Assessment of a Global Engineering Outreach Course

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Introduction.

Since the establishment of Engineers Without Borders in 2002[1], opportunities for students at higher learning institutions to participate in global development projects has been enhanced. In 2007, a multi-disciplinary course for engineering and technology students was established at Brigham Young University where students could work on global problems, researching not only technical but economic and socio-cultural issues. The two-semester Global Engineering Outreach (GEO) course has involved students who were selected following an application process that included an interview.

Each year, the GEO course involves 20-30 students selected from all engineering programs (chemical, electrical/computer, civil, and mechanical) as well as several technology programs. Teams are comprised of 4-5 students that work on projects that are identified by the communities in which the students implement the projects. Projects have been implemented in Tonga, Ghana, and Peru with over 200 students participating over the years. Communities within Peru have been the focus since 2009. The course is designed to give students a real-world design experience in a global setting on a scale commensurate with a 3-credit hour course. Thus, students learn that out in the real world, boundaries between engineering disciplines fade and all engineers at the simplest level are problem solvers, each contributing a unique viewpoint or technical background to solve the problem at hand.

With more than 60% of the students at the university fluent in a foreign language, many students in the course speak Spanish−providing a unique opportunity for students to interact with the communities during the two-semester course. Throughout the course, student teams are required to contact community members on a near-weekly basis to involve community members in the design process. Extensive documentation regarding project management, communication, technical and social constraints, concept generation and prototype development and testing is required throughout the course[2]. Following the course, students participate in a two-week trip where students interact with the community and implement the project, participate in cultural experiences, and identify projects for the following year. Following the trip, additional documentation similar to items noted above is required, as well as an executive summary, short video, reflections paper, and survey.

Previous publications related to the course have discussed training internationally responsible engineers[3], sustainability and impact[4], integration of sociology and engineering using key principles of human-centered design[5], GEO course insights[6], social connectivity between students and communities[7], the documentation strategy[2], and water filter implementation in Southern Peru[8]. Some of these publications have addressed various aspects of the student learning outcomes which are:

1. Problem Solving – Students gain experience in the design process that includes innovative problem solving skills applied to the design and implementation of global projects in developing regions of the world in the context of real needs, constraints, and opportunities.

2. Global Engineering – Students demonstrate an appreciation for global aspects of engineering, including social and technical constraints related to design and the importance of sustainability.
3. Teamwork and Leadership – Students demonstrate effective teamwork and leadership skills and an appreciation for other disciplines both within and outside of engineering as they work together on interdisciplinary teams.
4. Communication – Students demonstrate effective oral and written communication skills in the reporting of work, particularly to entities or individuals in countries in which projects are implemented.
5. Social Innovation – Students gain experience in how to be involved in developing and implementing solutions to societal needs as they progress through their careers.

At the end of each semester and following the trip, a survey is administered to each student to elicit their insights on communication, documentation, project development, teamwork, and cultural awareness and preparation. This paper summarizes key findings from the surveys, documentation, and reflections papers to address: a) What cultural resources were used by students to obtain community-centric and project-centric information? b) What cultural information was obtained and how useful was this information for the project design and understanding the community? and c) How were students impacted by the Learning Outcomes? A brief discussion of future plans for strengthening the GEO course will also be presented.

Surveys, Documentation, and Reflection Papers.

Surveys were developed in collaboration with faculty and students in the Department of Sociology at Brigham Young University. The surveys were administered using the Qualtrics software and included free-response questions, multiple-choice questions, rank order questions, yes/no questions, questions requiring percentile responses, and Likert-scale rating questions. Surveys were typically administered in December, April, and June and were part of the grade to elicit near 100% responses. Since each team had some students that spoke fluent Spanish and interacted with the communities throughout the course, some questions were only geared to those that spoke Spanish.

All documentation and videos from past and current projects are stored on a secure server at Brigham Young University. Details of the required documentation were previously described.[2] Access to the server is given to course instructors and students taking the current course. The use of videos eliminates an expensive aspect of having students travel to a location prior to project development. It should be noted that the final documentation following the implementation trip typically covers 80-100 pages which provides a very extensive coverage of the project. Videos for each team are typically several hours long.

Reflection papers, usually one page and single spaced, provided insights regarding students' experience during the course and implementation trip. Students address items such as a) how the course contributed to his/her education in a way that other courses have not, b) cultural experiences, c) insights on working in a global environment, d) challenges, and e) personal growth. The required reflection papers follow a free-response format.

Results.

a) Cultural Resources.

There are several cultural preparation activities that are imbedded throughout the course. These include required communication with community members, availability of past reports, viewing a subset of past videos, instruction by a sociology faculty member on community engagement and assessment, interaction with sociology students during design reviews, and integration of social constraints in the design process. Students also interact extensively with instructors and past GEO students regarding various cultural aspects of the communities.

During the first survey administered in December, students are asked how often their team seeks information about the people in the community and from what resource (both local and global sources). This question provides insights into what resources students are relying on the most to gather cultural information. Students can select a response from "Never or rarely," "Once a month," and "A few times a month or more" regarding how often they seek the resource for information. Figure 1 shows the percentage of students that selected either "A few times a month or more" or "once a month" (the December survey was not administered during 2015-16).

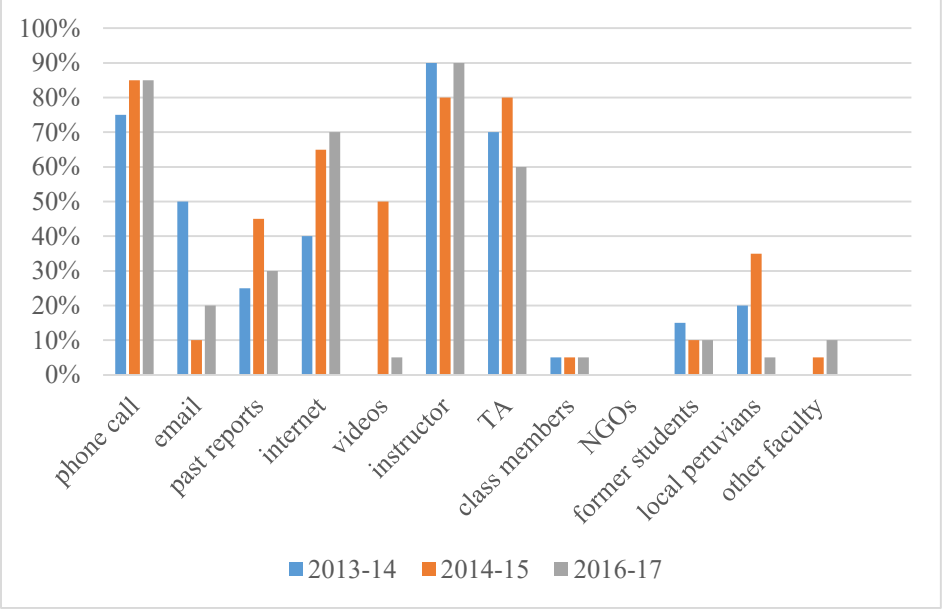

Figure 1. Resource utilization for learning about people in the community. Percent refers to how many students accessed these resources "once a month" or "a few times a month or more".

It is clear that most students relied extensively on the instructor and TA for information since the instructor and TA had previously traveled to the communities and had a wealth of information. Students also relied heavily on the internet although this result demonstrates the importance of talking to students about the quality of internet resources. It is also likely that these resources, which were predominantly accessed "a few times a month or more," are used the most since students regularly interact with the instructor and TA as well as search the internet during the

twice-a-week class. Resources such as past reports, videos, email, and former students were also used but not as often. Most of these latter resources were accessed on the "once a month" basis. Clearly, the use of videos, past reports, and former students can be strengthened. Utilization of these resources is currently not a strong component of the required course curriculum.

It is notable that students also relied extensively on phone calls to the communities, which is the most accurate resource, since students are encouraged to talk on a weekly basis with the communities. All communication is documented by the students and includes the contact date, the extent of the call (no answer, answer but short conversation, ….), and a summary of what was learned. Peruvians within the impacted communities are clearly an important cultural resource for cultural preparation and project development. Thus, regular communication with the communities is critical. As shown in Figure 1, the majority of Spanish-speaking students made phone calls at least once a month or more than once a month. However, making calls was quite a bit more difficult than the students generally expected. Figure 2 shows the results of phone calls made to Peru during the Fall 2016 semester.

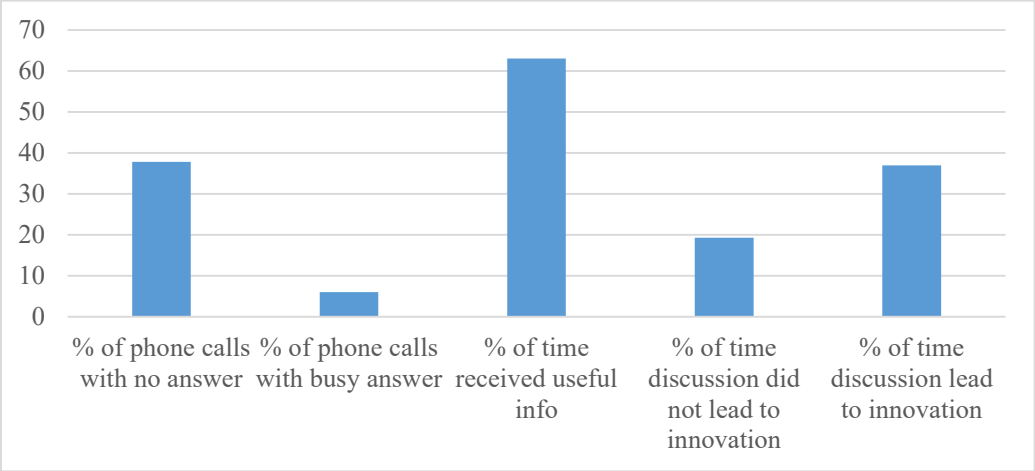

Figure 2. Effectiveness of phone contact with Peruvian communities.

As shown, nearly 40% of phone calls to Peru were not answered. This meant that students either had to call more often or wait longer to receive feedback on ideas and questions. This was very frustrating at times. Once the students were able to get hold of their Peruvian communities, they generally found the interaction to be very useful. Students felt that they received useful information for their projects nearly 65% of the time once they made contact. And while almost 20% of conversations did not end in innovative ideas, nearly 40% of conversations did end with innovative ideas that could be implemented into the project. Generally, following feedback from the communities throughout the 8-month project development, the projects were finalized by the time the students traveled to Peru. Thus, very little project variation occurred during the implementation trip.

Excerpts from student comments regarding communication provides some insights on intermittent communication problems, appreciation for the interactions, and the need for communication:

> Throughout the semester we stayed in frequent contact with N_ and intermittent contact with G_, our Peruvian contacts. We contacted N_ by phone and by email on a bi-weekly basis since he is the Peruvian contact for another team as well…Our contact with G_ was less effective. While he failed to respond to our efforts to contact him fall semester, he was much more responsive during winter semester.
>
> When people from the community are at the center, both for communication as well as implementation, the project becomes exponentially more sustainable and reliable. The key is to involve as many people as possible and recognize the people, their community, and any other particular circumstances.
>
> Often, communication was quite difficult. It was good for me to have to understand something well enough to explain it to others who have a different field of study than I do, and beyond that, to people in a different language. I was forced to take concepts that I now see as basic and intuitive (such as thermodynamics, structures, and fluid dynamics) and explain them in a way that makes sense to someone who hasn't studied it. (2016-17)

Survey data from 2015-16 and 2016-17 addressed several aspects of communication related to understanding cultural aspects of the communities where projects were to be implemented. On a scale of 1 (strongly disagree) to 5 (strongly agree), Figure 3 shows that most students agreed or strongly agreed that they were able to effectively find out about the culture of the communities during their calls. Most students also agreed that they knew what to ask about the culture and project design, they felt comfortable getting feedback, and they felt that the feedback was useful. As they progressed through the academic year, students also showed increased levels of confidence in their capacity for communication, as seen in the difference between December and April 2016-17 survey responses.

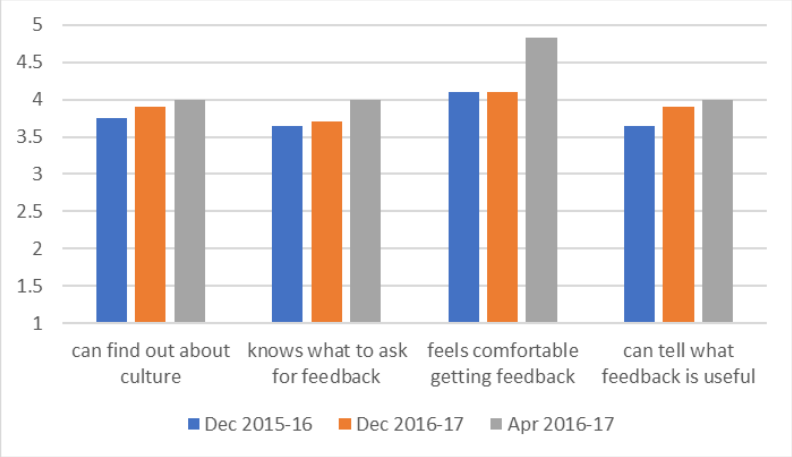

Figure 3. Student capacity for communication with contacts in Peru.

Written comments by students provided useful insights about student perceptions of the process of identifying community needs and characteristics from the available resources. Although the GEO course was the first time that most of the students had learned about conducting social

impact and needs assessments, many students commented on the value of having information about the social and cultural contexts of the projects, as noted in the following examples.

> It helped me reflect on what the real needs of the people in Peru are. For me it is very beneficial to take a little bit of time to reflect and think about people. It is important to try and understand their points of view. (2016-17)
>
> [Assignments] allowed us to understand the importance of doing what the Peruvian people want instead of doing what works best scientifically. Even if the project is effective and efficient, if the Peruvian's don't like it then they won't use it. (2015-16)
>
> I learned a lot about creating the right setting to receive feedback…I see this as a very important lesson in working with people from other cultures. (2016-17)
>
> I also realized just how important the sociological factor is to the success of an international project. No one from the islands [except the family on the island we were demonstrating] showed up on the day that we were demonstrating how our washing machine worked. That was really disappointing for us… I think communication is important. Not only between us and a single contact, but with more of the community. I understand that it is difficult to achieve at the scale we were working with and this experience still taught us a lot as students. (2016-17)

Increasing the ability for students to communicate with the Peruvian communities has been a focus of the course instructors for several years. Communication resources continue to improve. However, the fact remains that small towns often have bad phone service, people change jobs, and phone numbers change. Thus, communication can be difficult even in the best of circumstances. Encouraging the students to call their Peruvian contacts several times a week, instead of just once, has been imperative for increasing communication. However, the course-required communication logs have only been due every six weeks, allowing the students to put off a majority of their phone calls until the end of that time period. This results in a mad scramble to call more often in the last week or two in order to have something in the communication logs. With this in mind, there are plans to change the curriculum in the coming years so that the communication log is due every week. This will encourage the students to have better, more consistent contact with their Peruvian contacts. Students also have the ability to email and send Facebook messages to Peru (texts sent to the US cost the Peruvians money, so that has not been an option). Unfortunately, email and Facebook are still not widely available on a daily basis. Most rural Peruvians only check these resources once or twice a week at internet cafes, so phone calls remain the most reliable option.

In summary, cultural resources are important for project development. Establishing relationships and building trust enables students to obtain valuable feedback. Improving communication efforts and placing more emphasis on past reports, videos, and interacting with former GEO students can provide greater opportunities for students to receive valuable feedback towards developing sustainable projects.

b) Cultural Information and Usefulness

Although many resources were provided for the students to gather cultural information for the project design and implementation trip, it was important to look at the type of information that was being gathered as well as its usefulness. The December survey, which was the half-way point of the course, assessed how much information students had about various cultural aspects of the communities during the initial phases of the design process. Students could select a response (none, little, some, reasonable, adequate) about how much information they had related to several aspects of the project and community. Figure 4 shows the percentage of students that selected either "reasonable" or "adequate" on how much information they perceived they had. It should be noted that the survey was not administered during 2015-16.

It is clear that students felt that they had a high percentage of information about project-centric attributes (technical specs, safety, project attributes, and project benefits). This is consistent with an engineering curriculum where students are much more understanding of technical characteristics. However, Figure 4 shows that while many students in 2014-15 did not have much information on community-centric attributes, such as gender norms, lifestyle, family practices, traditions, and community institutions, in 2016-17 students reported having more information in these areas. This could possibly be a result of implementing videos and extensive reports into the curriculum after the 2014-15 year. In general, even though students are calling the communities on a regular basis (Figure 1), students are still not obtaining as much information on community-centric attributes in comparison to project-centric attributes. Therefore, it may be beneficial to emphasize community-centric aspects in more well-defined videos with a requirement that students review the videos and document what they learned. Also, additional training in communication may help students obtain more useful information during phone calls. Another interesting aspect of Figure 4 is that information related to project safety and maintenance could still be improved. These attributes are hard to glean from videos and it may be difficult to address these more technical aspects with community members during phone calls. However, more emphasis on safety and maintenance and how to address these issues with community members would be beneficial.

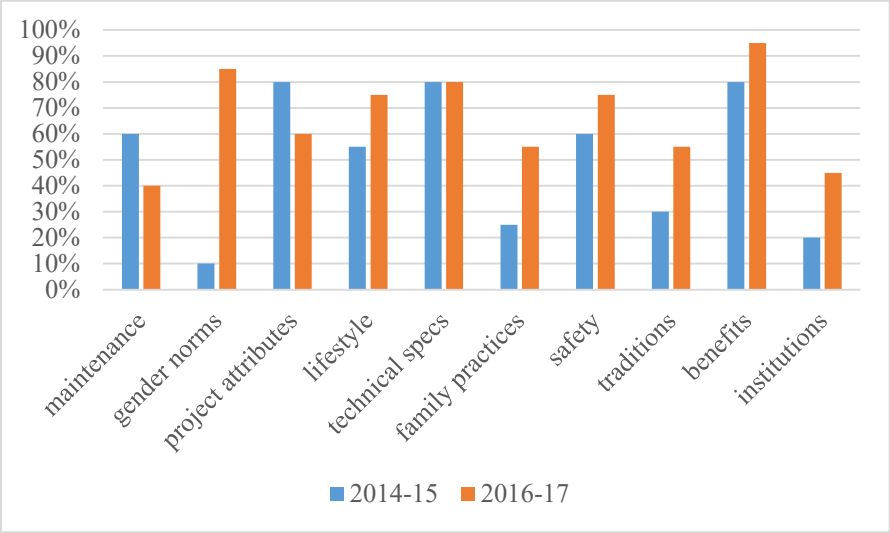

Figure 4. Cultural understanding of the community. Percent refers to how many students selected "reasonable" or "adequate" regarding how much information they had about each cultural aspect.

New questions included in the April 2017 pre-trip survey sought to assess the relative usefulness of the information gathered (both project-centric and community-centric) in relation to how much information was obtained. For example, Figure 5 shows that students felt that they had extensive project-centric information (maintenance, physical attributes of project users, technical specifications, safety, and project history) and also shows that students felt that they had more information in these areas than was useful. In contrast, as shown in Figure 6, although students indicated they had far less information about community-centric information (such as leisure activities, employment, household/family tasks, childcare, and decision-making), they felt that this information was nearly as useful as the project-centric information.

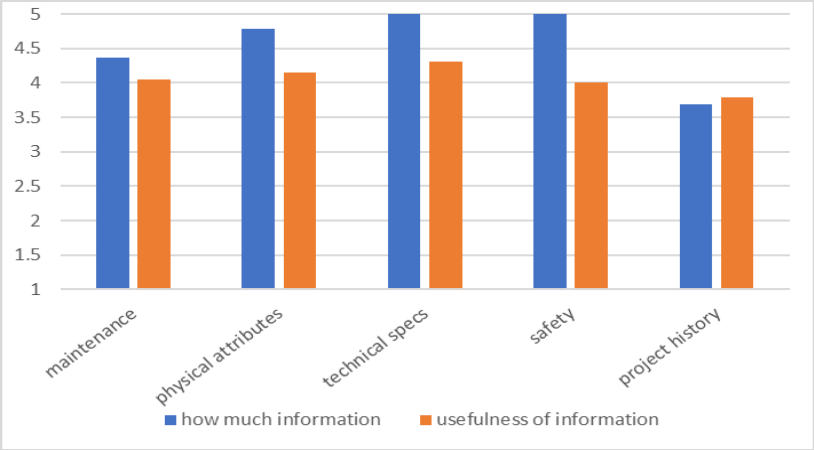

Figure 5. Usefulness of project-centric information, April 2016-17

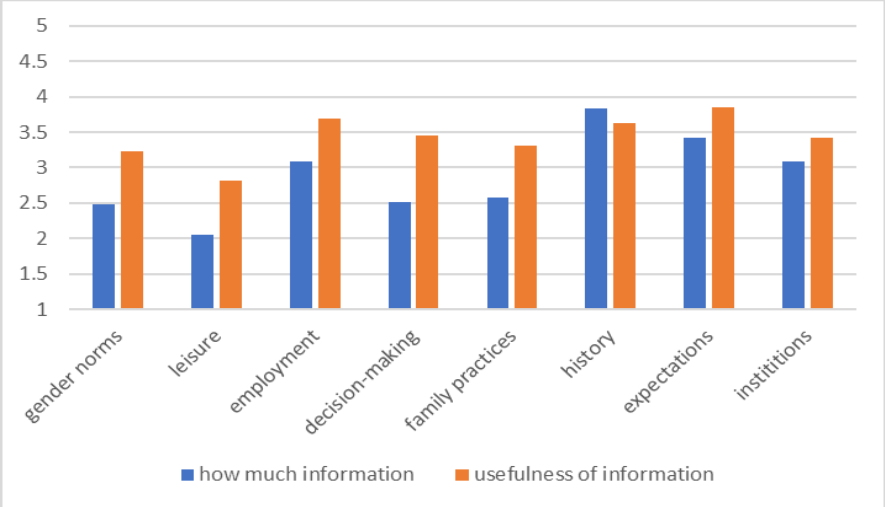

Figure 6. Usefulness of community-centric information, April 2016-17

From another viewpoint, the December pre-trip surveys provided details about what percentage students considered each of the community-centric and project-centric areas in working on their projects. Student responses to these questions are shown in Figure 7. In both years in which data were collected, students reported the greatest consideration of project-centric information in comparison to community-centric information.

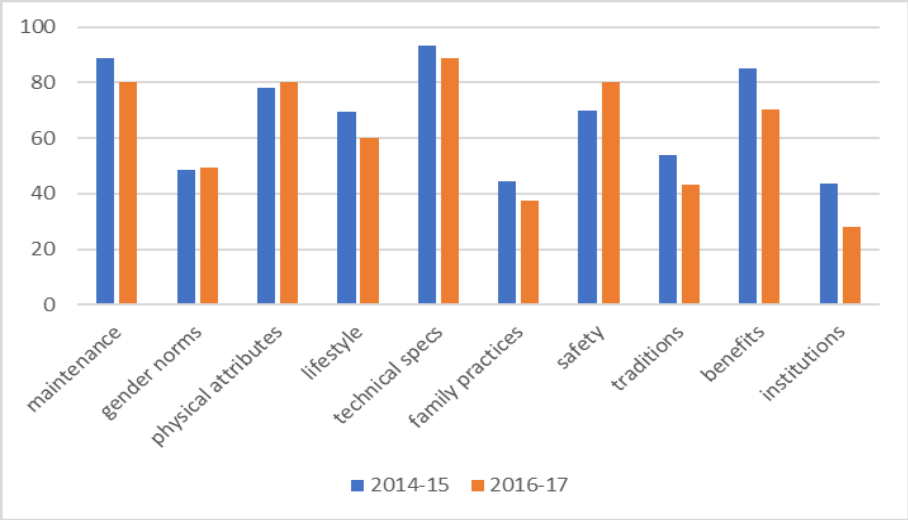

Figure 7. Consideration of project and community information.

In post-trip reports, students reflected on the value of their efforts to learn about community-centric attributes.

> I wish we had understood both the community and the project better (2016-17).
>
> We were so limited on initial knowledge that we had to do a ton of research to get a good background into what we were doing. (2015-16)
>
> The greatest challenge was in collecting information. We had to dig deep by watching all of the videos, study last year's report and talk to last year's team. (2015-16)

In summary, the data from Figures 5-7 showed that students had a great amount of project-centric information. Although students considered this information for the project design and they felt that it was useful, they felt that they had more information than they needed. On the other hand, students didn't have as much community-centric information. While they felt it was just as useful as the project-centric information, they didn't consider the information as much for the project design. It is likely that this decreased consideration was due to the lack of information. Thus, a greater focus on obtaining more community-centric information could help students implement more of these aspects into the design process.

c) Learning outcomes.

As stated in the introduction, learning outcomes for the course involved problem solving, global engineering, teamwork and leadership, communication, and social innovation. Communication aspects were previously discussed. In the April survey following both semesters, students rated themselves according to various aspects associated with the learning outcomes. The ratings ranged from 1-8 with 1 being "strongly disagree" and 8 being "strongly agree." Figure 8 shows the percentage of students selecting a particular response. The first two aspects relate to problem solving. Nearly 80% of students felt they contributed to ideas. Similarly, over 90% of students were confident in problem solving.

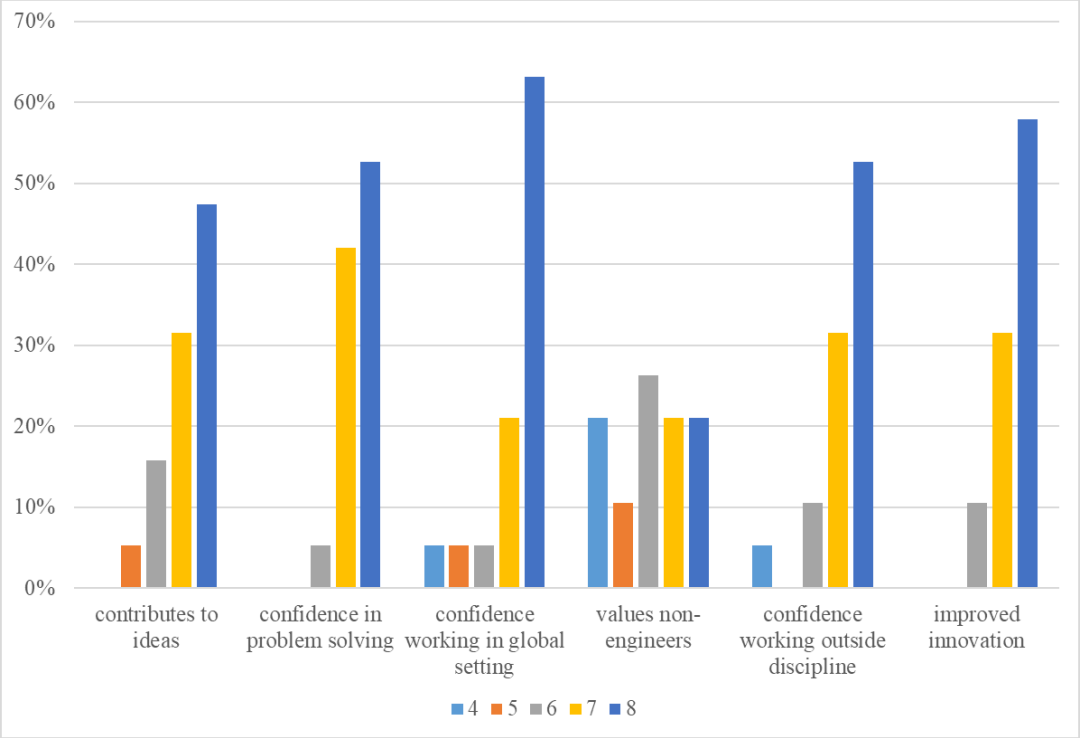

Figure 8. Assessment of various aspects associated with learning outcomes. The percentage of students selecting ratings from 1-8 are shown with 1 being "strongly disagree" and 8 being "strongly agree".

Examples of student comments related to problem-solving included:

> One of the other ways that this course has contributed to my education is that it provided me with opportunities to explore new problems and find creative solutions to problems that don't already have a clear defined answer in the back of the book. (2016-17)

> This class was very empowering; I realized that I can solve problems, that I can do something new; that I can create. (2016-17)

The third aspect in Figure 8 relates to global engineering where 84% of students felt confident in working in a global setting. In general, many students in the course experienced the incorporation of social constraints in the design process for the first time in the curriculum. One student summarized the global experience by stating:

> Another aspect of this class that I haven't experienced before was working with real people to deliver a usable product. The social constraints involved were something we don't deal with in classes very often. Working with non-engineering clients meant we had to be more creative about the questions we asked to determine the constraints for the project, we also had to take into account social aspects like height and strength of the people that would be using the product. (2016-17)

Data from new questions in the student survey following the 2017 implementation trip provided insights into students' perceptions of their eight-month preparation for working in a global setting. For example, when asked how much of their understanding of the needs and interests of communities they had acquired *prior* to the trip, students estimated on average a little more than 60%. However, their understanding increased following the implementation trip as 84% of students believed that their interactions with the community in Peru while on the implementation trip helped them understand more about the interests and needs of the communities. It should be noted that all students in the course participated in the implementation trip so it was not possible to assess a difference in global understanding between students that traveled and students that did not travel. Rather, the survey assessed global understanding prior to and following the trip. The majority (80%) of students reported that after demonstrating their project to the communities, they believed the project met the needs of the communities and fit the social and cultural context.

Participating in the trip provided some insights that may have been hard to experience without this type of first-hand experience. Examples of student comments included:

> It was difficult for me to understand initially why people would say they would show up at certain times or with certain things, and then wouldn't. It helped me learn patience and understanding that they see time differently than our culture does. (2016-17)

> It was hard to know what people really meant when they responded the exact way you wanted them to, etc. It was also challenging to really connect with some of the people we were working with because our lives are simply so different, but it was also one of my favorite parts. (2016-17)

> My favorite part was going to [the community] and seeing and learning what the community was really like. It helped increase my understanding of how the project could have been better implemented and how communication could have improved. (2016-17)

For other students, not being proficient in Spanish was an obstacle to having the types of interactions with community members needed to learn about cultural practices and community life.

Teamwork is also an essential part of the GEO class. Students work in teams throughout the entire course and their teamwork abilities certainly improved from this experience. Experts differ

on what constitutes good attributes for team members[9,10,11], and hundreds of characteristics and skills could be listed, but generally individual team members should have many of the following attributes such as good communication, reliability, ability to compromise, cross-functional problem solving, initiative, empathy, flexibility in job assignments, positive attitude, and appreciation of others' skills. The fourth and fifth aspects shown in Figure 8 relate to teamwork, particularly associated with interdisciplinary teams. Interestingly, students did not strongly value non-engineers. Several times throughout the course, sociology students interacted with the student teams. Also, one or more sociology student participated in the implementation trip. This low rate for valuing non-engineers is an area that should be strengthened. On another note, over 80% of the students felt confident in working on projects outside of their discipline.

In the April 2017 survey following both semesters, students assessed themselves according to various aspects associated with teamwork. The ratings ranged from 1-8 with 1 being "strongly disagree" and 8 being "strongly agree." The statements the students used to rate themselves in the survey were similar to the teamwork characteristics listed above. For example, the question associated with positive attitude was "I am pleasant to work with and I encourage my team members." Figure 9 shows the percentage of students selecting a particular response.

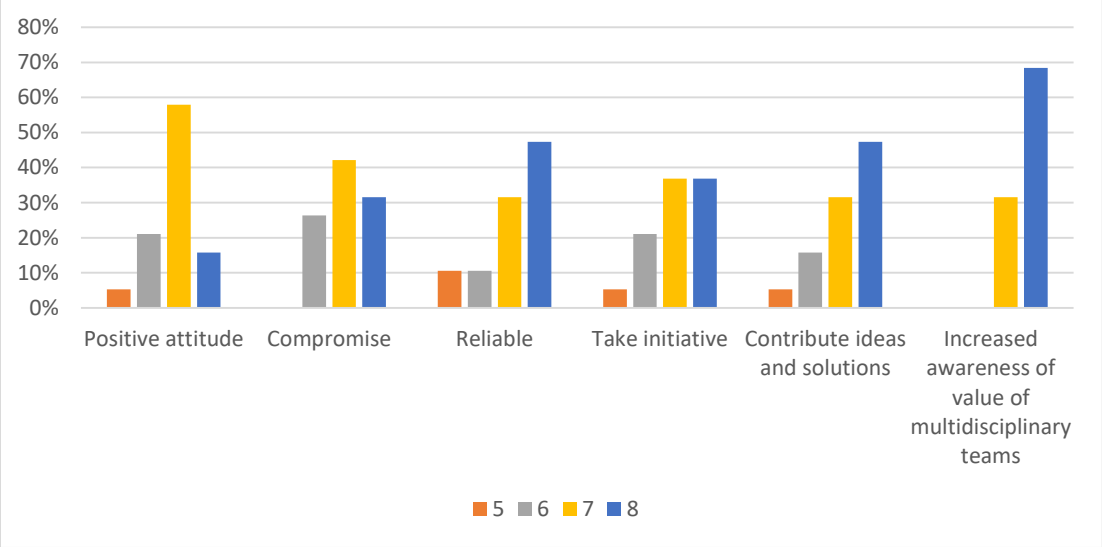

Figure 9. Assessment of teamwork attributes. The percentage of students selecting ratings from 1-8 with 1 being "strongly disagree" and 8 being "strongly agree" are shown for teamwork attributes.

Based on cumulative responses for ratings of 7 and 8, approximately 75% of students felt they were pleasant to work with and encouraging to others—an attribute of a positive attitude. Similarly, when it comes to compromise, nearly 75% of students felt they were good at listening to others' ideas. Almost 80% of students felt they were reliable team members and that they contributed to project solutions. Finally, 100% of students felt they had an increased understanding and awareness of the value of multidisciplinary teams.

Students certainly felt that the GEO course had helped them understand teamwork better and that they had developed positive characteristics which contributed to their projects. Reflection papers also showed the students' favorable views on learning about teamwork in the class. Examples of student comments include:

> I learned so much about engineering, innovating and team building in this class. One thing that I did not expect to learn was confidence. The entire experience, from August to May, helped me build confidence in my engineering skills, my social skills (with my team), and even my language skills. I feel better prepared to enter the chemical engineering field. (2016-17)

> Being on a team with my fellow GEO members helped me understand that we all have a responsibility and it requires a lot of effort…I was able to learn critical skills such as leadership, self-reliance, communication, organization. It is funny, because I never thought that these skills would be critical as an engineer, but it was so important.

Finally, the last aspect shown in Figure 8 relates to innovation: 90% of the students felt that their abilities to be innovative improved. Many students shared their excitement about interacting with the communities and desired to continue involvement in humanitarian-related service. One student had the opportunity to return one year later. The student stated that:

> The most rewarding part of the trip for me was to go back to the Uros Islands where we implemented the pumps last year. It was incredible to see how much of a difference they were making in the lives of the people. We talked to people who said that they used their pump every single day. (2016-17)

In summary, students felt that they had effective experiences related to the learning outcomes. These experiences led students to develop some advice and recommendations for new GEO students who will be working with the communities in Peru on both continuing and new projects. Their suggestions focused on learning more about the history of Peru as well as the communities themselves. The following quotes from two students reflect what a number of students learned from their experience and the importance of being open to learning:

> The people are incredible - reach out to them. (2016-17)

> Don't try to force their culture into your understanding, but allow your understanding to be formed by their culture. (2016-17)

Although students typically reported that their experiences were life-changing, course improvements can certainly continue to strengthen the learning outcomes.

Conclusions and Future Work.

This paper summarized key findings based on surveys, documentation, and reflections papers to address: a) What cultural resources were used by students to obtain community-centric and project-centric information? b) What cultural information was obtained and how useful was this information towards the project design and understanding the community? and c) How were

students impacted by the Learning Outcomes? With regard to information needed for project designs, students extensively utilized phone calls, the internet, instructor feedback, and TA feedback as the main sources. Improving communication efforts and placing more emphasis on past reports, videos, and interactions with former GEO students can provide greater opportunities for students to receive valuable feedback for developing sustainable projects. Regarding project and cultural information, students obtained a great amount of project-centric information which they considered and felt was useful. However, student felt that they had more information than they needed for the project design. On the other hand, although students did not have as much community-centric information, they felt it was just as useful as the project-centric information, but they gave less consideration to this type of information for the project design. Thus, a greater focus on obtaining more community-centric information, as well as helping students see the relevance of such information, could help students implement more of these aspects into the project design. With regards to learning outcomes, students felt that they had effective and often life-changing experiences. Course improvements could certainly continue to strengthen the learning outcomes.

Based on the assessment presented above, there are several recommendations to strengthen the availability and use of cultural resources, improve the usefulness of cultural information, and enhance the learning outcomes. Although not exclusive, recommendations include:

- Schedule cultural and social training classes (e.g. needs assessment) throughout the first semester, rather than just the beginning of the semester, to enhance the students' perceptions of the importance of social interactions and reinforce methods needed for gathering cultural information.
- Strengthen key assignments, without making them more time consuming, to focus on community knowledge:
    - Require students to read past reports, view the video segments, and then report on what students learned as well as identify gaps in information.
    - Include follow-up assignments halfway into the semester to assess what students know about how their community functions (e.g. leadership) and provide additional opportunities to obtain knowledge in areas that are lacking.
    - Change communication reporting from twice a semester to weekly. The communication reporting would continue to track the effectiveness of calls along with details of information gathering and questions to address.
- Identify key video components related to community-centric characteristics that could be filmed during an implementation trip and then utilized during the following fall semester.
- Develop refresher training on cultural aspects for implementation during the second semester.
- Optimize and align the survey tools to better coordinate the tracking of improvements based on course changes.

The assessment findings presented indicate the results of efforts over several years to facilitate learning among engineering students about human-centered design as they developed projects for rural communities in Peru. Important among these results are findings that the students' capacity to communicate and collaborate with contacts in Peru were enhanced by the course

instruction and hands-on experience. Additionally, improvements were seen in student consideration of both project-related and community-related information in the design process. Although students gave greater consideration to project-centric information, they increasingly valued and used cultural and community-centric information to achieve the goal of creating sustainable designs. Finally, student survey responses over several years indicate that team experiences with real-world project design and innovative problem-solving increased confidence in their engineering skills as well as their ability to work with clients in different cultural settings. These findings suggest not only the effectiveness of the instructional strategies used to date, but they also indicate areas in which improvements may be made that will further enhance learning and using human-centered design in developing communities.

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