ASEE 2022 ANNUAL CONFERENCE
Excellence Through Diversity
MINNEAPOLIS, MINNESOTA, JUNE 26TH-29TH, 2022 ASEE
Paper ID #37841

Investigating the role of compassion in engineering service-learning

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I am an environmental engineer specializing in many aspects of water resources and environmental fate-and-transport. His initial training was in chemical engineering (BS) at the University of Texas. I worked in environmental consulting in groundwater remediation. After consulting, I spent time at the University of Houston earning an environmental engineering PhD. My research there was in water quality modeling of persistent organic pollutants (POPs) and large-scale field sampling projects in the Houston Ship Channel coastal system. I currently works at West Texas A&M University in the Texas Panhandle, a semi-arid region. My activities there are applications of water engineering to benefit people and communities. The research and service span three areas. The first is the use of inexpensive biochar for preserving environmental quality in developing communities by using it as an adsorbent for agrochemical pesticides and nutrients. Second is the use of marginal quality water for irrigation to profit agriculture and maintain soil health. The third is the use of water footprint and blue-gray-green water categories to better understand the water impacts of food waste and strategies for its reduction. In the world of engineering education, I am very interested in the intersection between engineering student service, growth, and professionalism especially with respect to engineering service opportunities.

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ABSTRACT

Background: Four undergraduate engineering educators worked to examine the role of compassion in students in a senior design course using real world projects. We established relationships with non-profit community organizations (an international relief and a local trail development organization) through our professional networks. We found organizational needs and how engineering students could be involved to meet them.

Project design and execution: Students designed two sanitation projects. For the trail-based organization, we asked students to improve a public bike trail by providing a common bathroom facility. The international relief organization needed a prototype for a low resource bathroom facility to replace open defecation (OD) practices in Kenya. We sought to identify instances of compassion in students and to ascertain what role compassion has in professional development. Put simply, do compassionate engineers do a better job?

We examined compassion by two different means—a survey involving Pommier's Compassion Scale (CS) and a class focus group. We analyzed all qualitative data using Descriptive followed by Focused Coding analysis to see what themes emerged.

Lessons learned: Early researcher observations indicate that students perceive compassion for a community that is suffering as important in their design decision-making, but they are unsure how their potential growth in compassion will affect their professional engineering practice. Similar to recent developments on the importance of compassion in medicine, we hope to find evidence that compassion is an important aspect of engineering practice and education.

Conclusions and next steps: While we did not see growth according to the CS, we did see significant variation in students and in the domains that define compassion. The combination of qualitative-quantitative data illustrated important student experiences with compassion including that engineering work quality may be higher when students exercise compassion, and this higher work quality could translate beyond service projects into normal professional practice. In addition, service-learning and compassion work was seen as more fulfilling, but it is unclear if that fulfillment can go on for students as they transition from student to working professional. Finally, the work we present here highlights the need to study compassion in engineering more broadly, both in how it affects engineering design and how it might be consciously incorporated into curricula.

INTRODUCTION

Motivation of study

In engineering education and in the engineering profession generally, there has been a trend towards using engineering to serve people and communities in more direct ways than what might be called "traditional" engineering interests. This field or style of engineering is known by many terms including engineering-as-service, humanitarian engineering, and development engineering (DE). We defined DE as engineering that focuses on concerns related to global development and poverty normally in the context of particular communities. DE frequently involves projects that have socioeconomic components. As well, design-based projects in development engineering must consider cultural settings that are different from those of the engineers providing the design. The design frequently will require a strong attention to the use of technologies and techniques that are easy to learn and maintain, inexpensive, and allow for minimal use of centralized infrastructure such as roads, electricity, internet, communications, or modern supply chains.

Running parallel to DE is the trend in higher education for service-learning (SL), one manifestation of experiential education. SL has been defined as, "a form of experiential education in which students engage in activities that address human and community needs together with structured opportunities for reflection designed to achieve desired learning outcomes."[1] With such a definition of SL in view, it is not difficult to see how DE is one way that engineering education at many levels might be called service-learning if the activities in which students or professionals are engaged have some educational emphasis.

We recently conducted a surface level examination of service-learning for an engineering senior design class involving the design of a neighborhood for those seeking to leave a life of homelessness[2]. That study, while useful, left unanswered questions which became the genesis of the current study concerning not just service but compassion in engineering. Compassion is oft defined as the awareness of the suffering or distress of others combined with a desire to do something positive about it. Regarding compassion within the context of service-learning (SL) and the development of engineers generally, we ask:

1. Does the use of service-learning, development engineering experiences increase compassion in engineering students towards those for whom the design should benefit?
2. Does the use of these types of experiences increase professionalism and quality of effort in engineering students?
3. Do any potential gains in engineering student compassion and quality seem likely to continue into their careers?

Previous work on compassion's role in engineering service-learning

There have been many service-learning projects in engineering, as the discipline lends itself to outreach and development needs around the world. We present here a few examples of how it has been conducted at other universities to illustrate its use.

Civil and environmental engineering faculty working with Engineers without Borders (EWB) at the University of North Carolina Charlotte reported on study aboard initiative that sought to create social awareness in their students[3]. They sought to address which students are interested in service-learning, how well students understand how engineering addresses societal needs, and what are the differences in attitudes before and after the study. Students were self-selected on desiring to travel abroad and help others. They also became aware of societal needs once they were actively working onsite and found that it engendered positive attitudes toward their chosen field of study.

The Engineering Projects in Community Service (EPICS) at Purdue University is a well-known example of service learning in engineering education. The program was established in Fall 1995 and continues as of the writing of this paper in Spring 2022. A report from 2001[4] reflected on the program to that point. Project partners who are service agencies that work with student teams composed of freshman through senior level undergraduate engineering students in a wide variety of engineering disciplines. Design solutions are created, implemented, and supported by the students. Assessment was thorough, including student awareness of how their projects impacted their clients.

A study at Binghamton University examined how to incorporate compassion into an engineering ethics course[5]. This was integrated with a required practicum in a biomedical engineering program, for which service-learning projects are required for human and/or animals in order to improve their quality of life. A service-learning paradigm that progressed through three stages was present, which are initial charity, emerging compassion, and developing social justice. Students were asked to reflect upon their projects to see how student awareness of ethics and compassion was realized after completion of the projects.

Two researchers at Wichita State University (WSU) assessed service learning from reflections after completion of projects, inspired by two reports from the National Academy of Engineering[6]. Their College of Engineering implemented curriculum that addressed six activities: undergraduate research, internship, study aboard, service-learning, leadership, and multidisciplinary education. They sought to answer four major questions about service-learning: what is it, why is it necessary, how can it be incorporated, and how can it be assessed? Assessment was done by a series of reflections, similar to what this current paper will address.

Compassion in the professional world

We also examined the peer-reviewed literature beyond engineering education and service-learning and looked more specifically at compassion within professional preparation more generally. In doing so, we see that there is some work on the role of compassion in engineering, but there is far more in the health sciences [7-12].

Sham et al.[13] conducted a summer program to encourage high school students toward the field of engineering. Students learned engineering through lectures, field trips, projects, and service trip project within China. The authors described how the service trip instilled “a sense of compassion” in students but did not appear to specifically measure or define compassion. The previously mentioned study of Catalon [5] examined compassion as a step along the way to a social justice within service-learning. Like the current study, Catalon’s work was in the context of a course but one on ethics. Students had the opportunity to choose an individual project that would allow them to identify suffering, design a response to the suffering, and then enact their response. Perhaps what was unique about this course is that students did not necessarily have to involve themselves in a traditional “engineering” solution. Rather, the purpose of the activity was primarily to understand and increase compassion.

A study by London et al.[14] merits particular emphasis on engineering and compassion. In the study, authors noted the need to examine perceived need within engineering undergraduate curricula of “the heart” (affective) part of John Dewey’s Three Apprenticeship model for education (the other two being the head, cognitive, and the hand, skill, domains). Authors showed convincingly how little there is of affective constructs in engineering education as evidenced primarily by required coursework. In order to understanding the need for affective constructs, the authors compared civil engineering novices (early career and students) with experts (10+ years of experience) both quantitatively using a values survey and qualitatively using a small focus group. Specific terms they used for the affective domain include compassion, empathy, humanitarian, user’s needs, and trust among others. The study did not evaluate compassion in isolation but did distinguish it from empathy, care, solidarity, and related concepts. Important findings of the work include that novice and experts view affective values differently in terms of when those values should be incorporated into engineering curricula. A specific but telling result between experts and novice is that in the focus group, while both experts and novices frequently mentioned the importance of heart skills, novice engineers spoke much more on Community Involvement and Compassion while expert engineers spoke more on Safety.

In summary, it seems to us that compassion is mentioned alongside many other related concepts in engineering education generally and within service-learning. However, it is rarely quantified or examined closely. Moreover, we have thus far not seen expressed any idea that it might be exceptional or essential for engineering practice or education.

STUDY DESIGN AND METHODS

Connection of research to existing senior design course

In the spring and summer of 2021, we designed projects that would become real world designs for the Fall 2021 offering of CENG/EVEG 4380 Senior Design (civil and environmental engineers). From these projects, which were connected to serving others in some way, we purposed to examine student experiences with respect to compassion using the course as a case study.

Establishing community cooperation

This research study involves two community cooperation initiatives that led to two very different student senior design projects, though both projects are related to sanitation. We here describe the establishment of the partnership between each organization and the university's engineering college.

Near our university's engineering college, we had a locally-headquartered international relief agency (hereafter just called the NGO) come to the campus several time to describe their work for engineering student groups and in preparation for potential study abroad trips. Indeed, their work in Kenya was to be a study abroad trip in the summer of 2020. However, the COVID-19 Pandemic prevented any international travel. The NGO and the university still wanted to work together in ways that were mutually beneficial to students and the international communities that the NGO served. In lieu of being able to travel, we instead established a project that was focused predominantly on the design of rural latrine sanitation system which could be prototyped and then propagated throughout the state of Turkana, Kenya. Though connected to a local community in Kenya (with communication facilitated by the NGO and its partners), the design was meant to be reproducible. Thus, the particulars of the design, while important, did not have to be terribly specific to a particular Kenyan community. In this way, students were able to partner meaningfully with the NGO on a real project without being hampered by Pandemic travel restrictions.

Another local NGO focusses on organizing and coordinating activities like mountain biking, conservation, administration and maintenance of public lands here in the Texas panhandle region. This NGO together with the City of Canyon was interested in developing the public biking trail called Buff Trail, located to the north of the City of Canyon TX. One of the faculty in the COE is an active member of this NGO and thus this project was brought to the attention of the Civil Engineering faculty as a Senior Design project.

Focus group design

We designed the focus group to have a mixture of questions which were focused on drawing out student interaction as ideas as well speaking more directly to the research questions in our study. We generated a list of focus group questions with possible follow-up questions as needed. We recorded student responses during the focus group on a smartphone as well as by Zoom video in order to have two recordings if there was a discrepancy in the resultant transcript. The focus group lasted one hour. More details on the questions and how the FG were conducted are included in the results.

Study ethics

We submitted our focus group, survey, and data-handling protocols to our university's IRB before beginning any data collection. In addition, we used an informed consent form, given by a faculty member not in our college, to allow students to opt in or out of the course-as-research portion of the work. Students received course participation credit for all work in focus groups and surveys. All class work in this study was already part of the course in its academic design, and so that work had to be completed irrespective of student informed consent. All ten (10) students in the senior design course agreed to be part of the research study in addition to their academic participation.

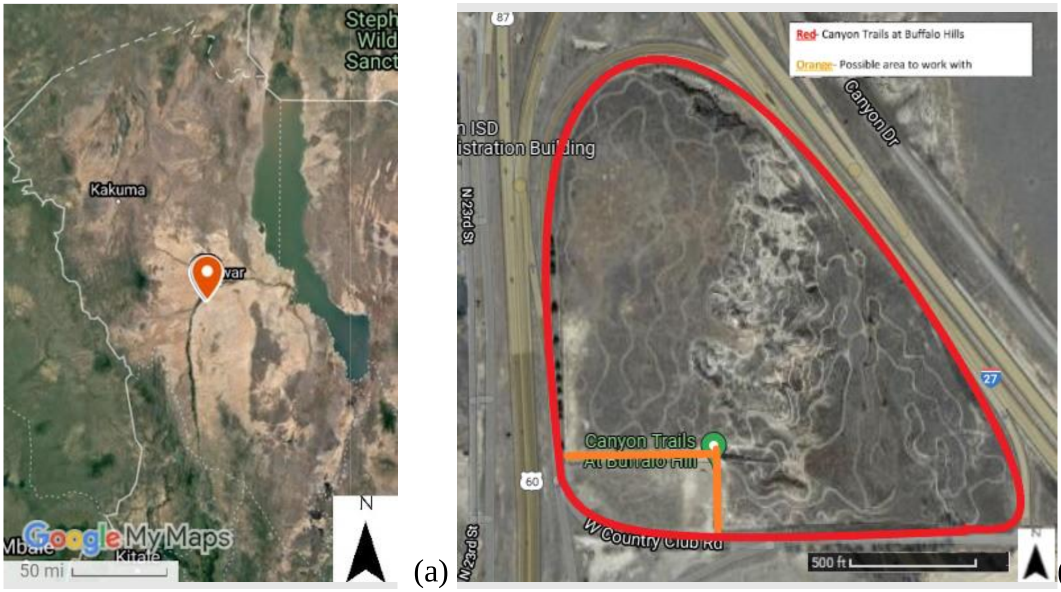
Survey and compassion scale

We used the Compassion Scale (CS) psychometric survey question set developed by Pommier et al.[15, 16] as part of a larger survey series designed in the Qualtrics online survey tool. The majority of the survey results used in this paper come from the scoring of the student CS results though there were other open-ended questions related to compassion and its intersection with our senior design course at a later time. Students were required (completion credit) to take the survey at a point early in the course (about week 5 of 16) and a point later in the course (week 16 of 16) with the intent being to see if there has been any noticeable change in any points of the overall CS score or its individual domains. The survey was given in class, and students took it on mobile devices or laptops using the class time to decrease distraction on the survey's submission. We intended to conduct the first survey during in the very first week of the course. However, we had to delay the first survey submission due to delays in our Institutional Review Board (IRB) application process.

RESULTS

Student design outcomes and instructor observations

Students worked on two distinct but related projects. The first project consisted of the design and development of a sanitation facility that is both functional and self-sufficient, and that can be culturally accepted by the people that are native to the Turkana County, Kenya (Turkana). In the second project, the students were asked to design sanitation stations in Texas at a mountain bike trail region called Buff Trails to attract more people to the trails. By developing two different sanitation facilities, the students were allowed to come up with design ideas that cater to the overall comfort and convenience of the diverse set of population that these facilities would serve. Site maps for each project area are shown in **Figure 1**.



(a) (b)

Figure 1. (a) Aerial overview of Turkana, Kenya, (b) Aerial view of Buff Trails

Sustainable Sanitation Facility in Kenya (Turkana)

For the Kenya project, the students produced two independent designs and finally a “merged” design that took into consideration the advantages of the two designs were chosen. In this design, a retaining wall inside the pit with cinder blocks was used. This was for the ease of construction and for sufficient weight to counteract the load from the soil around the pit. Since it was assumed that the soil in Turkana, Kenya has predominantly sandy soil, reinforcement with D8 rebar would provide additional security and prevent the pit from collapsing under a worst-case scenario. The actual toilet would be housed inside a locally thatched hut, that villagers gathered on top of a slab of concrete and a hole with a slanted pipe would lead to the reinforced pit. The pit would be capped with a cast-in-place reinforced concrete slab with a hole for a screened ventilated pipe. Further options of how to reuse the topper and slabs would depend on the villagers and the client. The construction process would include excavating the surrounding soil at a safe angle. The lining of the pit (cinder block lining) will begin to be placed in layers up to a certain height, after which the workers will backfill to the top of the wall. This process will be repeated, and the construction process is indicated in **Figure 2a** with the 3D layout of the sanitation facility around the pit is shown in **Figure 2b**. The schematic of the slab on grade view and the slotting process of the inlet pipe and placement of the corrugated sheet is indicated in **Figure 3**.

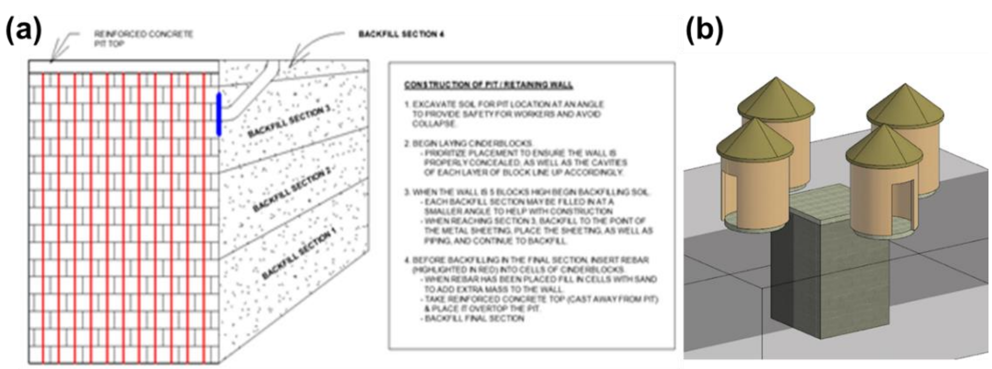


Figure 2. (a) Construction plan for the sanitation pit in Kenya, (b) 3D view of the sanitation facility with the pit.

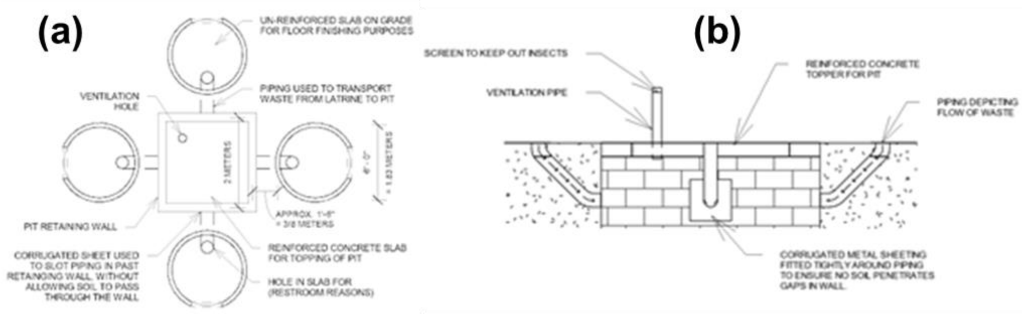


Figure 3. (a) Slab-on-grade view, (b) Design of pipe slotting with corrugated sheet placement.

For the facility to be efficient, the latrines would need to be positioned near the designated water wells. Federal policies in Kenya stipulates that the latrine should be at a distance of at least 40 meters from any water sources, and depth of the pit should be a minimum of 2 meters above the highest groundwater levels. It was also decided that water for the foot-pump hand-wash station should be carried by hand, and after consultation with the client it was decided that it would better serve the people if this water was used to rinse the toilet and pipes leading to the latrine. Using such a system will help the inhabitants of the village conserve water while maintaining proper hygiene. A foot pump hand-wash station which was most economical and low-tech concepts were also designed by the students and detailed instructions as to how to build and use the hand wash stations were also developed as part of the project (see **Figure 4**).

Figure 4. Instructions for (a) building and (b) operating the foot-pump hand-wash station

Buff Trails Sanitation Facility (Buff Trails)

The process of design for the Buff Trails facility was focused on serving the parameters of form and function. It was important to consider certain details in the design that may not apply directly structurally but would apply to the function of the facility. An example being that many bikers may use the facility at the same time and would need a place to park their bikes, therefore the design includes an area just north of the building with bike racks to suit this need. However, the process of structural design was to create a facility both aesthetically pleasing as well as structurally secure. After a detailed geotechnical analysis of the soil from the site, the structural design process consisted of designing the interior truss system to handle the exterior loads, followed by a choice of wall design that would suit the architectural design used by the City of Canyon for its utility buildings. This was followed by the design of slab and grade beam, and finally the footing was designed based on the structural design and geotechnical data. **Figure 5** shows the elevation and plan layout of the sanitation facility, with the 3D rendering of the facility in **Figure 6**.

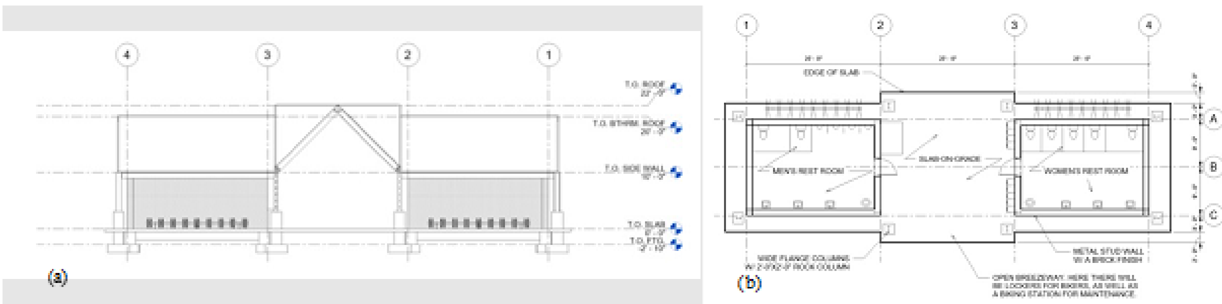
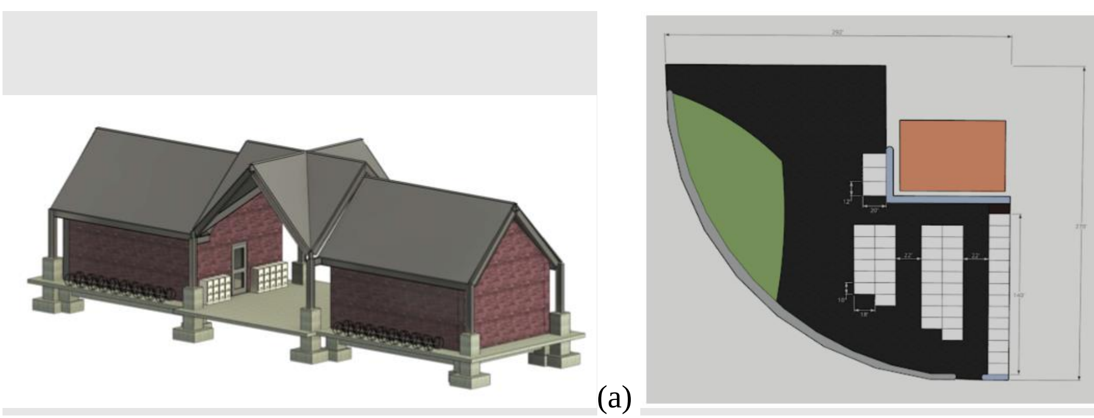


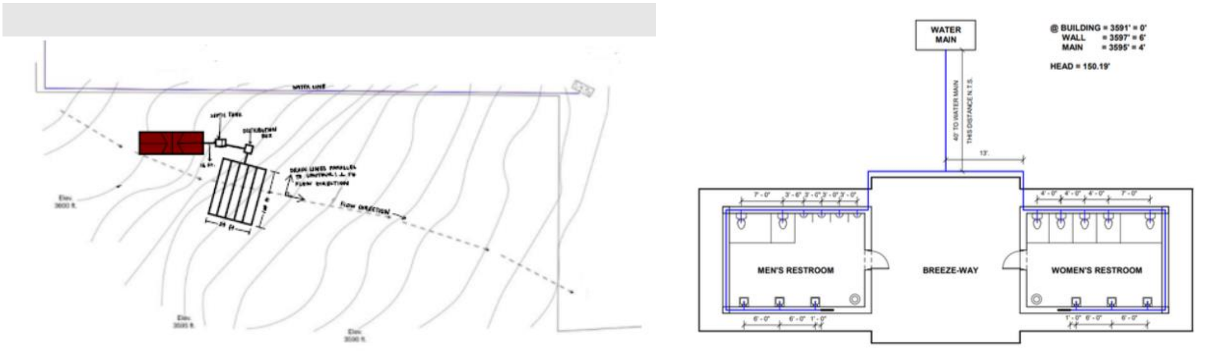
Figure 5. Buff Trails (a) Elevation View and (b) Plan View

It is assumed that an average of 50 people would use the facility per day, and this does not account for the special events such as races that might have peaks of more than 150 people at the park. The parking lot was therefore designed for daily peak usage and will be approximately 39,500 ft^2 for a total of 50 parking spots, with three extra parking spots reserved for handicapped vehicles which require more room for accessibility (see Figure 6b). The dimensions for the handicap spaces will be 12 feet wide by 20 feet long, with the parking spots at 90° along the direction of traffic flow. Having a 22-foot aisle will allow enough room for traffic to flow in both directions, minimizing confusion for the drivers. This was followed by the design of the water distribution system and sewage system at the facility as shown in Figure 7.



(a) (b)

Figure 6. (a) Buff Trails 3D view of the sanitation building (b) Layout of the parking lots



(a) (b)

Figure 7. (a) Design layout of the sewage system (b) layout of the water distribution system, at Buff Trails

Focus group analysis

<u>Qualitative analysis record</u>

There were ten (10) students that participated in the focus group (FG) which was conducted as part of the senior design class offering as a completion grade. Students were thus required to be part of the focus group, but their performance in the focus group was not evaluated. They received course credit for their participation alone. We conducted the focus group for about one hour after having first explained the nature of what a focus group is to the students, giving them ground rules for discussion, and having given them the official list of questions ahead of time to review. One instructor guided the discussion using both the official list of questions and occasional follow-up questions. The FG was conducted about two-thirds into the course. The students had time to work on their service-related design projects. They also had already had time to spend with the president of the non-profit organization with whom they were partnering on sanitation in Kenya.

Some authors on this paper were present in the room but did not participate in the discussion. Only nine (9) of the ten (10) students were able to be present the day the focus group was conducted. The other student recorded herself answering the written questions. Thus, there were ten (10) students in total that answered the FG questions. One of them answered them as a self-interview rather than in an FG. These two data sources together are hereafter called “FG data” without differentiation.

In consideration of the research questions for our study and the need to build trust and openness for the FG, we asked the following main questions. Some were more directed towards specific research aims. Others were meant to be more open-ended for individual student interpretation. The main questions are provided below in **Table 1**. They have been abbreviated to a simpler form for presentation.

Table 1. Primary questions used for focus group.

No.	Theme	Question wording
1	Senior design expectations	Think back to when you first signed up for engineering senior design. **What did you expect the class would be like?** What were you excited about? What were you nervous about?
2	Explaining engineering to high school student	Imagine you are speaking with a junior or senior at your former high school today. The high school student is considering going into college for an engineering degree. They want to know what valuable things they can expect to gain from a degree in engineering if they choose that path. **What would you tell them that they will gain?**
3	Value of service-learning projects	**What do you think is valuable or different about doing projects that are service-learning focused?** Do you like doing projects like this, or would you prefer to do more traditional projects where you design something like a complex structure, water treatment process, or residential subdivision?
4	Compassion in design work	In what ways **does compassion play a role in any of the design work** we are doing this semester? Should it play any role? Why or why not? Can you give me an example?
5	Suffering of those served as motivator	**Does the suffering that the Turkanans experience** make any difference in your enthusiasm or eagerness to work on your project for them? Do you think you do a better job in engineering design as you feel compassion for those you are trying to serve? Why or why not?
6	Service-learning and compassion gains for the engineer	Do you think that these service and compassion-related experiences **make you a better or more professional engineer**?
7	Most important gains from senior design	All things considered, what do you think are **the most important things that you have gained** from senior design this semester?

We recorded audio from the FG and student self-interview and had it transcribed by a professional service. We corrected obvious errors and inserted pseudonyms in the transcript record for all speakers. The basic demographics of the speakers were male/female 6/4 and race ethnicity six (6) white and four (4) Hispanic/Latinx. All students were traditional age students (ages 18-24).

We coded the data in primary and secondary coding cycles. In the primary phase, we created codes that were of a descriptive and hierarchical nature, looking primarily for the nature of what students were talking about and not the precise content. This process took two cycles to arrive at 39 codes. We then took some of the more oft-used codes to put into three main categories (secondary coding) as shown in **Figure 8**. The three categories were not defined *a priori* in acknowledgement of a grounded theory approach. The categories and specific student responses were certainly shaped by the FG questions we chose, but we strove to allow students to speak and interact with each other more than the discussion facilitator. Most of the facilitator’s record on the transcript is asking the specific questions above or occasional follow-up questions. Thus, the categories here, while likely not descriptive of all student comments, are emergent from the students’ perspectives and experiences.

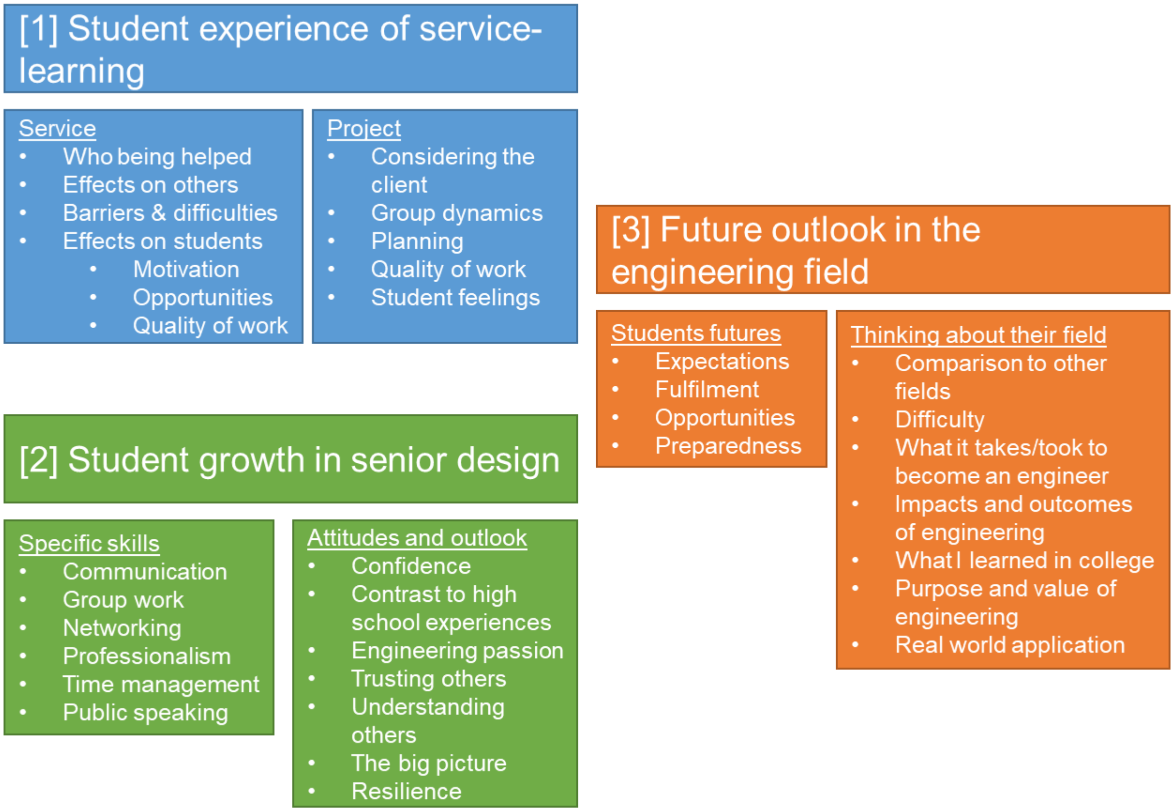


Figure 8. Major categories and their attributes found from Focused Coding analysis.

Narrative of Focused Coding categories

Category 1: Student experience of service-learning

A number of FG questions concerned compassion and service-learning, the relationship between the two and the ways that these ideas as understood by the students guided their experiences. The students responded to ideas about service-learning and compassion in two different frames of reference. One concerned the nature of service-learning generally, its value and significance in courses and on their professional development and future outlook (Service subcategory), and the other concerned how a service-learning mentality affected how they approached and experienced the particulars of their design projects (Project subcategory).

In interpreting the students' responses, it is important to keep in mind two points of fact during the semester. The first is that the students were working on two design projects at one time. They were both viewed as sanitation related and therefore "others focused". However, they were factually distinct in that one project, that of Buff Trails (bike trail sanitation facility), was very near where they lived. They could visit the site location, and they could imagine the impacts of the project. The other was in Kenya, a place they had never been, and it is unlikely that any of the students will ever get to go there or personally view an implementation of their designs. Indeed, even though the non-profit organization with which we were working facilitates trips to go and conduct projects there directly, this was never discussed or suggested to the students.

The second point of fact is that at several points in the semester and during the FG time, we brought forward some working definitions of service-learning and compassion. We did not attempt to provide any theory or structure for how service-learning and compassion were related. We merely provided them with the following definitions (**Table 2**) and then allowed them to use them as they responded to questions.

Table 2. Key definitions used in focus group discussions.

Term	Working definition given to students
Service-learning	A form of experiential education in which students engage in activities that address human and community needs together with structured opportunities for reflection designed to achieve desired learning outcomes. [cite, found in IRB]
Compassion	Awareness of the suffering or distress of others combined with a desire to do something positive about it.

[a]We note that this definition is slightly different from that of Pommier et al. concerning the Compassion Scale (CS), but the differences still seem fit the meaning well enough at a practical level for student understanding.

Within the Service subcategory, we could further divide student responses into those which are perceived more for themselves and those which are perceived more for others. In general, students provided more information concerning themselves and their relationship to service and compassion than they did for the effects on others. This trend may have been due to the nature of the questioning as well as to the nature of the projects in which they worked. Students were experiencing their project work all semester. Rarely did they have many direct interactions with clients or beneficiaries.

Service: effects on students - barriers and difficulties

Students identified barriers and difficulties in engineering service projects in some important ways. There are those difficulties which are connected to the work itself and difficulties that are related more strongly to the life of the engineer wanting to do the project. Concerning the projects themselves, students acknowledged and yet were grateful for the need to exhibit more cultural understanding when thinking about populations (like in Africa) that they might serve which they do not have strong experience with themselves. They thought critically about a sanitation system design that really be used saying, "We wouldn't have put so much consideration into what they would accept and what they wouldn't accept," if the population was not so different from their own experience.

Another strain of project-related difficulties concerns unintended consequences of engineering projects. Students were aware that the original need for sanitation in Turkana, Kenya was due to previous development projects, water well development in the region, which lead to stationary villages forming where people used to be pastoral. They knew that the need for more centralized and conscientious sanitation was a problem that came from an initial development that was meant to help people (provide drinking water). One problem solved lead to another problem that needed to be solved. These ideas lead to consider the ethical challenges of doing service projects for a community which is not their own in a situation where they could cause unintentional harm.

Students did not seem to think that doing nothing was an option. Rather, they focused on the idea of taking each project "one step at a time" and stating that we "can't frame what we are trying to accomplish." They seemed to feel that there were risks in taking on a project in terms of unintended negative consequences. They might know what some of those consequences could be, but there was uncertainty in (a) not knowing all of the potential negative consequences and (b) not knowing if any potential consequences would actually occur. Thus, the conclusion that they seemed to reach was that if the possible benefits outweighed the possible harm, they should try to do something for a community.

A final barrier identified by students was how an engineer experiences service-projects within their professional life. In thinking about how they might do engineering service project in the future, they were aware there is “a lot of thought and energy into learning a new culture” and that it would be difficult to sustain the energy required to do a good job in an engineering service project considering the demands of a regular job and family life. They noted as well that there were many restrictions on material resources, know-how, and technologies especially in international project and that these restrictions, while they force engineers to be more creative, make a difficult project even more difficult.

Service: effects on students - motivation, work quality, opportunity

There were several central ideas expressed by students in terms of how service- and compassion-focused projects have affected them and how those projects might affect them in the future in areas of motivation, the quality of the work they perform, and their opportunities.

Students felt that they were motivated to do work at a higher level of quality because they had more understanding of the needs of a population being served. Some statements they made to illustrate this idea were:

> Yeah. I think it makes you more passionate about what you're doing. You want those people that are less, have less than you to be able to experience what you have. And so you wanna give them the best that you can. –Alison

> I think this has been more than like, checking things off of a list for us too. Instead of like, the normal cost of, we go through homework, exams and we check them off a list as we go through the class. But this has more been, like, it's been open to us, you know, this project is gonna go as far as we want it to go. And so I think it's really driven us to go above and beyond, and do as much as we can. –Ryan

The nature of service-learning is that someone is doing the serving (the engineer/servant), and someone is being served (the client/beneficiary). Students thus expressed that they thought that what they were doing was for “real people” and motivated them to work harder than they might have otherwise. Related to students’ awareness of others is the distinction between a project which they undertake for a general sake of engineering excellence of performance as opposed to something which in their mind will clearly “help people” and has a “higher purpose” than traditional engineering projects. The feeling of the real people that they are serving is enhanced because they have to become even more conscious of the clients’ needs since they come from a different culture than the students. Frequently students expressed a need to do “more research” to be certain they would serve their client.

Another aspect of motivation is how these service-learning projects affect them personally and professionally. Some students felt that to sustain these projects more than money had to drive them. They must be “truly passionate”, and in the end they become “an all-around better engineer.” Students seemed to feel like working on these projects “lights a fire” in them and gives them rewards and fulfilment which is more than professional accomplishment and salaries. One student even pointed out the way that working with these communities is convicting for him causing personal reflection. He says, “I think they [people he might serve] have a lot more community appreciation and generosity that we’ve kind of lost.”

Motivation to serve with engineering is connected to the concept of unintended consequences in a way that could be described along the lines of guilt, duty, or inequity. Students did not want to do more harm than good, but they also said you “can’t just be cold towards them.” They also discussed their awareness of how different life is here versus a place like Kenya. Students felt that they have so many material things and technologies that they feel they are unable not to help, not to share what they have, or not to improve a condition that they see before them. There are certainly some echoes of the definition of compassion in this theme because it is recognizing suffering in others and not only wanting to do something about it but **feeling there is no choice but to do something about it.**

One final outcome on students came from their thoughts in comparing the two project settings. Some students initially treated the US-based, local project as more of a traditional project. In thinking about compassion, a student thought, “We don’t need to be very compassionate about people at Buff Trails” (the project involving the biking bathroom and rest stop). However, other students challenged this idea. They asserted that they actually thought more about how to be compassionate to bikers out on a trail in areas where the conditions might be lonely or cold. One participant summarized these ideas well in saying:

> If someone's at the bike trail and their chain breaks or something, they now have a tool to fix it, or even putting hot water in for…if it's freezing, or their hands are really dirty and they need some warm water. Like, that's compassion towards those people too. So I do think it's very important in any design…I mean, whether you realize it or not, you're being compassionate to the people that are using what you're building, I think. I do it unintentionally, even. It's like, it just is part of who I am I guess, that I think about, what would I want, if I were gonna be using this restroom. –Barbara

Service: Effects on others

It is difficult to disentangle the effects of service-learning as perceived by the students from those doing the service and those receiving the service. As students did not get to see anyone actually try what they were designing, the effects on others were more imagined or hypothetical. A few areas for service from the vantage point of “the other” include the feeling of novelty where you design something with the express purpose of helping others. Students also liked thinking about how their specialized training would be put to good use to benefit others, which for many of them was not the original reason that they went into the engineering field.

Students expressed the need to be compassionate and empathetic if you wanted to consider others and improve their quality of life. They discussed this in thinking about how they designed their bathroom in Kenya and the care they had to take to think of the “whole process” with respect to the feel of the bathroom, the handwashing, the cleanliness, and maintenance/consumables. They also were aware of the social dynamics in Turkana, Kenya whereby men and women should have entirely separate bathrooms. Even though each bathroom was for a single person at a time, they had to find a way to make it so that a male restroom was always used only by men and boys and never by the other gender. The world of American engineering students with single-person restrooms is often that they can be used by either gender. Students had to grapple with and ultimately accept this difference in culture and situation in their designs even if they could not fully understand it themselves. One student expressed some of this idea in describing the way to think about the foot-pump hand-wash station:

> But, you know, for example, I think compassion is very much so just putting yourself in somebody else's shoes, and trying to, uh, understand where they're at, and then for our

> purposes, taking that knowledge and taking that, uh, viewpoint and applying to like, our design for the latrine in Kenya.
>
> And there's several things that we had to consider, such as, like, Barbara and Alison came up with the hand washing, and the foot pump for the flush. They had to take into consideration, like, sanitation and just, how little sanitation is regarded over there, and to, like, almost put themselves in their shoes of like, "Well, what's the whole process that they have to go through?" –Bruce

Within the Project subcategory, some of the concepts listed have already been covered in the Service concepts already explored. However, one that yielded some new information about service-learning experience is in Group Dynamics.

Project: group dynamics

In some ways, the group of students in this study learned how to operate in a group in a manner similar to how any other group in a design class would have to operate. Much of their experience was likely not particular to the nature of a service-learning class, at least not as expressed directly in the focus group.

Some students had concerns about beginning a project with so many people (10). These students already knew each other, but none had worked in such a large group before. Students seemed more used to working in groups of 3-4 and thus were concerned about how they would find their place in a group of this size. Most expressed gratitude that they found a way to divide into subgroups. They valued these subgroups because they did not have to manage the entire project on their own. They could specialize once they learned to trust other group members that they would finish their work when required and would coordinate efforts (student growth: trusting others). They also liked being "able to find answers a lot quicker" than they would alone because they could get help from each other. One service-learning tie-in is that they had a unity of vision for what they were doing. They expressed that there were disagreements among them which they "discussed civilly", and they were able to find consensus for project actions because of a sense of the greater good for people that seemed to transcend any differences in personality or preference.

Category 2: Student growth in senior design

The category of student growth concerns ways that the entire class experience helped students to grow in character, maturity, skills, outlook, and attitude. Most of the data used for this category involves students directly acknowledging some way that they have grown through the senior design course. Some growth we determined more as an underlying implicit growth through a student's statement. With the course being conducted as it was, it is certainly possible that some of the growth seen is unique to service-learning and compassion-focused projects, but in most cases it is not easy to make that determination for certain.

Specific skills

Specific skills that students expressed growth in through the course were predominantly soft skills including communication, networking, group work, professionalism, time management, and public speaking.

Students seemed to take an account of their growth in senior design, but they acknowledged that much of what they observed about themselves had not happened only in senior design. This kind of reflection came about due to the nature of the FG questions concerning what they might tell a high school student concerning what the high school student might gain in engineering (Q2: What would you tell them that they will gain?, **Table 1)**

). This event highlights some of the value of the senior design capstone course and certainly the use of an FG or similar reflection activities in the course. Students became aware of growth in themselves at a conscious and at a group/team level in a way that likely consolidated the reality of the changes they experienced. They discuss changes with each other consciously, and then they discussed ways that they demonstrated these changes in their courses and typified them most strongly in senior design. As well, because they had the experience of working on projects together, they were able to validate the growth in each other using specific examples. Many times during the FG, a member would bring up something from their time in the course when "this happened" to demonstrate the point of growth that someone was expressing. Interestingly, there are not too many instances where students used the word "professional" or "professionalism" directly. However, in telling a high school student considering engineering what they might gain they used the words "responsibility", "consistency", "dedication", and "dependability". They also expressed the idea of being able to trust each other within a team. So students were experiencing what might be described as the experience of being in a team in an enjoyable way, a way where there is mutual respect for each other's abilities and a follow-through on project tasks and deadlines.

Attitude and outlook

Concerning attitudes and outlook, it is not simple to disentangle the way that students perceived growth in their attitude and growth in specific skills. It is likely that a change in student attitudes enabled the growth in specific skills. Some specific attitude-related growth categories we saw were confidence, passion for engineering, trusting and understanding others, resilience, and big picture thinking.

The students expressed resilience in thinking back on their engineering career. They acknowledged that engineering is difficult but that it is rewarding. They enjoyed the "sense of accomplishment" and also, at the end of their academic career, "how tough the professors have made stuff up to this point". They felt that most anyone could go into the engineering field if they worked hard enough and found it to be significant for them. None of the student used the word "resilience", but as one student summed it for many in the group, "I can do anything".

As well, most students grew in their ability to see the bigger picture (student growth: the big picture) and were able to express this in several ways. They looked back at their engineering academic career and could see how far they had come, what it meant to them personally, and how their desire to complete engineering projects had gone beyond merely "getting a good grade". It seems likely that the nature of service, while it may not have caused this ability to see the big picture better, allowed big picture thinking to emerge more visibly. We saw this in the students' ethical realization about how to do good and not harm in a community and the concept of the greater good. As well and unprompted by instructors, students discussed environmental concerns in their project work and a need to not focus only on the people being served. One other aspect of big picture thinking was students' realization of how difficult these service-learning project are in terms of the culture, the distance from the place where the project will be enacted, budget constraints, and resource/material strengths. Students discussed how this was hard but at the same time made them think creatively and "out of the box".

Category 3 Future outlook in the engineering field

This final category in the Focus Group data concerns how the students see the engineering field generally and themselves within that field. We asked them questions that helped identify something about the value or purpose of the engineering field to themselves or others, and we also asked them to think about what these service projects might mean for their future professional life. The two subcategories here were the conception of the engineering field (Engineering Field) and the students' futures (Future). Since much of what we found under Engineering Field was already touched on in previous categories, we chose to focus here primarily on what students said about the future.

Future

There were two broad concepts that emerged from the thought of students' futures. The first concerns the level of quality that students feel that they have as an engineer because of participating in this service-learning project. The idea is similar to how students expressed a motivation to do high quality work for those they serve (Cat 1: Experience in SL) and how they are better engineers because of the challenges they face in more difficult SL projects (Cat 2: Student growth in senior design). The difference though is how students see themselves first and thus how they market themselves to others. They feel more confident because of what they have accomplished in the service-learning projects in this senior design course. They also expressed their increased ability to network as a strength they have seen and feel that getting to work with many different people (both colleagues and clients) has helped them in their professional life and "life in general". This concept of being high quality engineers is something which students have seen demonstrated in their engineering career and in the senior design course. The concept is, however, a perception. Their confidence from the experience expressed in this forward-looking way will probably help them in their careers, but they must convince others through their demonstrated work quality once they leave the university. Hope and confidence in their quality of work is not the same as actually demonstrating high quality work once in the workforce. One participant expressed much of her confidence in what service-learning portends for the future in describing the versatility that has come to her from the experience:

> Whereas the service learning projects allow us to use these skills, but in a different way, and really stretch out our academic muscles, so to speak and think outside the box and solve different problems than what we've already seen, which I think is very important, especially as engineers to be prepared for multiple different situations and not just the things that we see in the classroom. And I think that the service learning projects do provide us with a very valuable opportunity to be prepared for the real world and have a mutually beneficial experience. –Heather

Also in the category of Future is a desire in several of the students to ***see their work to be <u>fulfilling</u>***. Many students acknowledged the need for their future work to support them and their families financially. Yet they admitted this alone was not enough. They wanted their jobs to be fulfilling in the work itself, in the way that it served others, through employers that might pay them in some way to do work that is more service oriented, or at least to have time away from their job where they could find an outlet for service. During the FG, some students became aware that they may have thought that being at a successful company and making money would be enough to "fill the hole". That may still be the case for some in this study, but many did not think that this would be enough and suggested that the experience in the course has heightened this sense in them. They wanted to have both a steady salary and work that was meaningful. At least one student was aware that the life fulfilment might not come entirely through an engineering career in saying, “I don’t want to be an engineer my whole life.”

Survey and compassion scale

Compassion can be described as demonstrating care by proactively finding ways to reduce discomfort. The compassion scale employed in this study was developed during dissertation work by Elizabeth Pommier at University of Texas at Austin[16]. The work describes a new compassion measure based on Kristin Neff’s self-compassion scale (CS)[15]. Neff’s work was originally derived from Buddhist philosophy and is a measure to help individuals become acutely aware of his or her ability to perceive suffering. From this work, Pommier’s measure applies Neff’s work in evaluating whether a person is more or less compassionate. There are six factors within Pommier’s compassion scale—kindness, indifference, common humanity, separation, mindfulness, and disengagement. These factors can be grouped into three categories—emotional response (kindness vs indifference), cognitive understanding (common humanity vs separation), and paying attention to suffering (mindfulness vs disengagement)[15]. **Table 3** provides a description of each factor within the compassion scale.

Table 3. The compassion scale factors with descriptions.

No.	Factor	Description
1	Kindness	Warm and understanding versus being harshly critical and judgmental
2	Indifference	In opposition to kindness: one is primarily concerned with self-preservation than the feelings of others
3	Common Humanity	Shared human experience, a method or way to connect with others, understanding that everyone deals with some sort of suffering.
4	Separation	In opposition to ordinary humanity: one cannot connect with another person because he or she sees that person as different from him or her; this reduces the desire to have compassion for that individual.
5	Mindfulness	An identification of suffering without exhibiting extreme feelings and emotions towards it
6	Disengagement	Antithesis to mindfulness, not wanting to identify with suffering

The compassion scale measure is a 24-question survey that requires respondents to answer questions using a Likert scale from 1 (almost never) to 5 (almost always). Each compassion factor has six questions mapped to it. **Figure 9** provides a graphical distribution of each question and how it links to each compassion factor. There are four questions for each factor.

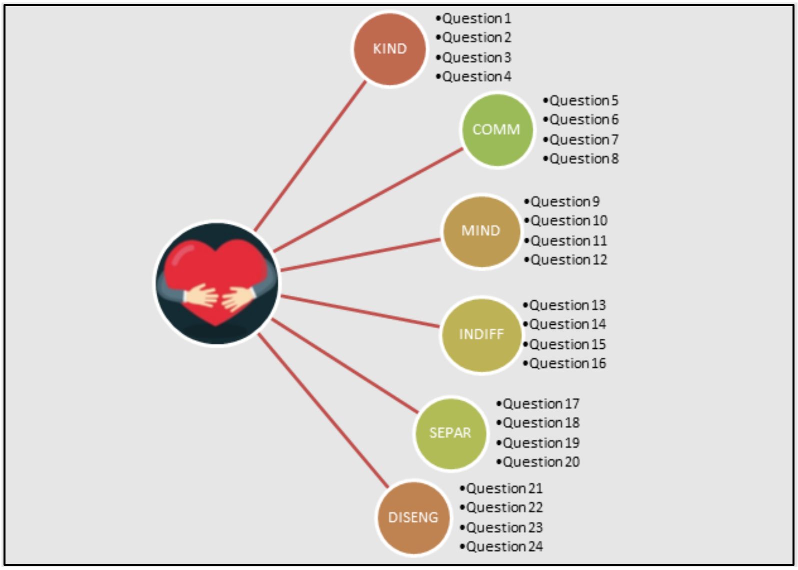


Figure 9. Diagram that depicts the question number with the compassion factor according to Pommier. Abbreviations for each factor are as follows—KIND = kindness, COMM = common humanity, MIND = mindfulness, INDIFF = indifference, SEPAR = separation, DISENG = disengagement.

We wanted to apply the compassion scale to engineering senior design students as there appears no prior use of the CS to engineering students or professionals to our knowledge. Based on the nature of the design projects, we thought that the Fall 2021 civil/environmental senior design course was the most appropriate course to apply this measure. This course had an enrollment of 10 total students from the civil and environmental engineering program (4 environmental, 6 civil). There were 4 female students and 6 male students, where three of the four female students were environmental engineering majors. We distributed Pommier's measure (24-question survey) on two different dates during the fall semester 2021—October 18 (week 9/16) and November 21 (week 14/16). Student data were collected and are de-identified by a unique identifier—s and three digits (i.e. s119). The identifier was maintained for both survey dissemination responses. **Table 4** provides descriptive statistics (number of responses, mean, and standard deviation) based on the two events. These tables were prepared using computations completed using IBM SPSS Statistics (Version 28) software. We note that the sample size for this study is quite small (only 10 students) as is the typical size of a senior design class at our university. Thus, the statistical summary on the CS is likely not generalizable to all engineering education contexts. Rather it reflects the experiences of this particular cohort as one example of compassion in engineering

Table 4. Summary table of responses by compassion factor during the (a) October and (b) November distribution.

(a) October

no.	compassion factor	n^a	p^a	r^{ab}	mean[c]	sd
1	KIND	4	10	40	4.15	1.03
2	INDIFF	4	10	40	2.55	0.99
3	COMM	4	10	40	4.60	0.74
4	SEPAR	4	10	40	2.30	1.02
5	MIND	4	10	40	4.08	0.76
6	DISENG	4	10	40	2.33	1.02
	ALL	24	10	240	3.33	1.33

(a) November

no.	compassion factor	n^a	p^a	r^{ab}	mean[c]	sd
1	KIND	4	10	40	4.23	0.66
2	INDIFF	4	10	40	2.50	0.96
3	COMM	4	10	40	4.68	0.66
4	SEPAR	4	10	40	2.13	0.82
5	MIND	4	10	40	3.98	0.66
6	DISENG	4	10	40	2.13	0.79
	ALL	24	10	240	3.27	1.30

[a]n= number of questions, p = number of participants, r = number of responses; [b]r = (p)(n); [c]Scale is 0-5 with 5 as the strongest in the factor

According to our results (evaluating the differences in mean from the two events), it appears that between the two distributions, student responses increased in kindness (+0.08) and common humanity (+0.08), but decreased in mindfulness (-0.10), indifference (-0.05), separation (-0.17), and disengagement (-0.20). Considering the greatest change in response between distribution (separation and disengagement), we can see that the students scoring changed for individuals and as a cohort. Consider the difference in the responses for Question 17 (SEPAR): “I don’t feel emotionally connected to people in pain” and Question 21 (DISENG): “When people cry in front of me, I don’t feel any pain at all” as examples. Regarding question 17, we saw that two of the ten participants responded with a 4 or 5 on this question during the October distribution. During the November distribution, no values were above 3. For question 21, while there was one fewer student that responded with a 4 in the October distribution, there were more students that responded with a 2 in the November distribution. Also, some students increased their responses from 1 to 2.

Since we have each student response organized by a unique identifier, we can also compare individual student responses between distributions. Using the same questions as previously mentioned, we generally observed that student responses changed by either 1 or 2 points (for example, a student went from answering with a 1 on question 17 to a 3, or from a 5 to 3). This amount of change shown here is a microcosm of what occurred for questions associated with the separation and disengagement compassion factors.

We did not see a large difference at an individual student level on the overall CS or on individual domains. However, it is instructive to see how the CS results vary between two students and amongst the domains of particular students. Figure 10 present those individual student results averaged over both survey events. We rescaled the negative compassion domains (INDIFF, SEPAR, DISENG) to be 1 (highest in them) to 5 (lowest in them) so that a larger value indicates increased compassion. Looking at the CS in this way, it is clear how the positive and negative compassion domains are generally correlated across most students. For example concerning Kindness and Indifference, most students had a value for these two which were very close on the absolute scale out of 20. Yet this was not true in every case as students s225 and s439 had an increase in Indifference over Kindness of 5-7. Other points of note include that there is variation across the student population (some students are higher in compassion in all domains compared to others), and there is variation even amongst the domains (some students do not score equally high/low in all six). Thus, compassion as measured by these domains, is complex and may be expressed in different ways within the context of engineering design.

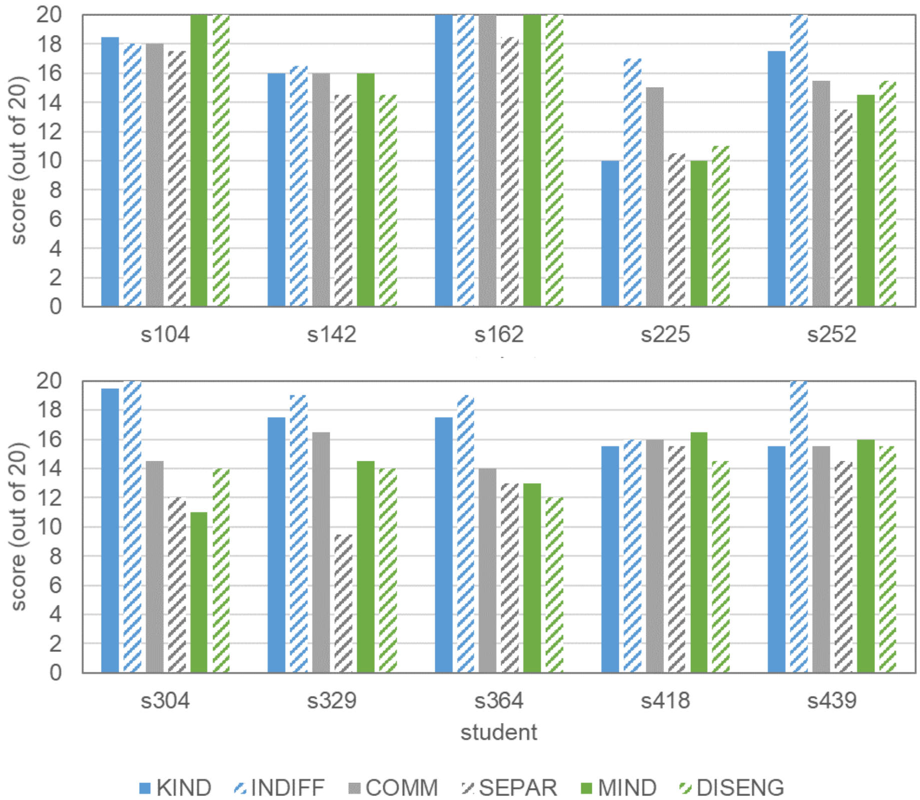


Figure 10. Mean value by factor for all students in study. Oct and Nov survey averaged together. All negative compassion factor (INDIFF, SEPAR, DISENG) were rescaled to be reverse. So a higher value is lower in these negative factors. Meaning an INDIFF of 4 became 5-4=1 such that a higher number indicates more compassion for all factors.

Overall, this was our first attempt at applying the compassion scale to engineering students. We found that students became more compassionate throughout the extent of the study. However, from a statistical analysis, we found that the number of participants maybe too low given the number of questions within the measure. We think that our next attempt at giving the CS to engineering students should be to a higher number of participants. We also think it would be interesting to determine what factors led our students to increase their kindness and awareness of common humanity, while decreasing their feelings of separation and disengagement. We feel that understanding "the why" in conjunction with the measure would also help us to better understand how engineering students perceive compassion within a design setting.

DISCUSSION

Looking back at our three research questions, the results are mixed and at times inconclusive. The first questions concerned increases in compassion seen in students towards those that they serving in a service-learning project. The Compassion Scale (CS) does not indicate an increase in compassion that we could measure. We think that it is likely that the survey times for CS were given too close together in order to see any definitive increase according to this scale. We did not see any marked increase or decrease in the overall CS scores. Looking at individual CS factors, however, we did see at least nominal decreases in the negative factors of Separation (from the emotions of others) and Disengagement (from others pain, characteristic of attention).

The FG results do provide some information that speaks to these factors. We could not find any particular points where students identified a time-based change in these factors directly. However, they did note how their creativity and planning increased in these projects more than in times past. They noted that they had to think harder about what would work well in a place like Kenya that was so different from their own cultural experience. As well, they tried to imagine what bikers would want when they were out alone on bike trails. To exhibit behaviors like these is to empathize with the difficulties of others and to choose to engage not just their minds but their emotions (affect). They were driven by a desire to do well in their senior design capstone course, and to do that in a service-learning project they had to have at least two important reference frames frequently at the same time—the technical content of their engineering design and the impact of those design decisions on people both during construction and during use. For example, they had to hold on to the technical aspects of soil strength for a pit latrine while at the same time considering how someone using only manual labor could construct that latrine without harming themselves or getting trapped in the hole during digging. Furthermore, they designed a durable cap structure for the latrine to address concerns given to them by the community about children accidentally accessing the structure. Putting these bits of evidence together—the design work itself, the CS psychometric results, and the FG experiences—we cannot say for certain that this service-learning experience increased compassion in engineering students. However, we can say there is good evidence for students being informed by compassion within themselves. We suggest therefore that these service-learning projects provided students an opportunity to demonstrate compassion through their engineering designs and furthermore that they were aware of the importance of having compassion during the design process. We call this process ***compassion-informed design***, the concept that a desire to do something about the suffering of others becomes infused with an engineer's design thinking. An engineer using such an approach makes strategic decisions to maximize the good being done to those being aided as well as optimize engineering performance.

This concept is in contrast to traditional engineering education. Traditional engineering education concerns technical competence, design-thinking, creativity, project management, group dynamics, and ethical considerations. Engineering ethics is the closest area of engineering education which relates to compassion as suggested by the previous example of an engineering ethics class that explored compassion[5]. However, ethics alone does not rise to the level of what we suggest within the concept of compassion-informed design. The US National Society of Professional Engineers (NSPE) details ethics in the form of safety, health, and welfare of the public; working only in areas of competence; issuing truthful public statements; acting for employer or client as faithful agents; avoiding deception; and conducting oneself honorably. In many ways, ethics is concerned with the moral accountability of engineers especially with regard to public trust. In contrast, compassion is highly concerned with individuals and their experiences of suffering or discomfort. Students in this study could have designed sanitation facilities that met project requirements in all of the ways commensurate with engineering ethics and yet have felt very little in terms of Common Humanity, Kindness, and Mindfulness. These compassion factors (and others identified in the focus group) require more than technical competence and professional behavior. They reach into the character, heart, and personal motivation of an individual engineer.

The goal of evaluating increases in compassion has a focus which must be at the same time on the engineering students in this study (the one for whom compassion growth examination is being conducted) and also on those whose suffering, discomfort, or difficulty provides an opportunity for service. Others have seen a problem with service-learning where compassion may be linked to paternalism [17-21]. The problem frequently arises when there is a perceived power differential between the server and the one being served. The server can be seen as being in place of privilege because they have resources and ability to provide for others which those being served do not have. Such a service-learning situation might be seen as merely providing charity. It becomes paternalistic when the one providing service (in this case the engineering students) begin to feel that they are superior and that they know what others needs are, perhaps even beyond what needs the served can express. One way to combat any real or perceived difference in power or worth is through community partnership models [22], which we employed in very limited ways on these projects. We did not design our study to examine paternalistic tendencies which may have been experienced in students through the projects. We would hope that the fact that we worked with an international relief agency which has a decade of experience in this community has avoided many paternalistic problems. This is an area which we would like to study further so as to promote the dignity of communities being served, their existing assets which can be leveraged for their good, and meeting a community's needs in a service-learning context.

The second point of inquiry concerned the use of service-learning experiences increasing the quality of work/effort in students and their professionalism. On this point, we would have liked to have had a means to use multiple group students groups, one which would serve as control on a traditional project which is not particularly service-oriented and one which is clearly service-learning. Our query concerned how the quality of effort/work would increase due to the service-learning experience, and we would thus need to compare the service-learning and non-SL experiences of students to evaluate this objectively. A comparison such as this would not be impossible, but it would be difficult. The difficulty of comparing the work/effort quality would arise because of the need to have an objective measure of effort and quality. In engineering education, instructors develop an intuitive sense of effort from students. Concerning work quality, this can also be difficult when student groups have projects which can be very different in scale and content. We did not anticipate the need for control versus treatment groups in this course, and such a study, properly considering all of the concerns just raised, is an object of future work.

Data from the FG did, however, demonstrate that students at least perceived their motivation for increase effort/quality of work was there. At times, they expressed how their grade in the course was not as important to them as they thought about who they were serving and the difficulties the clients faced. Students considered not only what had to go right about their designs but also what might go wrong and what unintended consequences might result. For at least some of them, the effort they gave was their very best because of what that effort meant to real people whom they wanted to help. Work quality and engineering design performance can be assessed on an absolute scale using metrics determine before a class is even begun. Our results here suggest that work quality may be better understood in the quality of work of an individual relative to themselves and their personal potential. Students and practicing engineers can sometimes conceive of their quality of work better relative to what they know they are capable of rather than by an external standard. Conceptualized in this way, we find support to say that the presence of particular human communities (either real or imagined), with the opportunity to use engineering solutions to serve and alleviate suffering, led to perceived higher quality of work and professionalism. More research is needed to be conclusive about the concept of service-learning, work quality, and professionalism interactions. We note some specific areas that we find to be vital including inquiries into if service-learning always or just sometimes increases work quality and professionalism, what the particular circumstance are surrounding how service-learning is conducted that promote such increases, and if there are particular types of engineering students (demographics, personalities, first generation, etc.) that respond more strongly to the gains in growth and engineering competency from service-learning.

The final research inquiry concerned whether and how potential gains in engineering student compassion and work quality seem likely to continue into their professional careers. We did not follow student progress concerning their service-learning experience impacts beyond this single semester course. So we cannot make any strong statements about any lasting impacts from service-learning in this case. Our FG questions and category of Future Outlook in the Engineering Field does provide some evidence of how we or others might go about this in the future. Within this category, students expressed desires to find opportunities within their professional lives for service using their engineering skillset. They noted that the experience they had with SL in the class grew them close together as a team and thus might aid in future networking. Thus, what we see currently is that students have a motivation to seek out more service opportunities on their own having had this opportunity for which they did not have a choice. Part of their motivation may be self-focused in that service projects provide more opportunity for networking and forcing them to be more creative and “out of the box”. These motivations do not preclude the possibility that genuine compassion, concern to alleviate suffering/discomfort of others, motivates at least in part their desire to find a role for service in their engineering future. Considering the evidence we have in our study, we hypothesize that the desire to find more service opportunities voluntarily comes at least in part from growth in compassion. To the degree that students-turned-professionals succeed in finding service outlets within engineering, such gains in compassion may be sustained. With specific reference to quality of work and effort, we furthermore suggest that if increased efforts are motivated through projects involving service with clear beneficiaries, those increased efforts should continue into the professional sphere.

However, it may also be important in future investigations to examine more closely the role of fulfillment in engineering work quality. Service seemed to provide at least one kind of fulfillment in engineering work. If we imagine a situation where a practicing engineer does most of their felt service work outside of their regular job, in other words on the margins of their time, then most of their work life will not exist in a way that is most fulfilling to them. Thus it would be helpful to understand better if increased work quality in engineer is tied to a continued experience of fulfillment through service or if service experiences had on an infrequent basis generate gains in work quality which carry through in all engineering projects.

CONCLUSIONS

In this study, we examined the impact of two service-learning sanitation projects, one in Africa and one in the US, on the growth of compassion in senior engineering students and the role of compassion in their current and future professional lives. To do this, we used a mixed-methods approach which included the use of the psychometric quantitative Compassion Scale (CS) and a qualitative focus group.

We did not see particular growth in compassion by the compassion scale but could see variation between and within students on the nature of compassion. Thus, we cannot preclude that compassion can be increased from service-learning. Using the CS as a measure of change in compassion is still reasonable. It just may take a larger difference in times of measurement to see it. We saw as well that service-learning does motivate students towards excitement in their profession, at least in part due to the fulfillment that comes from exercising compassion (alleviating the suffering of others), but it is not clear how service-learning experiences in higher education would translate into the profession. As engineering education is ultimately about the professionals that students become, if motivation for work and fulfilment in work is dependent on compassion in any way, we wonder if experiences like this can normally be found in working life in the engineering field or if professionals will have to find this elsewhere?

The end result of an engineering project may be higher quality work which honestly benefits those being served when compassion, entering into the suffering of others, permeates many parts of the design process. We call this concept compassion-infused design. While engineering design, both in education and in practice, does not have to involve compassion (indeed some projects lend themselves toward alleviation of suffering more easily than others), our results suggest that involving compassion in an engineer's experience is better for those being helped for and for the engineer as well.

Lastly, we see that compassion has not been examined in the context of engineering education or engineering design very much. The richness of the information on the intersection of compassion with design, using qualitative data and the recently developed CS as shown here, makes compassion in engineering studies more possible than perhaps previously seen. We thus recommend that compassion and related concepts in the heart (and not just hands/skills and head/cognitive) be incorporated more strategically into engineering education if the aim of engineering education is not to have only competent engineers but competent engineers focused on human impacts. We see the potential for many topics related to compassion in engineering which could be explored in future research such as the initial level of compassion that an engineer brings to their education relative to educational growth in compassion; the ways that core engineering education curricula can intentionally (and not just incidentally) cultivate compassion; and ways which compassion exercised in development engineering projects might translate into better outcomes in traditional engineering projects such as neighborhood subdivisions, electrical generation, and environmental remediation.

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APPENDIX

Additional information on Compassion Scale validation and realiability

While Pommier‘s Compassion Scale has already been validated, we still thought it would be important for us to complete statistical analysis to determine if the sample size selected for this research activity was adequate. We analyzed the survey questions (and student responses from the two survey distribution events) using IBM SPSS Statistics (Version 28) software. We completed two analyses on the data—1) reliability analysis; 2) factor analysis. In general, the reliability analysis allows us to determine the interconnectedness of each question group, answering the questions—1) does the selection of questions to be mapped to a specific compassion factor make sense?; 2) do all of the questions in the survey as a group make sense? Subsequent descriptive statistics (mean, standard deviation) were also computed. The authors employed factor analysis to answer two questions—1) how many factors can be generated from the survey questions?; 2) can each survey question be mapped to one (and only one) factor? The authors anticipated that six factors would be generated based on the survey questions, with each factor having four questions mapped to it. Although the authors have already validated the efficacy of the compassion model, we decided that it would be necessary to reaffirm this validation for our own data since we are using a smaller sample size.

The figure below diagrams the organization of each question by compassion factor based on the work from Pommier et al (2020). **Table 5** provides a summary of the output from the reliability analysis (expressed by Cronbach’s Alpha, α). Included within the table are a few descriptive statistics (mean, standard deviation).

Table 5. Summary table containing reliability analysis results.

no.	compassion factor	n	r	mean	sd	Cronbach's Alpha (α)
1	**KIND[a]**	**4**	**20**	**4.19**	**0.86**	**0.868**
2	**INDIFF**	**4**	**20**	**2.53**	**0.97**	**0.721**
3	COMM	4	20	4.64	0.70	0.574
4	**SEPAR**	**4**	**20**	**2.21**	**0.92**	**0.909**
5	MIND	4	20	4.03	0.71	0.464
6	**DISENG**	**4**	**20**	**2.22**	**0.91**	**0.814**
	ALL	24	20	3.30	1.31	0.647

n = number of questions grouped within the compassion factor. **Bolded** results indicate factors considered acceptable. These have Cronbach’s Alpha (α) values greater than 0.70. Responses are the number of individuals taking the survey. There were ten students that took the survey twice.

According to the results from our reliability analysis, four of the six factors are interconnected—kindness (α = 0.868), indifference (α = 0.721), separation (α = 0.909), and disengagement (α =

0.814). This means that it is acceptable to say that four of the six compassion factors have questions grouped properly to the compassion scale.

Using the 0 (almost never) to 5 (almost always) scale for the survey response on each question, the students scored high (greater than 4) on kindness, common humanity, and mindfulness, but scored close to low (between 2 and 2.99) for questions associated with indifference, separation, and disengagement.

The factor analysis provides a distinct perspective to the analysis done within the reliability analysis. Our factor analysis included analyzing communalities, total variance explained, component matrix, scree plot, and related component matrix (transformation of the component matrix).

From the total variance explained output (expressed by eigenvalues greater than 1) and the scree-plot (values prior to the elbow bend in the graph, not included in this paper), we discovered that the data can be grouped into ***seven*** factors. This is one more factor than what was to be expected using the compassion factor.

From the component (factor) matrix output (**Table 6**), it was found that 20 out of 24 survey questions fit one factor, and only one question fits uniquely with one and only one factor. Ideally each question should fit within one factor, limited to having just a few questions organized within each factor. An alternative method within factor analysis is to have the data undergo a process within SPSS called rotation. The objective of computing rotation calculations would be to ensure that this would eliminate the problem of questions being linked to multiple factors. We ran the factor assessment procedure several times using different rotations available within the software in hopes that the rotations would eventually group each question into one factor. However, the results of rotating the data did not resolve this issue. Using the Varimax rotation (**Table 7**) as an example, the rotation appears to have distributed the results to more factors (i.e. 15 out of 24 survey questions fit within factor 2 instead of 20 out of 24 survey questions fit within the first factor). While this has improved the ability to try and assess the data, it still does not fit within the objectives of having each question fit within one factor.

Table 6. Component Matrix Table. The table output is organized from the highest coefficient to lowest for each of the question.

Component Matrix[a]							
Question No.	Component						
	1	2	3	4	5	6	7
Q20	0.907						
Q22	0.854		0.332	-0.309			
Q19	0.852						
Q24	0.851						
Q17	0.809			0.405			
Q18	0.779	0.455					
Q13	0.752	0.315					
Q21	0.749			-0.493			
Q12	-0.745	0.324					
Q15	0.71			0.374			
Q3	-0.697	0.359	-0.375			0.306	
Q23	0.613		-0.587	0.332			
Q14	0.583				-0.467	0.458	
Q2	-0.527	0.698					
Q1	-0.621	0.692					
Q11	-0.493	-0.641		0.351			
Q5		0.639					
Q7	-0.549	0.617			-0.312		
Q8		0.57		0.483		0.317	
Q9		-0.401	0.664		0.36		
Q6		0.329	0.598	0.437			
Q16	0.461	0.322	0.523			0.517	
Q4	-0.469	0.355			0.571		
Q10	-0.424				0.359		0.668

Table 7. Rotated Component Matrix Table. The table output is organized from the highest coefficient to lowest for each of the question.

Rotated Component Matrix[a]							
Question No.	Component						
	1	2	3	4	5	6	7
Q20	0.864						
Q22	0.853						
Q19	0.828			0.365			
Q24	0.825		0.320				
Q17	0.781	-0.348					
Q18	0.761		0.387			0.374	
Q13	-0.748	-0.343		-0.301	-0.352		
Q21	0.663			0.493			
Q12		0.921					
Q15		0.869					
Q3		0.793					
Q23	-0.494	0.692					
Q14	-0.501	0.659					
Q2	0.417	-0.586	0.324			0.491	
Q1	-0.324	-0.310	-0.789				
Q11		-0.365	0.760				
Q5	0.304			0.830			
Q7	0.310			0.758		0.326	
Q8					0.859		
Q9	0.394	-0.480	0.350		0.572		
Q6						0.802	
Q16							0.868
Q4		0.395			0.441	0.303	0.546
Q10		0.469	-0.397				0.499

Based on the results from the statistical analysis (both the reliability analysis and the factor analysis) and number of respondents employed in this study, the statistical analysis indicates to us that the number of responses employed is too low. So, what can be done to ensure that our survey can better fit the compassion model? We purpose the following—***increase the number of respondents***. As currently constructed, the sample size of our current compassion scale model is only 10 participants. In contrast, Pommier et al.[15] described six separate studies conducted to effectively assess the fit of compassion scale model. These include sample sizes ranging between 80 and 1,394 participants. Having a value of 10 participants might just be too small for us to determine if the questions within our survey can be mapped to six distinct factors of the compassion scale. Since our civil and environmental engineering senior design classes are typically small (no more than 10 a semester), we can consider collecting data over multiple semesters. Another option to quickly obtain a large sample size is to distribute this survey to other engineering design classes within our College. Our mechanical engineering program has the largest student population in the College. Students in this program will take three different design classes (thermo-fluids design, machine design, and senior design). Dissemination of the survey to these classes along with the civil environmental senior design class might increase the numbers of participants within the study.