEO of IDEO, identifies empathy as the key step in the design process where observations are translated into meaningful and useful design concepts.[5] Stanford's Hasso Plattner's Institute of Design (d.school) highlights empathy as the first step in the design process.[6] Spurred by this need of designers to connect with and understand users, empathy has begun to make its way explicitly into the engineering classroom. At the most recent Mudd Design Workshop (2015), Altman and Krauss, organizers of the workshop, report that the topic of user empathy was discussed at length.[7] The faculty at both Loyola Marymount University and Lafayette have integrated empathy for users into their first-year introductory engineering courses.[8,9] At USD, we have just added a required first year course focused on user-centered design where developing empathy for users is an important focus.

While empathy for the end user is an important part of the design process, it is not the only place where empathy is required in engineering. Unfortunately discussions of empathy are comparatively scarce in the engineering education literature. In 2013 Strobel et al. performed a broad review of how empathy and care are addressed within engineering. They examined the existing literature and interviewed engineers in both academia and industry. They found that while engineers recognize empathy as having a place in engineering, it is seldom explicitly addressed.[10] In her 2017 book chapter "Engineering is caring about and helping others?" Angela R. Bielefeldt provides a more recent summary of engineering education research related to caring about and helping others.[11] As she notes in her abstract, "The predominant culture in engineering education may somewhat dehumanize students, largely removing care and empathy from their notions of engineering." Remarkably only one article in the entire JEE database contains empathy in the title. In this 2017 article, Walther et. al tackled exactly the challenges identified by Strobel and Bielefeldt. They explored the empathy literature within social work and developed an approach to explicitly include empathy within engineering contexts. They "propose a model of empathy in engineering as a teachable and learnable skill, a practice orientation, and a professional way of being."[12] While empathy has certainly not been well studied within engineering education, it seems that the tide may slowly be turning in this direction.

In the course described in this paper, we are interested in teaching students about empathy crossing disciplinary boundaries. Engineers need to develop empathy not only for users, but also for colleagues and collaborators from other disciplines. While few would dispute the notion that engineers can learn from other disciplines, our current educational framework is devoid of opportunities for students to have meaningful engagement across disciplines. Engineers instead repeatedly find themselves in teams consisting of exclusively engineers, usually all from the same sub-discipline. There is no opportunity for students to see in practice the value a biologist or social scientist can bring to the problem solving team. As one student remarked during a senior design lecture, "How are we supposed to learn interdisciplinary collaboration when our senior design teams are made up of only mechanical engineers?"

Recognizing this need for cross disciplinary practice, our course will bring together students from two very different worlds: engineering and peace studies. By allowing these students to work together on a project of topical relevance, designing a drone, we aim to create an environment where students can begin to understand the limitations of their own disciplinary lens. More importantly, we want students to recognize that approaching problems from multiple disciplinary perspectives can lead to better solutions. In this way, we aim to foster a cross-disciplinary empathy that facilitates collaboration.

Course Design

The course itself is organized around an objective, an outcome, and an output. The *objective* is that each student will learn: "about a) working in teams, to b) build things, that c) collaborate with people in ways that matter." The anticipated *outcome* is the student's increased ability to identify their own strengths (and weaknesses) in working and communicating alongside people in other fields than their own. The anticipated *output* will be team-constructed drones, and team designed and implemented drone payload systems.

In the syllabus students are alerted to the fact that these objectives and outcomes are a bit different than those in most classrooms in the social sciences and engineering. Much of the material presented in the first pages of this essay builds off of the core message communicated by the syllabus' "course description." The first two pages of the syllabus, then, do a good bit of work in setting student expectations for the course structure. Building on a belief that setting proper expectations is key to any collaborative endeavor, the first page of the syllabus bluntly states: "There is every reason to expect that this class will be more demanding than others, since the project's completion relies on your team's effort, and since your team will be comprised of people from different backgrounds."

At the broadest level, the course is divided into two general sections: 1) a series of lectures and discussions that will span the first half of the course and 2) the execution of a team-based project Over the course of the term the ratio of time spent on lecture and discussion will taper off, and the amount of time spent on projects will increase.

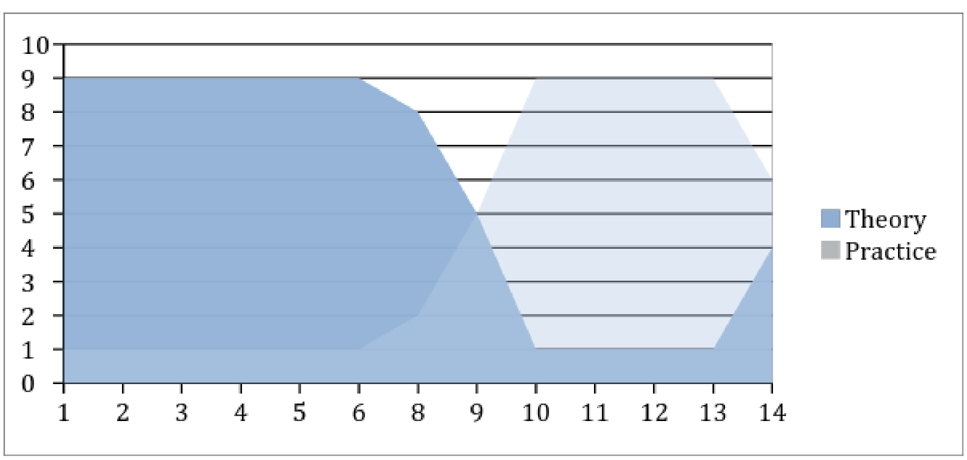

Figure 1. The proposed balance between theory and practice over the 14 week semester.

The course's learning outcomes are mapped along these general phases. We hope that by the end of the course students will be able to engage meaningfully in evaluation metrics along three dimensions: Process, Project, and Reflection.

With regard to the process we anticipate students will be able to:
- Describe the "lens" of one's disciplinary framework
- Find, read, and incorporate information from across multiple disciplines
- Communicate one's perspective and decision-making process to colleagues from other disciplines

With regard to the project we anticipate students will be able to:
- Design and build a quadcopter using open source technology
- Plan and implement projects in an interdisciplinary team environment

With regard to the reflection component of the course, we anticipate students will be able to:
- Articulate in verbal and written form the importance of interdisciplinary teams
- Identify the strengths of others when working on team projects
- Leverage a sense of empathy to see things from a different perspective

This last learning outcome has the most relevance for the theme advanced in this paper. The core assumption in our course design is that *interdisciplinary teamwork on projects with both technical demands and socio-political constraints are best positioned to enhance skill and empathy among students*. Positioning students for success involves properly sequencing the course. In the first week students will engage in exercises intended to break down barriers between individual students, while also identifying and addressing stereotypes about each of the majors/disciplines in the room. The faculty (GDH and ACF) will model these activities by engaging in exchanges about the core assumptions in our home disciplines, and in frank assessments of how we (or our colleagues) often view the world. Specific exercises from Stanford's d.School are being modified for inclusion in this class, and are available upon request.

Within the first two weeks, the students will also get out of the classroom in order to tour the spaces used by other disciplines, including (but not limited to) Peace Studies and Engineering. These forays will run alongside course readings and class discussion on a range of broader topics, including: *How does social change happen?* (week 2), *What is social innovation?* (week 3), *What about power, politics, and inequality?* (week 4), *What about new technologies* (week 5), and finally a session entitled *Designing drones for social good* (week 6). Across this first half of the class the pedagogical focus will be on building a common language with regard to the role and impact engineers have on the world.

Student teams will build drone platforms staring in the fifth week, a process that will terminate in the test flight of their devices. We anticipate this process will highlight skillsets more frequently found in engineering, especially in terms of building and troubleshooting the device. The engineering school's makerspace is equipped with rapid prototyping devices, soldering stations, machining tools, and raw materials. All students will be trained in how to use this space safely. We anticipate the engineering students who will take the lead in this phase, and we plan to use a peer instruction model where they can train their team mates from peace studies on these tools.

From the eighth week onward students will work in their same teams to design, plan, and prototype a payload for their devices. It is in this phase that we anticipate facilitating conversations (and perhaps mediating misunderstandings and conflict) about the ethics and appropriateness of the ideas developed in these teams. We anticipate students from the social sciences (e.g., peace studies students) will tend to ask more questions about cost, appropriateness, sustainability, and privacy than will their colleagues in engineering. Here too we find a place for the two of us to engage one another in public conversations about the tradeoffs involved in these projects, thereby modeling communication across disciplinary differences for the students.

This process will be facilitated by an additional component of the course design. The authors are exploring a collaboration with an engineering program in Rwanda, and will use this course as an opportunity to challenge students to design payload concepts that account for Rwanda's unique topography (mountainous terrain make roads unreliable), size (only 160 miles across at its widest), and stage of development (strong economy and growing infrastructure). Having a concrete case in mind will encourage students to focus their solutions, thereby increasing the chances that their concepts survive beyond the prototype stage. The final weeks of the course are dedicated to pitching the payload concepts developed in these teams and supporting students in an application to USD's social innovation pitch competition.

Perceived Challenges

How do you manage course logistics?

As with any team taught course, logistics will be one of major challenges for this course. As currently conceived the course is an elective that will be open to students with junior and senior standing. The course will meet once a week for 3 hours and be limited to 10 students from engineering and 10 students from peace studies. Both instructors will be present for each class. To ensure that the students are aware of the unique class format, an information session will be held that will give students a clear picture of the kind of class they will be taking before they register. Students will only be allowed to register for the class after indicating they are interested in this unique structure. Certainly the self selectivity of students who choose to enroll in such a class will impact our results and will need to be taken into consideration.

Does the specific technology matter?

One question we have challenged ourselves with is: might this course be taught with another technology, rather than drones? While we have worked hard to limit the cost of each build, and have done our best to ensure that the drone platforms can be disassembled for future assembly in subsequent courses, the class cost is comparably high. While we believe the incorporation of drone technologies will drive attention to the class, and drive up enrollment (thereby increasing selectivity), we are similarly confident that comparable pedagogical results can be obtained using other projects. Our goal in this course is to develop it to the point that we can comfortably swap out drone technology for another technology. The selected technology could be dictated by the particular institutional setting where the course is being taught or even determined by the student groups. We hypothesize that for a successful course the technologies must match on the following criteria: 1) be technically doable for both engineers and non-engineers, and be 2) socially relevant, i.e., exposed to debates about merit, ethics, local relevance, cost, sustainability, and so forth.

What's the role of external actors (clients / stakeholders / customers)?

A central component of this course is to put engineers into conversations with normative perspectives on the impact of their work. There are several ways to do this. The first is simply by pulling together students from engineering and elsewhere. The second is to have the course team-taught by colleagues from engineering and beyond. The third is to integrate into the class' lesson plan readings and conversations that tease these issues out. The fourth component, however, is perhaps the most critical: putting students into conversation with the key stakeholders they mean to engage with their work. Do customers interact with an affordance in the way an engineer intended? Do communities need a particular intervention? Does the particular intervention get perceived or used as the policymaker (or designer) intended? How much of this occurs in the workshop, how much outside? In our first iteration of this course we hope to proxy this process by focusing student attention to solutions for a particular national context (Rwanda). Future iterations, however, may incorporate key stakeholders (perhaps Rwandan engineering students) into the process from the very beginning, thereby ensuring USD students are working with a clear idea of what the customer/beneficiary says they need and want.

How do we measure outcomes?

One of the challenges in developing this course will be measuring outcomes. We have identified three potential approaches to examine the impact of our course. The first approach, taking a holistic view, is to use the Engineering Professional Responsibility Assessment Tool developed by Canney and Bielefeldt.[13] This recently validated instrument assess engineering students in three areas: personal and social awareness, professional development, and professional connectedness. While we intend to have an impact on students view on social responsibility, we are concerned this instrument may be too broad to quantify in a detailed manner the impact of our intervention.

A second approach would be to use Davis' Interpersonal Reactivity Index, a tool for measuring individual differences in empathy.[14] This instrument, developed by a social psychologist, has been used successfully in engineering education research by Hess to explore the relationship between empathy and innovation.[15] The survey evaluates individuals in four areas: perspective taking, fantasy, empathic concern, and personal distress. While it does not specifically address empathy in the context of collaboration, it would provide a useful data point to see if students overall empathy profile changes as a result of our class.

A third approach would be to adapt Fila's methods in investigating the role of empathy in a non-immersive conceptual design task.[16] Fila developed an empathic design framework and then quantitatively coded students 30 minute solutions to an open ended design challenge. For our course, we could develop an empathic collaboration framework and use it to evaluate student progress throughout the semester. With strategic selection of assignments, we could build some of the data generation into course assignments. This information could be coupled with pre and post interviews of students regarding their attitudes towards empathy across disciplines. While both more challenging and susceptible to our own biases, such an approach could provide more specific data about the impact of our course.

Why not just do service learning?

Service learning classes are an integral part of the way in which engineering is taught at USD. Our new general engineering department has been founded on the premise that engineers need multiple opportunities to understand the social context of their work. Within our department there are two required service learning courses. One, taken in either the first or second year, teaches user centered design and pairs students with community partners. The second, which has not yet been taught, is the senior capstone design experience which will also be done in collaboration with community partners. (For more on this new department, see Chen and Hoople.[17]) The course described in this paper has been designed to complement these service learning activities. Service learning can help students to cultivate empathy for users and community members, but our focus in this class is to cultivate empathy for peers from other disciplines. We argue that both of these skills are integral to educating successful engineering leaders.

Conclusion

Empathy is a critical practice for any individual or institution designing public facing solutions. This is true for businesses (who can use empathy as a tool for better understanding their customers) as it is for non-profit organizations (who can use empathy in order to better direct free services to at-risk communities). This paper described the way in which an interdisciplinary course might build empathy between students from the schools of engineering and peace studies. It is our hope that the project-based approach developed here will be easily transported outside our home disciplines and on a wide range of projects. The pedagogical deliverables, in the final analysis, are intended to prepare students for a real world in which they work with heterogeneous teams on complicated projects over extended periods of time. Our hope is that the process detailed above will lead to additional feedback on how we can better meet these objectives.

References

1. Hess, A. Is ‘Empathy’ Really What the Nation Needs? *The New York Times* (2016).
2. Oxley, J. C. The Moral Dimensions of Empathy: Limits and Applications in Ethical Theory and Practice. (2011).
3. Batson, C. D. *These things called empathy: Eight related but distinct phenomena*. (MIT Press, 2009).
4. *The social neuroscience of empathy*. (MIT Press, 2009).
5. Brown, T. *Change by Design: How Design Thinking Transforms Organizations and Inspires Innovation*. (HarperBusiness, 2009).
6. Stanford d. School, Design Thinking. Available at: http://dschool.stanford.edu/our-point-of-view/#design-thinking. (Accessed: 30th December 2016)
7. Altman, A. & Krauss, G. G. The key ideas of MDW IX: A summary. *International Journal of Engineering Education* **32,** 1331–1335 (2016).
8. Siniawski, M. T., Luca, S. G., Saez, J. A. & Pal, J. S. Design Thinking and Service-Learning for First-Year Engineering Students *. **32,** 1508–1513 (2016).
9. Rossmann, J. S. Engineering design as a liberal art: A first-semester introduction to design thinking. *International Journal of Engineering Education* **32,** 1502–1507 (2016).
10. Strobel, J., Hess, J., Pan, R. & Morris, C. A. W. Empathy and care within engineering: qualitative perspectives from engineering faculty and practicing engineers. *Eng. Stud.* **5,** 137–159 (2013).
11. Bielefeldt, A. R. in *Focus on Educational Research: Practices, Challenges and Perspectives* (ed. Hernandez, B.) 89–118 (Nova Science Publishers, 2017).
12. Walther, J., Miller, S. E. & Sochacka, N. W. A Model of Empathy in Engineering as a Core Skill, Practice Orientation, and Professional Way of Being. *J. Eng. Educ.* **106,** 123–148 (2017).
13. Canney, N. E. & Bielefeldt, A. R. Validity and Reliability Evidence of the Engineering Professional Responsibility Assessment Tool. *Journal of Engineering Education* **105,** 452–477 (2016).
14. Davis, M. H. Measuring individual differences in empathy: Evidence for a multidimensional approach. *J. Pers. Soc. Psychol.* **44,** 113–126 (1983).
15. Hess, J. L., Fila, N. D. & Purzer, Ş. The relationship between empathy and innovative tendencies among engineering students. *International Journal of Engineering Education* **32,** 1236–1249 (2016).
16. Fila, N. D. & Purzer, E. Engineering Students ’ Utilization of Empathy during a Non-Immersive Conceptual Design Task *. **32,** 1336–1348 (2016).
17. Chen, D. & Hoople, G. D. Contextualizing a New General Engineering Curriculum in the Liberal Arts. in *ASEE Annual Conference and Exhibition Proceedings, Columbus, Ohio* (2017).