Innovative Neighborhood for the Homeless: A Combined Technological-Socioeconomic Approach to Engineering Senior Design

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Abstract

Engineering education literature provides evidence for many positive impacts from Service-Learning (SL) on engineering students and young engineering professionals. Traditionally most engineering coursework is heavy on hard science and math and very light on courses involving social sciences. Four faculty (all noted as co-authors) from West Texas A&M University (WTAMU) advised or led in two different civil and environmental engineering senior design student groups in a SL opportunity in Amarillo, TX in the 2019-20 school year. We worked with a local non-profit organization called Christ Church Camp (CCC) that served as the primary client for design. The project was to design a neighborhood for those transitioning out of homelessness and into greater self-sufficiency. The design had to fit within a budget determined by grant money sought by CCC. There were engineering challenges concerning how to build sustainable tiny homes and use rainwater harvesting to support an urban garden. Student designers also had to learn the basics of social work and poverty alleviation so that they could design a neighborhood that would build confidence and community for homeless individuals. Frequently, the homeless we served were coming out of addictions and had deficient relational skills.

We conducted the class over two individual semesters of senior design. In the first semester, students had to select a large piece of land that was in an urban area. They were free to design a neighborhood that could house about 40 individuals between temporary tent-structures and tiny homes with few constraints. In the second semester, different students improved on this design by redesigning tiny homes to be built from shipping containers, removing the tent dwellings, designing a central community building, and incorporating sustainable design choices that would result in a LEED certified neighborhood[1]. In addition to guiding the project, faculty examined student comments from weekly memoranda to evaluate both ABET outcomes[2] and growth in empathy/compassion. We expect that this kind of partnership between engineering education and social-work related non-profits will become more common. Specific challenges we faced included interfacing with city government, uncertainties about land locations to purchase, and having clients very different from students and their experiences. We hope that other engineering educators will be able to surmount these challenges by building upon our experiences.

Keywords: Service learning, engineering-as-service, civil engineering, environmental engineering, LEED, ABET, sustainable development, compassion

Background and Motivation

Service-learning (SL) has been described 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."[3] Volunteerism is the act or philosophy of using beneficial service for another without financial compensation to the individuals providing the service. Field education and internships are experiential education avenues for students to learn through hands-on practice. SL captures aspects of both volunteerism and field education (Figure 1). Volunteerism focuses on the benefit to the ones receiving service while field education focuses primarily on the educational objectives for the student. SL should have real service. The activities which students perform meet a real need for a community.[4] SL also has real educational benefits. The choice of service used in the learning should have particular educational objectives in mind. If a SL activity meets a community need but does not provide any meaningful experiential education for a student, it is useful service, but it does not rate high in learning. If the activity has extended learning opportunities but the service provided is not something that a real community needs, then it is educational, but the service is too small to be SL. **Thus, the use of SL as an educational tool, especially in higher education, is to both to teach and to serve in equal measure.**

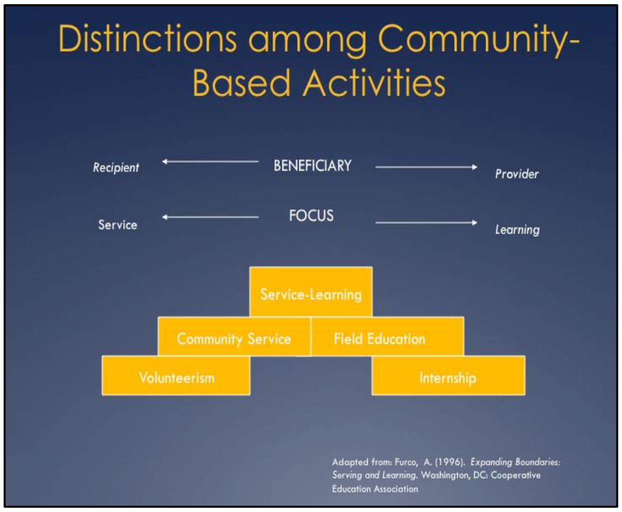

Figure 1. Conceptual diagram explaining the uniqueness of service-learning (SL).

Considering a broad sampling of SL in STEM education as provided in peer-reviewed literature, SL has shown beneficial outcomes particularly with regard to the types of learning objectives that have generally been more challenging to achieve in traditional engineering coursework. These objectives include instruction in ethical responsibility, engineering solutions in a global context, and contemporary issues[5]. SL has documented effectiveness for instruction in related ideas including effective learning of sustainability[6], broadened social-cultural experiences[7, 8], post-graduation development volunteerism[6, 9], increased professional skills[8, 10-13], commitment to engineering[14], social justice challenges[15], leadership and confidence[16], and empathy[17]. In the last decade the graduation rate for STEM professionals lags behind the appearance of new STEM employment opportunities. The problem relates to the need to diversify the field of STEM generally. Thus, SL has demonstrated capacity to increase women's interest in and persistence with STEM[8, 14, 18] and to generally enhance diversity[18] in STEM. In K-12 education, SL education research has shown gains in academic engagement and achievement, particularly for at-risk students.[19]

Engineering educators have strategically utilized SL in civil and environmental engineering senior design. A cursory review reveals several examples. Some examples of design in capstone classes include bridges[20, 21], a public greenway with water resources design[22], school and community building construction[23], smart communities implementation[24], and more. It is in this spirit that we will describe our contribution with this paper.

It would be too optimistic to state that the use of SL in STEM education has such high value and efficacy that traditional educational strategies should be eliminated or deemphasized. The appropriate use of SL is ***a compliment*** to traditional education strategies has been evidenced in general practice and literature. The complementary use of SL in engineering design courses is something, which our faculty have employed because we have seen the educational benefit in general, and we have observed the increase in student interest beyond merely the grade when a person or group in need of service is involved.

University Location and Programs

West Texas A&M University (WTAMU) is a regional institution enrolling over 10,000 students and has been a member of the Texas A&M University System since 1990. WTAMU currently has four ABET-accredited engineering programs (civil, electrical, environmental, and mechanical) and an engineering technology program, all contained within the College of Engineering (CoE).

Both the civil and environmental engineering programs feature mathematics, natural sciences (chemistry, physics, biology, and/or geology), and required engineering coursework prescribed by ABET EAC standards. Each program requires a one-semester capstone course called Senior Design that serves to use these required subjects to design an engineered system that meets real-world requirements. During the Fall 2019 and Spring 2020 semesters, the civil and environmental engineering capstone consisted of a large project that is described in the following section. While one faculty member oversees the operation of Senior Design, all four (4) civil and environmental faculty collectively mentor the class and ensure appropriate resources and lab access are provided for project success.

Figure 2. CCC Facebook information and support page.

Project Description

The project which faculty gave to a combined civil and environmental engineering major senior design class was the design of a unique neighborhood that catered to the particular needs of the homeless. Two different groups of students worked on the same project, in differing phases, over two semesters. Students conducted the project in partnership with and for the benefit of the non-profit organization, Christ Church Camp (CCC, **Figure 2**). CCC's mission is:

1. To meet our residents where they are with the love of Christ. It is our belief that rebuilding what is broken on the inside will positively impact what is broken on the outside.
2. To provide the safety, edification, and access to the resources our residents need to step out of and stay out of homelessness.

The organization's mission is indeed to tackle homelessness but to do so from a social work thinking perspective whereby they ask themselves, "What are the root causes for homeless in a particular individual's life?" We thus see homelessness as an economic and social problem. Engineering faculty tasked engineering students to address one aspect of homelessness alleviation using their skills as engineers in land development. They were to develop a neighborhood that in a direct sense provided shelter and community for the homeless. However, their ultimate objective was more indirect. They had to consider the unique challenges of homelessness and design a neighborhood, which would help CCC staff and volunteers to lift people out a homeless lifestyle and attitude to become whole and self-sufficient.

Engineering students are not social workers and do not have much background in social sciences. We as engineering faculty spent time consulting with CCC to make a list of concrete design requirements that the students would meet for their neighborhood before any students were involved. Two separate groups of students in different semesters worked on the neighborhood's design. Students had to show that they had considered social thinking and the nature of homelessness itself in what they were doing. While not experts in social problem solving, they did learn enough about homelessness from meeting the homeless, working with CCC staff, and social work speakers to incorporate social aspects in their designs. The specific aspects of the neighborhood's design were:

1. Involvement of the major areas of civil & environmental engineering--environmental, surveying, geotechnical, structural, transportation, and water resources
2. Design of very simple light-frame living structures for 1-2 people per structure
3. Design of tiny homes for 3-4 people each
4. Design of a multi-purpose large building with climate controls, shower facilities, job and skills training, and Christian worship services
5. Design of an intracommunity road for cars, walking, and bicycles
6. Incorporation of water reuse and urban farming

Results and Course Experiences

Observations from instructional faculty

All four faculty from our civil and environmental engineering program groups lead as instructors in the senior design capstone course for each semester. Due to the differences in expertise and familiarity with CCC, each of the faculty approached the course in different ways. The project was essentially the same in each semester, but the project was conducted in such a way that what students began in the Fall of 2019 was continued in the Spring of 2020.

Figure 3. Many of the experiences at the camp location were around meals cooked or served near a campfire.

Fall 2019

Dr. Nathan Howell, environmental engineering professor, was the lead instructor in the first semester. Drs. Butler, Leitch, and Unnikrishnan served in a mentoring and supervisory role. The term had a class of five (5) civil engineering students and one (1) environmental engineering student. Dr. Howell observed two trends in the students' behavior and experiences.

The first trend concerned the highly open-ended nature of the project. The students experienced a feeling of being overwhelmed at the magnitude of their project and the magnitude of the homeless problem in the Amarillo-Canyon metropolitan area in general. Thus, students had to organize themselves early in the semester and determine what parts of the project they would attempt and which they would not design at all or just lightly design with the expectation that later students would complete. The students struggled with where to begin and how to cooperate. The situation was more difficult in that the project was for a real client, the CCC, and involved service to kind of person that was highly unknown to most students, the homeless. Most students, unless they have once been homeless themselves, know little about what it means to be homeless. Students began understanding homelessness in a highly literal fashion meaning that they took it to mean "the condition of being without a home." Using conversations with the director of the CCC and professional workers from the City of Amarillo, they were encouraged to understand that homelessness is a mindset, a pattern of behavior, and a condition that creates a feeling of helplessness. They also visited the current homeless encampment on multiple occasion to speak with the homeless their directly. Having to think about how to design a neighborhood, knowing that simply building a structure was not the answer, challenged their ability to know how to use their engineering abilities to participate in a solution. They knew the problem would not simply be an engineering or technical solution but rather a techno-social solution of which their neighborhood design would just be a part.

The second trend observed in the students was the way that directly interacting with the homeless and those that served them affected their personal growth and their motivation for design. It is common for engineering students to find motivation in the desire to be a professional, to use science and math in an applied fashion, and to solve complex and interesting problems. Serving the homeless certainly is a complex and interesting problem, but their project did not involve the kind of complexity that students expected having come from four years of highly STEM-directed coursework. Students had many opportunities to visit the current temporary homeless encampment, which was merely an out of sight piece of vacant land with some tents for shelter within the 1% flood plain (Figure 3). By spending time directly at the encampment, students began to develop an understanding and empathy for the homeless. The experience of knowing them, having a meal with them, and spending time in conversation with them helped them to see the greater extent of their suffering. The etymology of compassion provides its literal meaning, "to suffer with", and the time simply spent with the homeless certainly met this definition. Without having to be told directly that the neighborhood they were designing was not ***the*** solution to local homelessness, they nonetheless understood how their designs contribute to the general challenge of homeless poverty alleviation.

Figure 4. A 3D rendering of the light structure Conestoga hut. Note the human figure on the front of the hut to indicate the scale.

An illustrative example will help to visualize how the students' direct interaction with the homeless informed their engineering design thinking. The CCC director had asked the students to design some kind of "light structure" that would be possible for 1-2 peoples to live in when they first moved from off the street and into the neighborhood. The structure would be the first kind of neighborhood experience that the resident had before moving into a more traditional home. The director's experience was that the homeless should not have too many resources given to them at once so that they could learn to be responsible for taking care of a small living arrangement. Related to the need to gain responsibility was the desire for the neighborhood to create a culture of community. The director had observed that many homeless persons took some time to trust anyone else in the current temporary encampment and would isolate themselves in tents. She was concerned that if they moved into a fully independent structure (bathrooms, kitchen, laundry facility, garage) immediately that the resident would not participate in the larger community efforts being created at a central community structure where meals, showers, activities, and job training would occur. Thus, the students found a design from an Oregon non-profit organization for a Conestoga hut. The design the students settled on, though inspired by the Oregon non-profit (shown in **Figure 4**), was nonetheless their own. The Conestoga hut provides basic shelter for one person and resists the elements much more than a tent. It give the homeless the chance to be responsible to keep a home on their own. Yet they would have to participate in the life of the community at the neighborhood's central gathering space (**Figure 5**, details given by Spring 2020 students). Thus, there was much more to the design of the structure than merely the number of occupants and building codes.

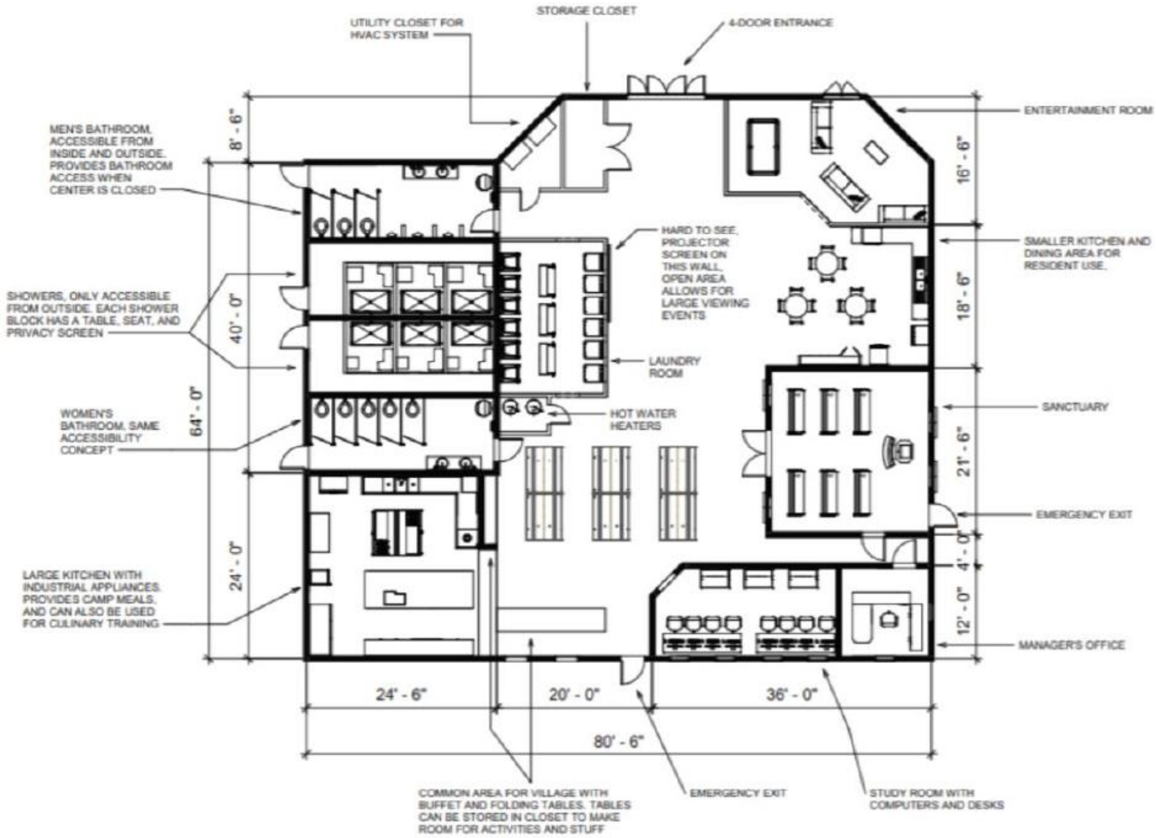

Figure 5. Central community building floorplan. This was designed in this form in the second semester, Spring 2020. Students in Fall 2019 knew that the basic feature shown here would be in place which include men's and women's bathrooms, kitchen, entertainment space, chapel, and CCC offices.

Spring 2020

Dr. Vinu Unnikrishan (civil engineering) was lead instructor for the second cohort of students (nine (9) civil students and one (1) environmental student), with Drs. Butler, Howell, and Leitch in an advisory role. The initial feeling was the course was to be a continuation of the previous group's work. However, after discussions with the client it became clear to the group that they needed to produce an innovative design beyond the previous efforts. These students focused on the design of a large multipurpose community facility and a small-scale residential building, which would be reproduced many times over when the neighborhood was actually constructed. These structures would be completed along with the development of appropriate road and parking facilities. The demand for sustainable designs, construction practices, and land development projects has grown tremendously, and it is not only due to increased environmental awareness but also due to prospects for long-term economic benefits[25]. Thus, for sustainable development the design project would also require various recycling facilities and facilities to provide for the training and empowerment of socially disadvantaged homeless resident population.

For the design of the communal facility, the students decided that every room in the facility would be created with multi-purpose utility. The design was to provide early-phase access to the central facility for new residents, and the design was to be a a central location from which to operate. Students included plenty of office spaces in the design for processing the incoming residents and other daily operations. Due to the unique psychological challenges that residents face, students designed the central facility with multiple windows at the front entrance. As well, students incorporate a clerestory to allow abundant natural light (see **Figure 6**). These features create a feeling of openness and minimize "confinement" issues. Other notable building design features include a dual-purpose chapel, which could be converted to a computer-learning center; large food services facility with kitchen; and space for dining, laundry and bathroom with shower facilities that are ADA compliance and made of durable materials. To facilitate rapid and sustainable construction, the multipurpose facility was designed using a tilt-up construction system, where the concrete panels were cast horizontally on the ground and are tilted up and secured in place using machinery with insulation applied prior to final interior finishing.[26]

Figure 6. Rendering of the (a) multi-purpose community facility (left), and (b) its internal view (right)

The group then turned their focus on the design of a small-scale residential building. With a focus on sustainable development with the highest durability, lower costs and maximum functionality, students planned to repurpose shipping containers for small-scale residential facilities (see **Figure 7Error! Reference source not found.**). These containers are inexpensive, easy to modify, and the steel shell makes them exceptionally durable. Shipping containers are typically 8 ft tall, with high-top containers up to 9 ft in height. The dimensions allow for the installation of a drop-down ceiling and recessed lighting that would make them

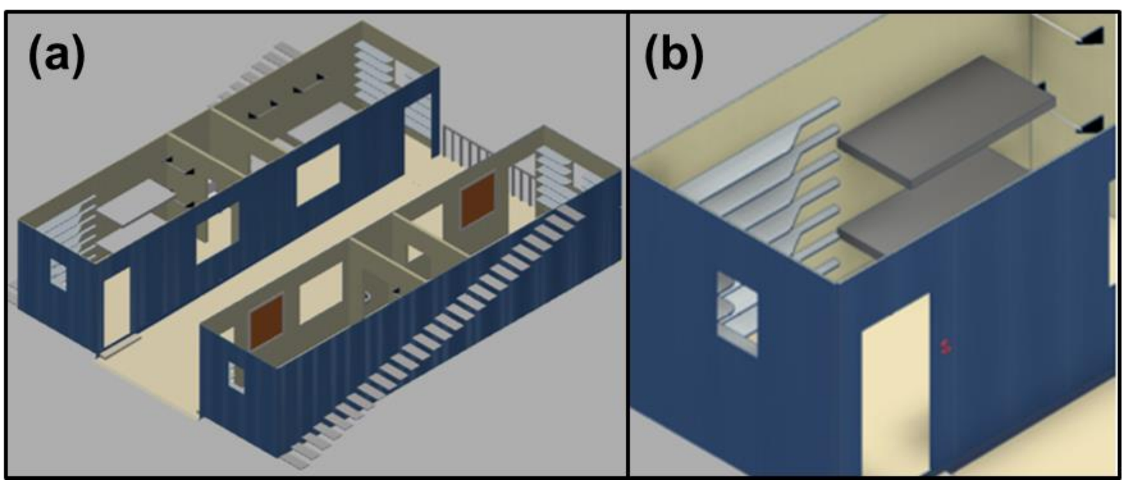

Figure 7. (a) Rendering of reclaimed shipping container as a residential facility, and (b) rendering of a single room within the facility

inaccessible to the residents. The increase in headspace would also create a feeling of openness and could minimize perceptions of confinement in the residents who are used to living open space. Students maximized the number of windows to increase the feeling of openness, allow natural light, and reduce energy demands. The shipping containers are large enough to accommodate ADA compliant doors, with fold-down or secured in place beds. A staircase along the longer edge of the container provides access to rooftop features. With adequate steel framework, the roof is strong enough to support small private gardens, storage crates, and more.

The next major design consideration was the development of transport and parking facilities to make the community accessible to not only for the residents, but also for emergency or law enforcement and garbage collection vehicles. The roadway, driveway, parking lot and other transport facilities were designed to meet as per the City of Amarillo, Texas Department of Transportation (TXDOT), and the American Association of State Highway and Transportation Officials (AASHTO) design specifications. A sidewalk was provided in the design of the community center to pedestrian traffic throughout the facility (see **Figure 8**Error! Reference source not found.**a**). These sidewalks are ADA compliant and traverse parking lot and residential area in addition to the community center. With a focus on sustainable design, the pavement was designed using porous asphalt. Permeable pavement has many advantages including reduction of contamination of runoff water, better recharging of ground water supplies, better storm water management, etc.[27, 28].

In the design of environmental systems, excessive water runoff is an issue most cities experience with an ever-increasing population. This excessive runoff can cause serious problems such as flooding, water pollution, and habitat degradation. The environmental focus of this group was the development of low-carbon footprint system that can improve stormwater management, implement, and promote sustainable

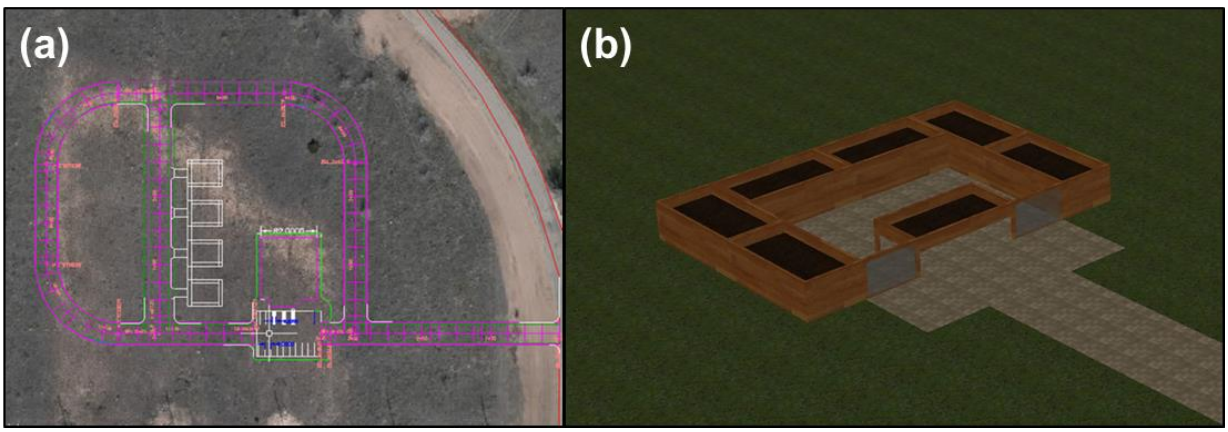

Figure 8. (a) Aerial rendering of roadway transport system, and (b) 3D rendering of community garden

engineering designs within the residential neighborhood. The students also looked at ways to improve the quality of life of the residents by providing garden areas for cultivating fruits and vegetables, and for acquiring new and marketable skills. Among the novel design concepts were the development of a rainwater harvesting system and repurposing the harvested rainwater for irrigation. The community garden design included raised beds for cultivation of food crops that are viable for the Texas Panhandle area (see **Figure 8b**). The students also carried out a soil quality analysis from the site to determine the optimum crops.

Course Assessment

We assessed the students' learning in the course according to common student learning outcomes (SLOs) used throughout our civil and environmental engineering programs. The SLOs come largely unchanged from current ABET Student Outcomes (2019-present). We assessed SLOs on a response form that given to faculty and engineering professional observers at a student project presentation. We provide a statistical summary of the forms in **Table 1**. The observers rated the students' ability to "recognize ethical professional responsibilities…make informed judgments…global, economic, environmental, and societal contexts" the highest with an overall score that was nearly universally at the "strongly attained" level (mean ± sd = 3.83 ± 0.41). They rated the student group lowest in communication abilities though the mean was still at the "attained" level or better.

The nature of the project, being a project of social good through poverty alleviation, provide an opportunity for students to present how their design addressed social and economic contexts. Moreover, students became aware of how engineers can use service projects in exploitive fashion towards the poor. Sometimes the poor being "served" are merely a means for engineers to experiment with design ideas rather than truly being the focus of beneficence[29, 30]. The student group was able to talk about this during their presentation, how they were using their designs to benefit others, which helped to communicate their awareness of the need for ethical conduct.

Table 1. Faculty and observer ratings for Fall 2019 senior design project group based on oral presentation performance. The scale used in the assessment is—0 not attained, 1-minimally attained, 2-somewhat attained, 3-attained, 4-strongly attained.

crit	description	count	mean	st dev
slo 1	Identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.	6	3.67	0.52
slo 2	Apply the engineering design process to produce solutions that meet specified needs with consideration for public health and safety, and global, cultural, social, environmental, economic, and other factors as appropriate to the discipline.	6	3.67	0.52
slo 3	Develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions.	6	3.67	0.52
slo 4	Communicate effectively with a range of audiences.	6	3.33	0.52
slo 4a	Communicate effectively orally	6	3.33	0.52
slo 4b	Communicate effectively in writing	4	3.25	0.50
slo 4c	Communicate effectively graphically	6	3.67	0.52
slo 5	Recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts.	6	3.83	0.41
slo 6	Recognize the ongoing need to acquire new knowledge, to choose appropriate learning strategies, and to apply this knowledge	6	3.67	0.52
slo 7	Function effectively as a member or leader of a team that establishes goals, plans tasks, meets deadlines, and creates a collaborative and inclusive environment.	5	3.80	0.45

Gathering Feedback from Students

In addition to outside faculty and professional observation for assessment, we wanted to examine students' direct feedback from their experience in this engineering service form of senior design. Students in the course only take one senior design course. They do not have multiple experiences by which to compare this one as different from others. Nonetheless, we find the direct feedback from students to help illustrate the impacts of this kind of project on their professional development.

Table 2 provides the Course/Instructor Evaluation Questionnaire (CIEQ) results for the spring 2020 senior design offering. There was only one respondent (out of six) in the Fall 2019 offering. We did not think it was representative enough to submit here.

Table 2. CIEQ results for the spring 2020 senior design offering. The scale used is 1-4 with 1 being "Strongly disagree" and 4 being "Strongly agree". The response rate was 30% (3/10).

No	Statement	Course Average (4.0)	Std. Dev.
1	**This course increased my knowledge of the field.**	**3.67**	0.62
2	**Course content was consistent with course objectives.**	**3.67**	0.57
3	**I would recommend this course to a friend.**	**3.67**	0.73

We also had direct data from students experiences through weekly memoranda that students were required to write. The in-course purpose of the memoranda was for students to reflect on what they did each week, what they learned, and what goals they set for subsequent weeks. Examining these memoranda (**Table 3**) over the semester illuminates student experiences.

Going through the timeline (weeks 1 through 15), themes do emerge. In weeks 1-3, the beginning of the project period, students visited the temporary homeless camp. That camp could never become a permanent location due to poor road access and its presence in a FEMA floodplain. However, visiting the camp with actual residents and community present helped students to understand better the challenge of designing a neighborhood for those coming out of homelessness. Most of the time there they spent with just a few of the residents and the CCC director. The students heard from residents concerning how the residents' homelessness comes from life events that can send them towards urban poverty. None of the students felt like the homelessness was "deserved" or an individual's story of homeless was simple. As well, many students commented on the energy and drive of the CCC director. They got to hear how she had taken an organically organized and dangerous homeless camp and made it something, which was safe and respectable.

Table 3. Direct quotations from three students in Fall 2019 that illustrate their experience in time. Authors took quotations from weekly progress memos. Each student has been anonymized with a simple random number.

Weeks	S61	S99	S95
1-3	Last week, the groups visited the Christ's Church Camp to obtain more information about the overall project…to explore the site and experience the life of Christ's Church Camp. ***After hearing their stories, I learned that life can be changed in unexpected ways.***	Visiting the camp aided us in that aspect; getting personally involved triggered emotion and realization that what we have been challenged to do this semester has a real purpose. Seeing the actual camp and getting to know all the individuals was <u>truly a learning experience.</u> [CCC director's] passion to help others is quite inspiring…sincerely loves what she does.	… we had the chance to meet with [CCC director]. <u>She talked about some of the hardships that she has faced</u> while setting up the camp as well as hardships they are currently facing. We also walked around the camp to get an idea of how we might implement some of the things that they currently have in their current camp….
4-6	The problem that I am having right now is not being able to obtain the elevation data with applying the Geographic Information System accurately. For this problem, *<u>I plan to learn</u>* how to obtain accurately by watching the tutorial video.	The group is using "GroupMe" as an immediate medium of communication. I try to remain updated on team activities and to update the team on information. Realistically, I feel like we need to gather and really sit down, discuss, and make our own deadlines to accomplish tasks/goals.	Over the last few weeks I haven't really been able to fully start on working on a specific part of the project. I have researched general ideas that help, but ***<u>I don't really know where to start</u>*** in getting into specifics.
7-10	…had been working on the laboratory reports for sieve analysis, liquid limit, and plastic limit...**I noticed that it is important to analyze the data accurately** because these results will be shared with the structural engineering, water resources engineering, and transportation engineering lead…	I had the opportunity to hear about homelessness directly from [social work faculty] and [City of Amarillo social work staff member], who face/deal with homelessness on a day to day basis. ***The presentation was a reminder of why it is so important to move the project forward and attempt to deliver the highest quality work*** all around...	There seems to be **<u>a recurring problem with the group</u>** that happens when we have a deadline for something. We can't seem to all be able to meet until just a few days before the deadline...everyone just starts to work on something without really knowing if it is a priority…

11-15	Last week, I did not do much…***because I had been admitted to a hospital***. However, I was reading "The Panhandle Residential Foundation Manual" to obtain more information on the city of Amarillo Municipal Code and understand an approvable foundation systems within the city limits of the City of Amarillo, Texas…	The only challenge I'm facing is not knowing where my design team is individually. We're each focused in the area of engineering we are leading…I'm hoping it's a good thing, **assuming that means each area of engineering is coming to a successful conclusion**…	At the beginning of the semester I honestly felt very overwhelmed and there were many points during the semester where I felt that I was not going to be able to finish. <u>You pushed the group, but I believe we were able to design something great because of that.</u>

The middle period of the record, weeks 4-6 and 7-10, students discussed things that they realized about themselves, their group, or engineering design generally. Some discussed why the data that they were working on mattered to their analysis or to others in the group. Most directly or indirectly discussed the need to teach themselves something that they did know well enough (a reference to SLO 6 in **Table 1**). Most students recognized that group communication and organization (SLO 7) was a problem. Even though nearly all of them mentioned this in the middle weeks of work, there is no discussion of them directly confronting the problem and addressing it.

The last several weeks of the term (11-15), the students were busy making final presentations which including both a poster presentation night (two posters addressing different aspects of the design) and a final live presentation to an audience of about 12-15. The students sensed their work was ending. They were glad they did the work, and they felt that it mattered. At the same time, many were unsure how the project would continue and especially if the CCC would ever use their design to build a real neighborhood. They felt that they may have served the homeless in some way, but it was not entirely clear how until construction could occur.

Going through weeks 1 to 14 with the second batch of students (**Table 4**), it felt like a roller-coaster ride going from an initial bewilderment of the magnanimity of the project, to getting the basics of the work done. The primary reason for this bewilderment was the fact that the students have not experienced working on such a project and that too with a significant socio-economic component. Initial comments illustrate this fact through statements like "there aren't any other classes like it" that the students had. After discussion with the manager overseeing the homeless shelter, students started assimilating information by delegating tasks to individual subgroups. At which point, the students started getting overwhelmed with "lots of data to analyze" and each subgroup started working independently as can be seen in the case of pavement design.

From week, 4-6 the students started working on miniature design tasks like "2D layout of the main facility," etc. and started collected samples for experimental analysis that they determined would be major milestones during this project.

By week 7-10, students have multiple ideas as to how to carry the project forward and are prepared to proceed after having completed some initial design tasks. The SARS-CoV-2 pandemic now created additional hurdles and students quickly figured out the best means of communication during these tough times. During this time, they started forming clear ideas as to how they could complete the project, though they still had more learning to do. Finally, during week 11-14, they started reaching out to companies having expertise in novel sustainable construction or visiting sites that have low carbon footprint designs. The students completed the bulk of the work completed during this time and as can be seen from the comments this was a "long and very bumpy journey," that they had. Of specific significance is the fact that the students had trouble in finding low-carbon footprint guidelines from the City of Amarillo or elsewhere.

Table 4. Direct quotations from three students in Spring 2020 that illustrate their experience in time. Authors took quotations from weekly progress memos. Each student has been anonymized with a simple random number.

Weeks	S74	S76	S70
1-3	The trouble coming into this course, is ***there aren't any other classes like it***, and it's difficult to figure out the direction and steps to take.	There is a ***lot of data to analyze***, but there is also a lot of questions we need to ask before some parts of design can begin.	For the main road traditional concrete seems to be the best option taking in consideration there will be more traffic and big trucks will be using the main road, therefore a stronger pavement would be more efficient.
4-6	This week we ***designed a 2D layout of the main facility*** based on function. A rough sketch of it was made….. - Found some videos about tilt up construction and learned a little about the process.	With our newly found documents of the landowner's approval, I ***went to the property Monday morning and collected three 5-gallon buckets of soil to begin geotechnical testing***. I feel we are still on schedule despite the length of time it took to find the information we needed.	the group believed the main road and the parking lot should be redesign, which I agree to some extent therefore I am ***waiting for a layout of the main building to be able to adjust the main road and the parking lot***
7-10	- Everything's ***in chaos trying to figure out the online classes***. - I continued the tilt up examples building them into a spreadsheet to alter numbers to apply to our project.	Here are the ***topics I plan to discuss***……: • Community center layout- • Use of concrete walls- So far, the plan is to use reinforced tilt-up concrete walls. We are starting to put a lot of work into structural engineering with tilt-up walls…. • Tiny homes- There hasn't been a lot of work on designing the small homes yet …..	the group gave me the location for the Community Center complex, and I worked on the road dimensions and design….. ***I took a couple of days just learning how to design a road*** and how to get those alignments. …
11-14	…calling the girder ***company today to find what girder or information is needed*** to best suit our project. We can make sure the girder will hold the factored load of the roof and add the girder weight into the load on the wall.	…was a ***long and very bumpy journey*** from the beginning of the semester. The whole time I had this thought in the back of my head: "Are we even on the right track?" Senior design is very much baptismal by fire. You say, ***"I've given you the tools, now go build something with them."*** But as anyone who has pursued this education knows, having the tools and knowing how to use them are wildly different concepts. So we start hammering in the dark until eventually we hit a nail, something to let us know that we're on the right track. Then ideas start bouncing around and building and growing exponentially. The next thing I know, our final report is FINISHED. It's amazing really, to look back at myself at the beginning of the semester and see how much of my engineering knowledge I've learned to put to practical use.	… I had done some research on the permeable pavement, but I really did not believe permeable pavement would be so hard to research and put together, I was ***not able to find anything specifically for the City of Amarillo regarding permeable pavement*** but was able to find some credible sources in order to find the thickness and design for the parking lot.

Conclusions and Recommendations

Conclusions

- Two different groups of students worked on the design of neighborhood that a non-profit organization might use as a tool to address the root causes of homelessness.
- Students learned through guidance of more than just faculty. They learned to design via the guidance of their client, Christ Church Camp, direct interactions with the homeless, social work professionals, and professional engineers who volunteered time to help.
- Students were able to become better engineers through a real project that had a clear beneficiary. Through the process, they understood that many problems are not solved entirely by an engineering solution by require some understanding of social work, economics, and urban communities.
- Faculty observed direct evidence in student reflections of a growth in compassion and a broader understanding of what engineering projects can do for community social dynamics.
- Students demonstrated a consistent effort in adapting to use various tools necessary especially during the pandemic.
- Students became aware of challenges in engineering design and its importance in overcoming or mitigating the psychological challenges of the homeless.
- Faculty observed that students showed considerable interest in incorporating sustainable development principles in their engineering design. Emphasis on sustainability and low carbon footprint was the highlight of all the engineering design iterations and the students have demonstrated considerable success in realizing this goal.

Recommendations

- The knowledge of how or if the neighborhood development project would ever be funded and lead to construction created some anxiety for both students and faculty. It would have been better to understand fully the nature of the non-profit's financing and workflow before committing so many hours of volunteer engineering services.
- Students involved in SL design projects need continued education both in the form of the social science background that they do not have and practical guidance on project management and team cohesion. We found that they were lacking in both areas and needed a great deal of guidance on both the social background and the practical skills of engineering project scoping and team synergy.
- If faculty want to measure civic-mindedness, compassion, empathy, and increased ethical proficiency in students, then they need to design more strategies to measure these gains in students beyond simple memos or reflections. In our experience, students did provide insight into these areas of character and personal growth. However, technical communications are wjat students know best, and so they speak most easily in those terms. They might feel like expressing their personal growth through service is superfluous and that is it is better to "stick to the hard facts". Thus, faculty who want to use SL to document increases of compassion in students will need additional means beyond what is normally done for grading and course assessment.
- Our observations were that the use of SL did enhance students' learning experience and their civic mindedness. However, we suggest that others conduct more research beyond what we have done to better establish how growth in engineering proficiency and in civic mindedness can be mutually enhanced through SL senior design projects.
- It was difficult to incorporate sustainability principles in the design process and the students had to resort to alternate means to understand these principles and incorporate them. Faculty felt that students should be made aware of such practices earlier in their studies, to be able to better appreciate sustainable design considerations.

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