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Adding an International Senior Design Component into the Civil Curriculum

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ADDING AN INTERNATIONAL SENIOR DESIGN COMPONENT INTO THE CIVIL CURRICULUM

Abstract

International exposure as well as project-based service learning for undergraduate students has gained much attention for their positive impact on students. Additionally, ABET engineering criteria require international exposure for all undergraduates. As such, a goal of the University of Pittsburgh is to have fifty percent of our students directly participate in an international experience. Over the past few years the university has offered a senior design service learning engineering experience as part of the Senior Capstone course. This has provided evidence that service learning is a valuable educational tool to develop a sense of value and direction, teach team dynamics and communication skills, challenge the students' mindsets, and engage them in a community. This paper will discuss how the typical Capstone course is modified to include an international component. Over the past four years undergraduate students were given the opportunity to design potable water systems for two poor rural Ecuadorian villages and two villages in Panama that did not have a reliable water source. The paper will discuss the creation of a new course that allows the university to offer an international design experience within the traditional Capstone course, and it will further compare the outcomes of the international service learning frameworks to the standard senior design projects.

Introduction

Many Engineering programs are becoming interested in including an international service learning project into the school's curriculum [1-6, 8, 9, 12-20]. There are many components in a typical international service learning experience that can benefit both the students and the school. [7, 10] One of the first and well documented benefits comes from the value project based course work adds to the students experience. Students who are involved in projects have the chance to gain experience and develop their soft skills while actively engaged in hands on Civil Engineering learning. Projects can bring different learning styles into one place so that students can have the opportunity to learn the material to a depth that is difficult to attain in a typical course. Students can develop their personal skills such as critical thinking, project management skills, and improve self-confidence. Engineers in real world projects have to work in teams and therefore a project based course help students to practice teamwork, and to develop effective communication skills. These projects demand that the students communicate within their teams and with their clients, thus improving their communication skills. On the technical side the design process in a service project typically must satisfy the needs of more constraints than a typical academic exercise requires. In a project based course, students can learn to consider real world construction materials, geographical, economical, and even socio-cultural limitations and these constraints must be added into their designs. Plus, the nature of working in a poor remote area requires the students to make decisions based on engineering judgments since the data is

very limited. Another benefit comes when students are involved in providing engineering services to communities who are in needs. Firstly, the benefit is for the community that is served by students, and secondly, students are encouraged to connect and reflect how their education connects to their professional career. Through the experience students feel better about their actions and understand the need and therefore the impact engineers have on a community. This encourages them to learn more about their chosen profession, and feel more confident about their achievements. Also, students have a chance to practice and apply what they learn in class in a real project where they are exposed to the results of their design. The positive side of the service learning is at the end, the students are giving back to the communities and society the knowledge they gained in the classroom. Finally the obvious outcome of international service learning is the students get international design experience. The projects make it very easy for students to expose themselves to international design codes and standards rather the national and local requirements. They can interact with more engineers around the globe, and perform engineering services where needed. They are also exposed to other cultures and understand the real world problems and constraints. This opportunity easily enhances students' personal skills, and improves their ability and confidence in dealing with bigger problems, and therefore prepares them for their engineering career. Another important benefit for students is that the international service learning experience can change their mindset. When students are involved in a project based engineering service learning in another country, they face many challenges that do not exist in the United States. One big challenge is when they have to adjust or change their designs based on the community's ability to fund the projects and the available materials. They also have to cooperate with local people and their clients to satisfy project objects. What students learn at school is to provide engineering solutions to problems; however they typically do not learn how to incorporate the community's long term needs and financial resources into the design. Students have this opportunity to learn to break their mindset that tells them what they designed is the solution, and to engage and involve community needs and resources. This creates a relationship between the students and local community and ensures the long term impact of their engineering services. It also helps students learn and implement sustainability and globalization into their project context.

International Service Learning Experience

There are several different methods that can be used to incorporate international service learning experiences into university curriculums [6, 8, 12, 16, 17]. What method you use is based on the individual university and their ability to evaluate the capabilities and potentials of their department, the specific learning outcomes, and then select the appropriate model that works best to include international service learning projects within their environment. When designing the program, the length of time that students are required to work on the project has to be selected. The program can be a short term project such as a week, or as long as one or more semesters [10]. Short mission-style trips abroad for engaging students in simple projects that provide service where needed, e.g. physical labor in construction, is one of the initial efforts to expose students to the overseas issues. Although they are easy to plan, manage, require less funding, and require less curriculum changes to incorporate, they have low educational impacts. By increasing the time that students are involved, and requiring them to engage in different stages of the project such as data acquiring, design, and assessment of alternative solutions, they can create deeper impacts [4]. Students require time to absorb important components of their service learning. Therefore, longer exposure and involvement helps them acquire more aspects of the design

process. The University of Pittsburgh has been using a semester-long service learning model to implement international experience into a project-based senior design course.

Another factor in designing an international service learning program is to determine if students are going to be required to travel to the site project or can they stay connected remotely too the project or maybe a combination of both [10]. Travelling overseas brings more complexities and challenges but it also exposes the students to the real world problems and helps them understand the impacts of engineering service learning. Generally three models are developed to expose students to international service learning. One is to put students in contact with students in the project country, and they interact remotely to complete the project. The other method is to collect required data through international institutes such as Engineers without Boarders, and ask students to perform the necessary design remotely. They may work with the engineers and clients at the project country without travelling. Third method is to send students to collect data, perform design, and/or help in construction process, and students may come back to finish the project at home. Each method has its pros and cons. The University of Pittsburgh has implemented these methods for different project depending on the nature of the project and the service needed. Clearly, the cost and effort needed for each model is very different from each other. Moreover, the international exposure and students outcomes can be different. Among these three techniques, the two model where the students stay at home and remotely connect to the students in the project country, or stay in touch with engineers and clients working locally or overseas are mainly dependent on communication skills. Due to advances in technologies, these methods can be effectively incorporated into the curriculum without much cost, however you do need to find the clients and in country partners and this might require the instructor to travel to the site. The other method of sending students can be very expensive and requires more organizations. It also requires the instructor to have enough experience in performing international designs and construction projects so the instructor can take a lead role in the onsite activities. In this method, students need to be educated about the culture before the trip and typically they are required to meet various university study abroad requirements, such as insurance, medical clearances, and agree to liability agreements. Plus it often requires more time abroad for the instructors, to make sure the service learning experience is under control, such as bus agreements, hotel arrangements, meals, etc. However, these programs are more rewarding in terms of the experience and students' outcome and broader engineering impacts. The goal of this paper is to explain the experience at the University of Pittsburgh, and to evaluate students outcomes with respect to the ABET criteria, and to compare domestic to international design projects, as well as different international service learning projects.

Previous Experience at the University of Pittsburgh

During academic year of 2010-2011, the first international engineering service learning project within the University of Pittsburgh was developed. The pilot project was a collaboration between the senior design course and local chapter of Engineers Without Borders. The project was to design and construct a potable water system for Tingo Pucara community in Ecuador. Tingo Pucara is a poor community that is located in Cotopaxi province in central highlands of Ecuadorian Andes. The project was to build a storage tank to store water and a distribution network that gravity feed via the tank. The objectives of the course were to help the community in Ecuador, to expose students to engineering challenges in an environment with a different culture while considering economic constraints. Students were involved in different stages of the

project: engineering design, project management, dealing with local material and economic constraints, and effective communication. Students learned how important and urgent their service could be to this community, and how helpful they can be to local governments that are in need of engineering resources. The design was started in the fall semester by the local EWB chapter with student involvement, then during the Spring semester a group of senior students within the senior design Capstone course traveled to the site over Spring Break and constructed the distribution system. Surveys were conducted on all domestic and the international service learning projects within the senior design course for that Spring semester, and especially before and after the international trip, and at the end of the senior design course. Gradoville et al [10, 11] evaluated the project outcomes by conducting surveys and evaluating students' performance throughout the course. It was found that all the senior design students succeeded in their project requirements. Moreover, those students who travelled to Ecuador showed better performance, attitude, and motivation compared to students working on domestic projects. For example, in a survey they ranked team work, communication, and engineering judgment as their most important gains. These students also indicated after their trip that understanding of local daily lifestyle is a very important factor in engineering design. Regarding the ABET Engineering Criteria, Gradoville et al [10] found that the most distinct outcomes between international and domestic service learning projects were the ability to design within realistic constraints, appreciation of engineering in global and social context, and a knowledge of contemporary issues (ABET C, H, and J). The results evaluated and supported that the international experience had a great impact on students' attitudes, motivations, and experience and improved the overall outcome [10, 11].

Initially in 2011, the international service learning project was defined as one of the projects in the typical engineering senior design course. There was no extra requirements for students who travel overseas although the amount of efforts it required from both students and instructors were more than domestic projects. Also, since there are several restrictions and regulations at the University for Study Abroad along with costs and fees, a better solution was needed to integrate international experience into the existing design course work. A one-credit course was defined separate from the senior design credit for students who are interested in international exposure.

International Senior Design Course (ENGR 1098)

Our goal is to provide students with an opportunity to extend their engineering senior design projects to an international experience. After several communications with individuals involved in several Study Abroad courses, it was concluded the best way to meet safety requirements and manage the related issues was to create a one-credit course that would be added into the existing senior design course. Therefore, students could register for the standard senior design, within any engineering department, without any changes to the syllabus and course requirements for the Capstone course. Registration for the additional course could cover fees, insurance, and other expenses related to Study Abroad requirements. By using this two course sequence, the needs of the senior design course and globalization required by ABET can be met with one project spanning two different courses. Many aspects of the ABET Engineering Criteria can be addressed in the international service learning project format that would be difficult to address through typical senior design course.

The ENGR 1098 course therefore was designed as a one-credit course concentrating on international experience helping students understand globalization and technology and importance of sustainability design. The learning objectives are to make students understand the basic history, government, and economic strategies related to the project county; produce a final design that is the most cost effective design (limited funding for construction and future repairs/improvements); consider availability of materials at local and at least country level; select an appropriate technology, where several physical, economic, cultural, and political constraints should be considered to weight advanced and more common technologies; consider future expansions in designs; produce an entire construction plan for their system; define "globalization" and identify the impacts on respective field of study and future employment; and gain awareness of differences in the business environments of the US and other parts of the world.

The design would be "graded" as part of the Capstone course, and the grade for the ENGR1098 course would be based on a journal the students kept during their travels and a trip summary report the students would give within their capstone design course "progress reports".

Typically Senior Design Service Learning Projects

There were four projects (see Table 1) defined in Fall 2014. One project was to provide alternative designs for water distribution network for a poor community in Ecuador. The second one was to design an extension to the current water distribution system and construct the network for another community in Panama. The third project was to design the infrastructure to connect Three Hiking to Biking Trails nearby the Glenwood Bridge. The last project was a construction management to develop a plan for the Davis Avenue Bridge. Among the four projects, the two projects on water distribution system in Panama and Ecuador are international service learning, and the other two were local projects. The two international service learning projects are described in the next section.

TEAM	**PROJECTS – Fall 2014**
Team 1	Design of a Potable Water Supply System to a Native Village in the **Ecuadorian** Andes.
Team 2	Design and Installation of a Potable Water Supply System to a Native Village in **Panama**.
Team 3	Design of Infrastructure to link Three Hiking/Biking Trails near by the **Glenwood Bridge**.
Team 4	Development of a Construction management Plan for the **Davis Avenue Bridge**.

Descriptions of International Service Learning Projects

A. Curingue Community – Ecuador

Curingue is an indigenous community located in the Ecuadorian Andes Mountains. Home to approximately 300 people, the mountaintop community has no access to running water. Community members currently retrieve their water from a natural source about 1000 feet below the community, which takes several hours a day, and is carried in buckets by hand and on llamas. After successfully implementing a potable water supply system in the neighboring

Tingo Pucará community in 2011, the local professional chapter of Engineers Without Borders (EWB-PPC) was contracted to design and implement a similar system for the Curingue community, to be constructed in the fall of 2015. Thanks to past partnerships with the university, EWB-PPC invited a team of senior engineering students to provide the preliminary design for the proposed system. The project scope included an alternatives analysis of several design concepts, which were developed by the seniors and professionals collaboratively. The alternatives were evaluated on several criterion including functionality, constructability, maintainability, reliability, cost of construction, operation & maintenance cost, and safety. Once the most feasible option was identified, the students completed a comprehensive design report. The design includes a French drain collection system, which captures water from a natural source approximately 1700 feet below the community's peak elevation, and uses a high-pressure pump to transport the water to a storage tank at the top of the mountain. The tank then feeds into a gravity-fed distribution network, which delivers water throughout the community. The design report provided to EWB was submitted to the local government and EWB-USA, as well as various other sponsors for funding purposes. The team has also been invited to join EWB-PPC on their implementation trip to Ecuador next year to help construct the system.

B. La Paz Community – Panama

The second team took on the project of installing a water system in the community of La Paz in Panama. This project was an extension to the previous projects for the Kuna Nega community.

The Kuna Nega community is supplied water by a pressure main running from Panama City. Every week, this pressure main is shut off for up to 36 hours, and the community is supplied water solely by an existing 10,000 gallon storage tank. The existing tank does not have sufficient capacity to supply the entire community for more than 10 hours. In addition, part of the community lies at a higher elevation than the existing tank, and therefore does not receive any water when the pressure main is shut off. In this project, the Team 2 conducted calculations for the first six weeks of class to expand the storage capacity and add additional tanks at higher elevations to feed water to the entire community and provide enough storage during the periods when water is not available from Panama City. The design team then traveled to Panama to construct the systems that they designed. The designing and construction included a water distribution system, and a water storage tank feed by a pump. This tank was designed to be placed in an area where it could be gravity feed to distribute the water to houses in the community. For constructability purposes, the tank was designed to be rectangular in shape and constructed from cinder block and cement. The system included numerous check valves, pressure reducing valves, and shutoff valves. The shutoff valves were place so that when maintenance would be performed on the system the smallest number of houses will lose service.

While the Ecuador project is an international service learning experience, there is no requirement for students to travel. The students met with the EWB chapter in a regular base to receive data, learn about project aspects, perform preliminary designs, and discuss the alternative solutions. They were asked to work with course instructors, a mentor, and EWB engineers to complete the project. This project was organized as a "stay at home" international service learning so that

students did not register for ENGR 1098. On the contrary, the Panama project required students to travel internationally and thus register for ENGR 1098. Team 2 students were asked to work closely with course instructors, the mentor, and local clients at the project site. We were interested to assess how the international component could impact our ABET outcomes, and evaluate the impact of a stay at home, versus travel experience compared to a domestic design project.

Survey and Questions

At the end of the senior design course a survey was administered to help measure the benefits of the international service learning exposure. The survey was given to all four senior design teams. The survey was designed to give each student a chance to reveal their attitude, motivation, and experience while each ABET Engineering Criteria outcome was evaluated through several questions. The survey questions that we conducted were put together from several literatures on service learning, senior design and international service learning.

Results/Discussion

A. Result Validation

To better evaluate the outcomes and to compare students' responses, results from Gradoville et al [10] are adopted as our reference. Gradoville et al studied the service learning in Ecuador as part of senior design course in spring 2011, and developed a survey to measure students' outcome. The same survey questions (seven questions in Table 2) were included as part of our survey. The questions were answered on a scale of 1 – 10.

Table 2: Survey questions adopted from Gradoville et al 2011

OUTCOME	QUESTION
Ethics	How much has your senior design enhanced your understanding of professional and ethical responsibility?
Communication	To what degree has your senior design experience enhanced your ability to communicate effectively?
Global/Society	To what degree has your senior design experience enhanced your understanding of engineering in a global and societal context?
Contemp. Issues	To what degree has your senior design experience increased your knowledge of contemporary issues in the world?
Constraints	How confident are you that you can complete a design within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability?
Overall Educ.	Compared to your previous undergraduate coursework, how educational was your senior design experience overall?
Altruism	Upon graduation and searching for jobs, within the continuum below, you hope to find a job that: (financially secure - useful to society)

Comparing our results to results from 2011 indicated an overall increase in students' response. The average score for all students in 2014 was calculated to be 7.60 while the 2011 score was 6.78. The standard deviation was calculated to be 1.63 in 2014, and 2.00 in 2011. This indicates that the overall score among students has increased while the variability of the score has

decreased. Lower standard deviation can be an indicator of a robust improvement between teams and different projects. Figure 1 compares the classes' response to each question. It was found that the overall response pattern was consistent between our class and class 2011, while the mean response from class 2014 is higher than class 2011 for every single question. The maximum difference between mean scores (1.20) was discovered when asking about students experience in a global and social context. Similarly, students scored higher (1.16) when they were asked if they were more interested in selfless jobs (altruism). This overall increase shows that the 2014 senior design projects with the additional of the Study Abroad component did enhance students understanding of engineering in society and global context, and students' beliefs in selfless practices. It also gave us basic repeatable results and confirmed the same findings that we saw in 2011, thus supporting the concept that the 2011 findings were not a one year result.

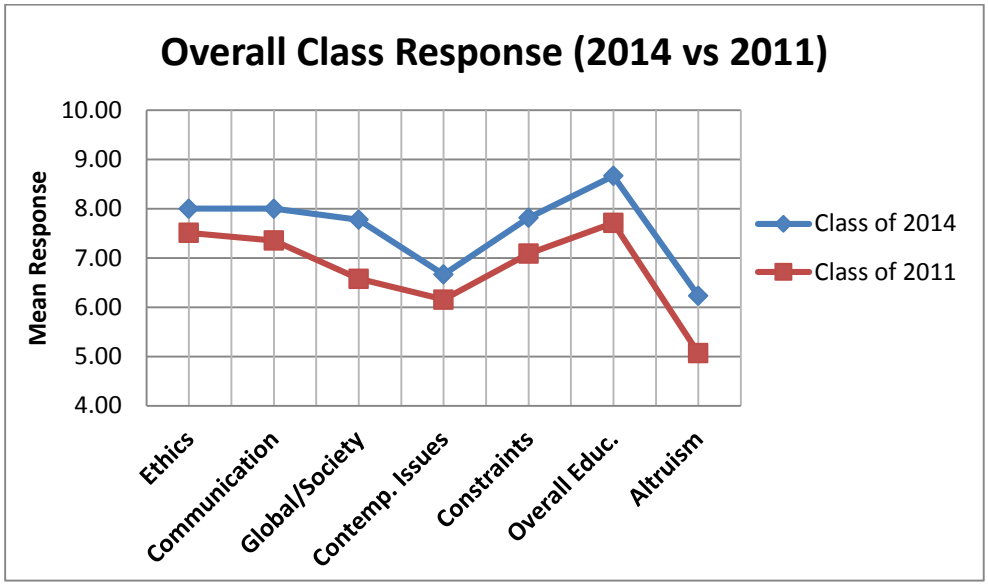

Figure 1: Comparison of our results to class 2011 from Gradoville et al 2011

In addition, we were interested in comparing responses of international and domestic service learning teams from our study to Gradoville's study (2011). Teams 1 and 2 (Ecuador and Panama respectively) were international service learning projects, where only Team 2 travelled to Panama for 10 days. The other two teams (Glenwood and Davis bridges projects) were local service learning projects. In 2011, only Team 2, the Yaku water supply project, was an international service learning team, and the other five teams were all domestic projects. Figure 2 shows the mean responses for the two different years. Comparison of responses from the international teams for 2011 and 2014 indicates that the overall outcome is similar except the international teams in 2014 ranked their experiences higher for most of the questions. The responses for the two questions asking about understanding of global/society as well as contemporary issues are basically the same for the different design experiences. Figure 3 which compares the two teams from 2011 and 2014 that travelled shows similar trends. The travelling and getting exposed closely to the community culture was the common experience. However, the overall average score of the international teams in 2014 was found to be higher than the international team in 2011 (7.91 vs 7.36). Necessarily, the difference was found to be the highest when students were asked about realistic constraints in design (such as economic, ethical, etc.). Firstly, it appeared that the two teams in 2014 were more informed about the projects due to the

previous efforts and studies. They had better understanding of the problem and the overall situation of the community in need of service. Secondly, the travel team in 2014 took the ENGR1098, the one credit Study Abroad that was deigned to prepare the students necessarily for international exposure. This is also indicated clearly in Figure 3.

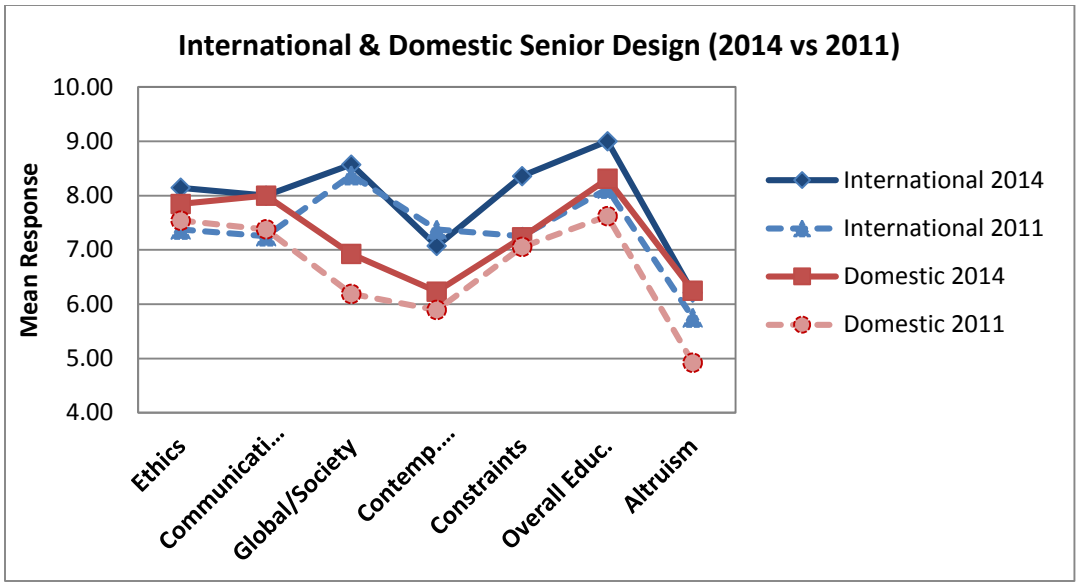

Figure 2: Comparison of international and domestic service learning projects in 2014 and 2011.

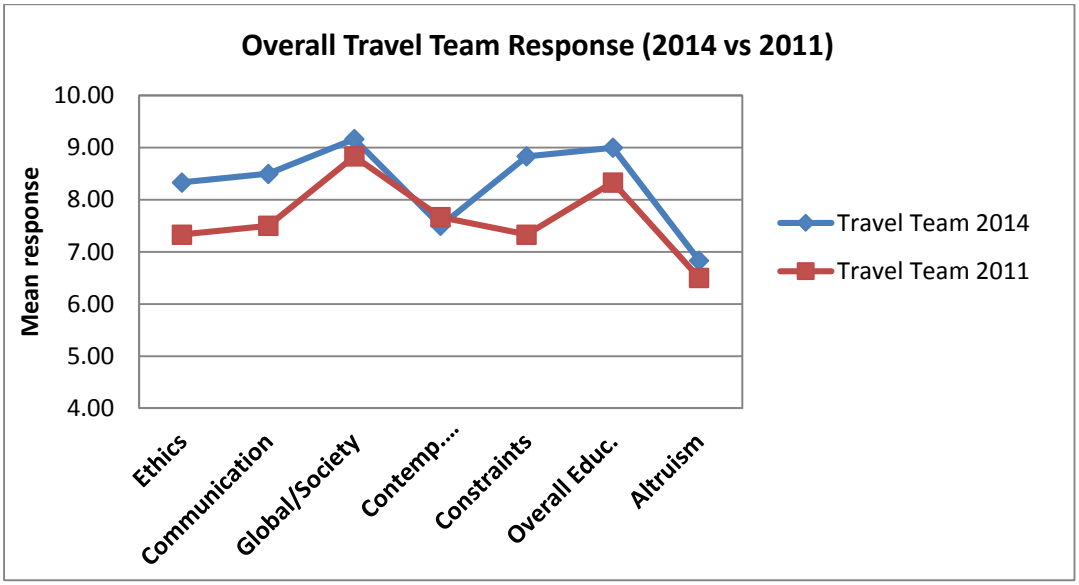

Figure 3: Comparison of travel teams 2014 and 2011 (Panama vs Yaku)

B. Survey Outcome

After validation of our survey results with Gradoville's study (2011), we can further evaluate and discuss the entire survey outcomes in this section. Overall, the students' responses confirmed that the senior design course for 2014 performed an effective job on enhancing students'

understanding and knowledge about engineering projects, training them to conduct engineering calculations with respect to real world constraints and working in teams. The average score for all 38 rating-questions (See appendix) in the class was calculated to be 7.46 out 10. The average score was calculated to be 7.99 for international teams, which was well above 6.89 for domestic team. This emphasizes how exposure to international service learning projects increase students' overall attitudes and motivations. One major reason could be that students could see the impact of their engineering design, and feel confident about their ability in design and effective communication. Moreover, by comparing the two international teams, it was found that the average response score by Team 2 who travelled (8.39) was also higher than the team who only stayed in contact remotely with their international clients (7.69, yet above class average). This could be an indicator of motivational aspects of getting exposed to poverty in other countries and understanding how engineering service impacts society. Also, the students who travelled took the ENGR1098 and were prepared before their trip by working closely with the instructors, clients, and their mentors. That helped them have overall the best performance in the class. The standard deviation of scores for international teams was 1.56 compared to domestic teams indicating that the score population in the international teams was less variable. This further shows that the students in international teams have better confidence and deeper understanding of all the ABET questions.

Figure 4 shows all 38 questions and compares the average ratings for the international and domestic. It was observed that the overall patterns of responses were consistent. However, in almost all questions, the students in international teams rated their experience higher than students in domestic teams. This could be an indicator of a general positive improvement in students' attitude and perception.

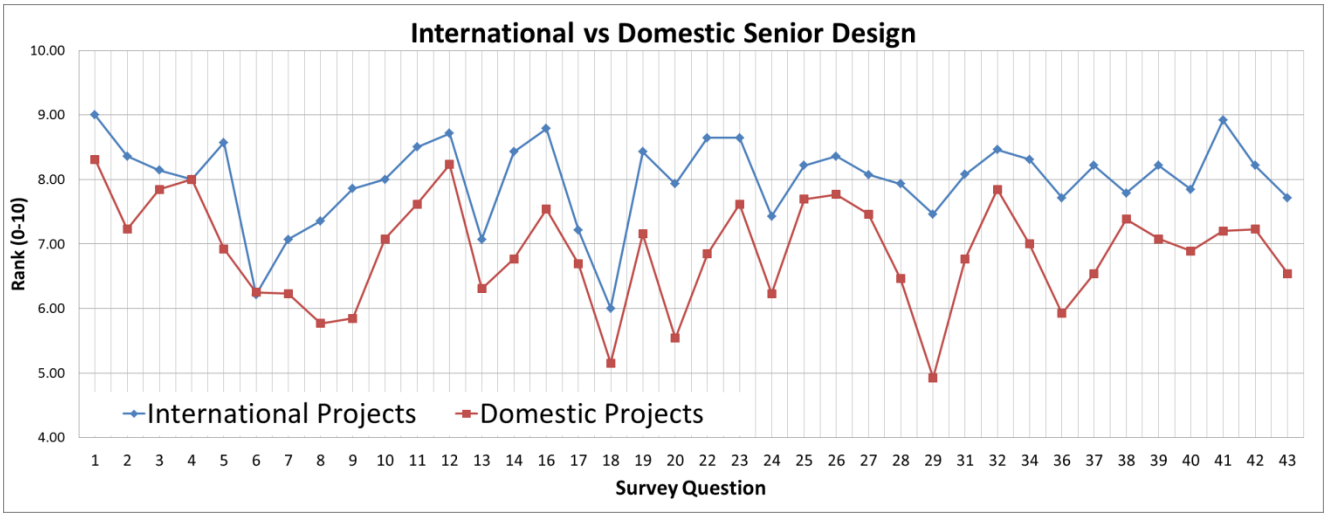

Figure 4: Response comparison of international and domestic service learning teams

Average students' rating responses to Questions 4 and 6 are the same across international and domestic. These two questions are adopted from Gadoville's study and are discussed earlier. The maximum differences between responses are in Questions 9, 20, 29 when the average responses differences are above 2 (2.01, 2.39, and 2.54 respectively). Question 9 tested students' confidence about the quality of their work. International project teams show better confidence which could be a result of dealing with the international aspects of the problem, and in the case

of Team 2, the exposure to the community and understanding the impact of their efforts. In Question 20, students were asked about their experience in design, analysis and data interpretation. And, Question 29 tested them for their overall experience, attitude, and perception regarding the senior design course changing the values in their life. This indicates how exposure to poor communities in the other part of the world, and understanding their needs could change students' perspectives and make them feel better about their profession and its impact. It is also interesting to find the questions where the responses were not very consistent. Question 5, understanding of engineering in social and global context, is already discussed. Questions 37 and 39 tested students experience and motivation on valuing their efforts and understanding the need for lifelong learning. Students within international projects rated higher since they were exposed to a broader application of engineering where they potentially helped increase the quality of life of a community in another country.

When students were asked what aspects of their project required them to consider "blank" (see Question 21), there were some interesting outcomes (see Figure 5). It was found that international service learning teams did not consider the political issues into their design. This makes sense since both international teams worked on designing a water distribution network for a poor community in another country where there a well-defined government structure was not in place. They felt their engineering service could be free of any political boundaries. Also, they were closely in contact with the community and were fully aware that there were no political issues that they had to concern about. It is observed that domestic team, and especially the Glenwood Bridge team (see Figure 6), considered the political issues in their project design. This tells about their understanding of design constraints as well as the type of projects they were involved. Another interesting finding from this question is that international student had a better understanding of sustainability and they considered it in the project design while the domestic Team 3 members were not confident about including it.

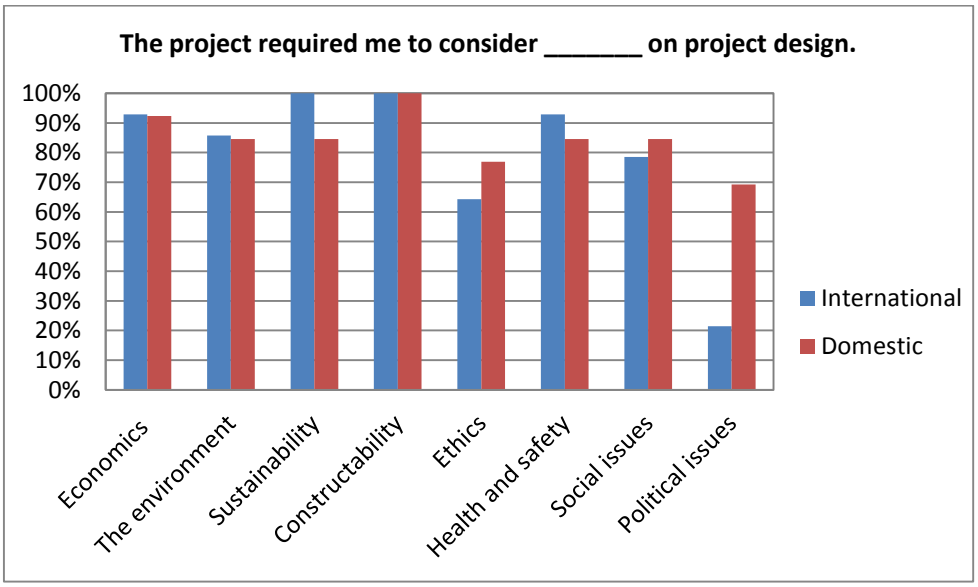

Figure 5: Student responded what aspects the project required them to consider in project design

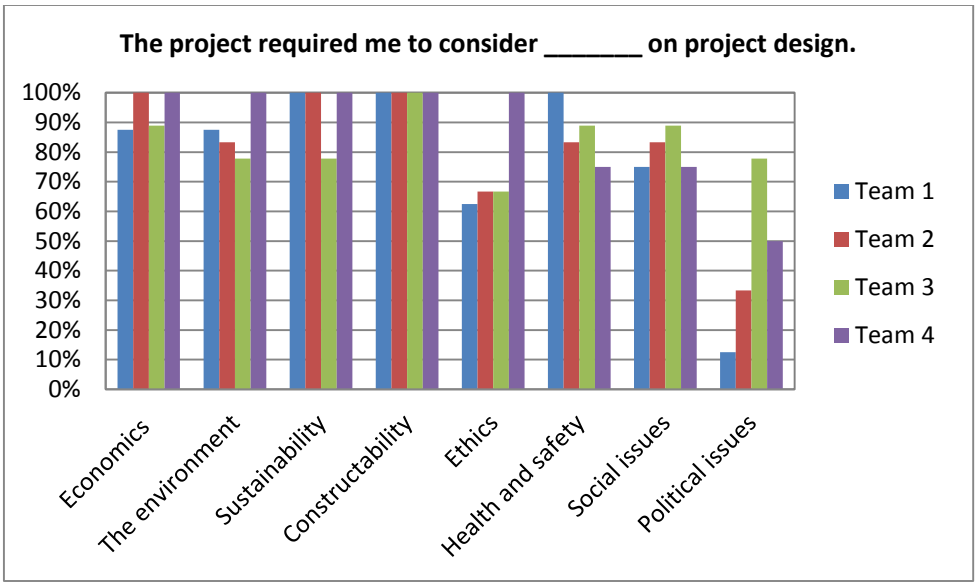

Figure 6: Team responses to what aspects the project required them to consider in project design

Question 30 tested students' motivation on why they worked on the project. Students were asked to select only one although a few selected more than one option. It is interesting to find international students considered to help solve community problems the most (62%), and then to benefit their clients at the project site (46%). This indicates an increase in students overall attitude, perception and motivation to give engineering services as their professional and ethical responsibility. However, students working on domestic projects indicated that the most important reason was to fulfill degree requirements (85%), and then for their benefit (31%), and none of them considered working on the project to benefit their clients.

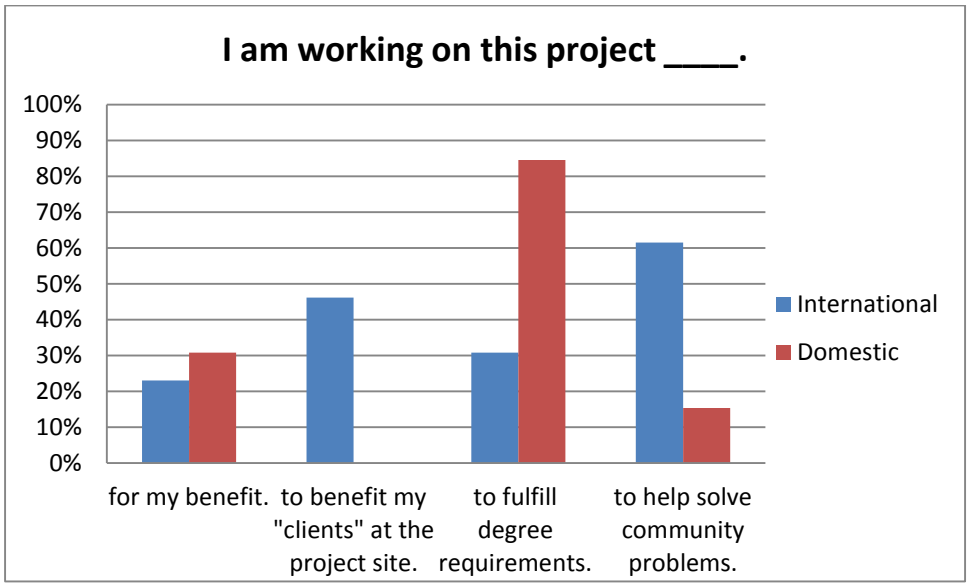

Figure 7: Motivations behind working on the project

In another question (Question 33) students were tested for their motivation and experience. They were asked to check as many as applied. The summary of the results for international and domestic service learning teams are presented in Figure 8. Because the international teams were more exposed to their community that were located in another country, they showed more confidence in report preparation, presentation, and effective communication. They also showed less indication of problems within the team members or with their skills as they were perhaps more motivated to worked and finish the international project. International teams in overall showed less confidence in interacting with the local population. It is interesting to find that actually the travel team (Team 2) who was exposed and interacted with the local community was the most confident while the other international team (Team 1) who only stayed in contact with their clients remotely and necessarily through EWB felt the least confident. Similarly, Team 2 showed less confidence in dealing with people from industry as they were working more with the community directly.

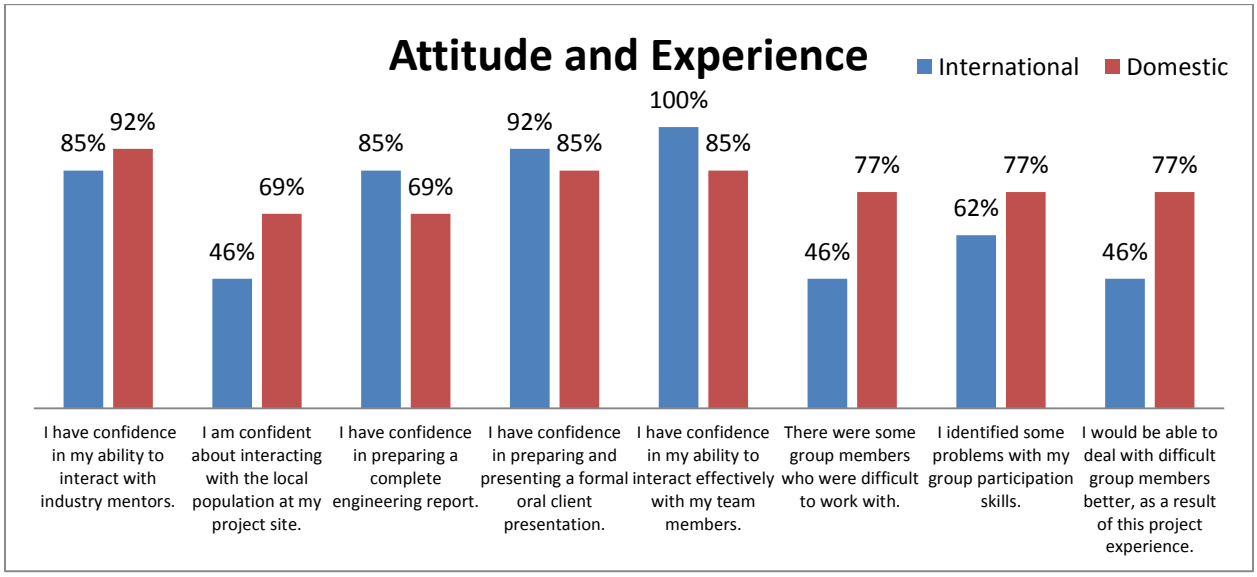

Figure 8: Attitude an experience over the course of senior design project

Finally, Question 35 evaluated the students overall experience in the senior design course. Interestingly, it was found that the international service learning teams believed that the design course and the international service learning component could enhance their knowledge of other cultures and their social issues, while domestic students indicated that they become more familiar with social issues in local scale. Both groups checked that the course helped them understand socio-economic issues in the country of the project. Domestic teams also showed higher confidence than international teams in understanding the political climate of the project country, perhaps because they are more familiar with the country they live in.

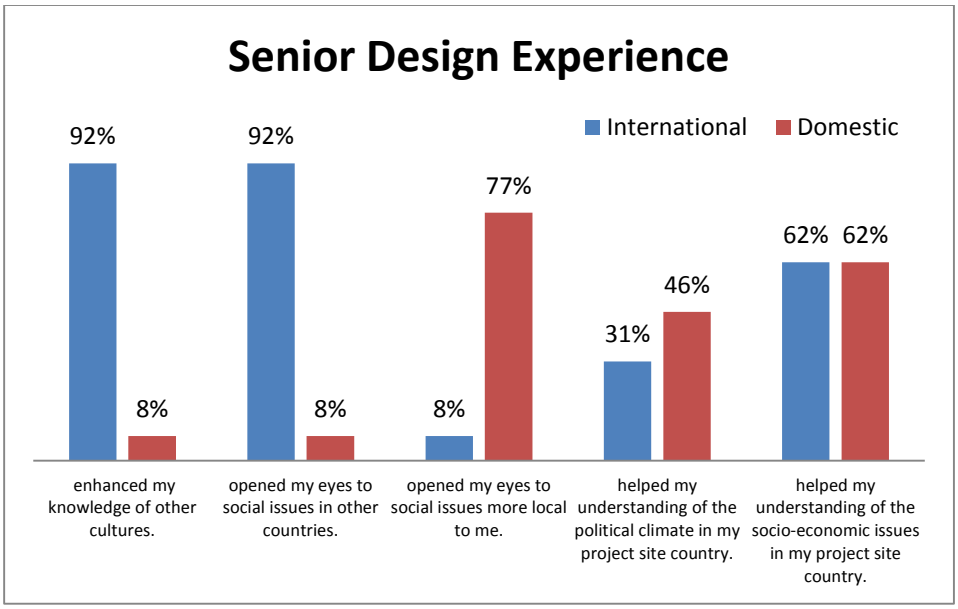

Figure 9: Evaluating students experience during senior design course

C. ABET Outcome

All 38 questions were binned into 11 ABET outcome categories, and compared across international and domestic service learning teams. Figure 10 shows the average score (out of 10) by international vs domestic service learning. It was found that in all ABET outcomes students involved with international service learning projects rated their experience higher. The motivation and experience of working on an international project appears to raise the experience for the students. ABET outcomes C, D, H, and J that are the main objectives of the ENGR1098 course and the results show improvements in students' attitude and experience. We observed similar patterns in responses to almost all ABET criteria except ABET B and H. Question 20 tested ABET B asking students about experience with design and analysis. There is a distinct difference between international and domestic project teams. We observed more confidence and attitude among students in international projects. Questions 5, 31, 34, 37, and 41 were designed to test ABET H. The results indicate that mainly the design experience and value of international service learning increased students response. These results show a great advantage by including an international service learning experience within the typically Capstone design course.

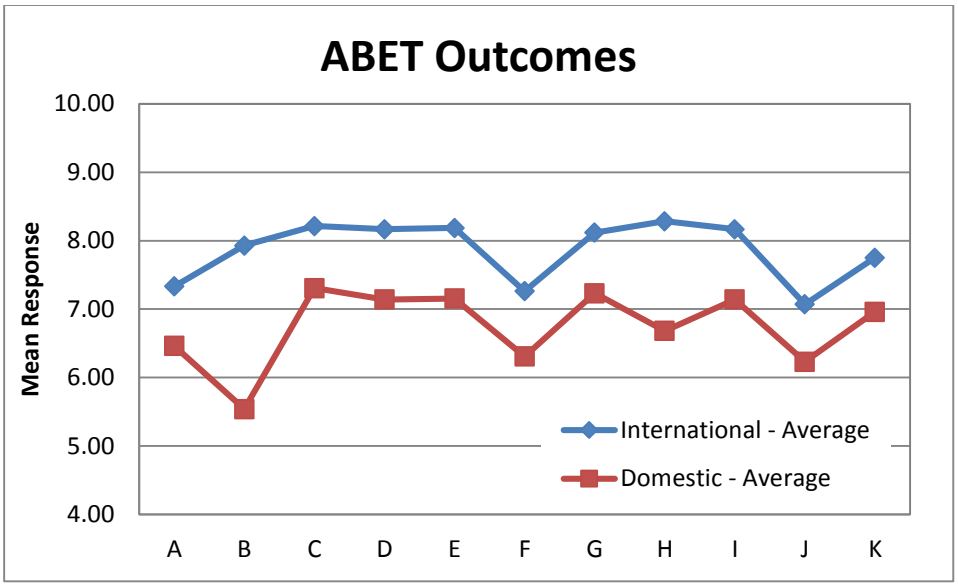

Figure 10: ABET outcomes of international and domestic service learning teams

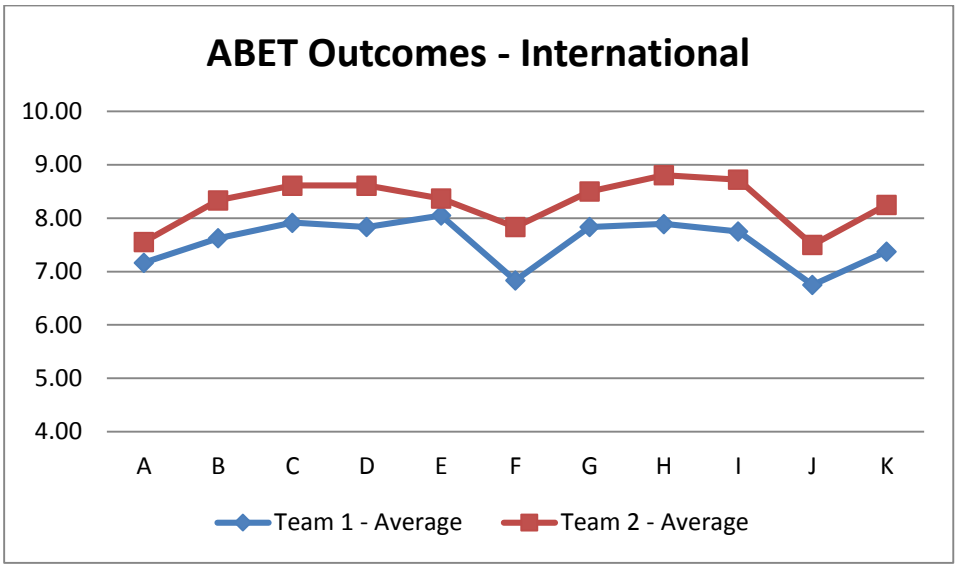

Figure 11: Comparison of international service learning teams

It is found that both international teams responded fairly similar to all ABET outcomes. Figure 11 indicates that Team 2 members who took the ENGR1098 and traveled to Panama showed a higher attitude and confidence. Team 1 performed similar but certainly with no international exposure to the community, they have less experience and lower confidence. The reason that the patterns are very similar is that the projects were both on designing a water distribution system for a community. However, if we compare the two domestic teams, it is clear that these teams had different experience over the project. Team 3 designed a trial nearby Glenwood Bridge, and Team 4 was involved with construction management of Davis Bridge. In overall, Team 4 responded with higher confidence regarding all ABET outcomes. The difference is more obvious when we look at ABET A, B, G, and J. The overall Senior design course objective was to improve students' outcome on C, D, H, and J. While Team 3 showed similar pattern in ABET J,

Team 4 performed necessarily better. ABET J concerns about lifelong learning. ABET A and B deal with students' ability to apply the knowledge, design and conduct experiments and analyze data. And ABET G focuses on their ability to communicate effectively.

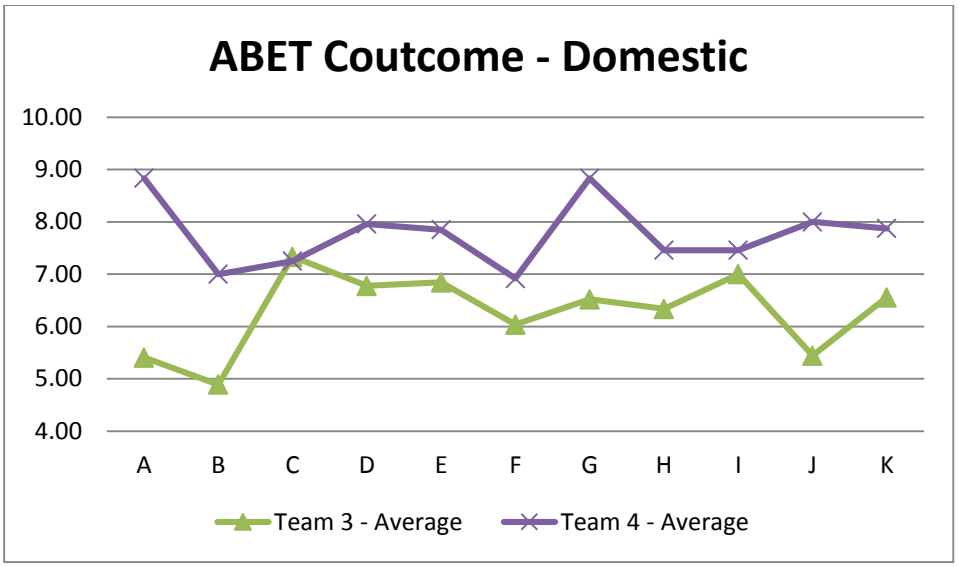

Figure 12: Comparison of domestic service learning teams

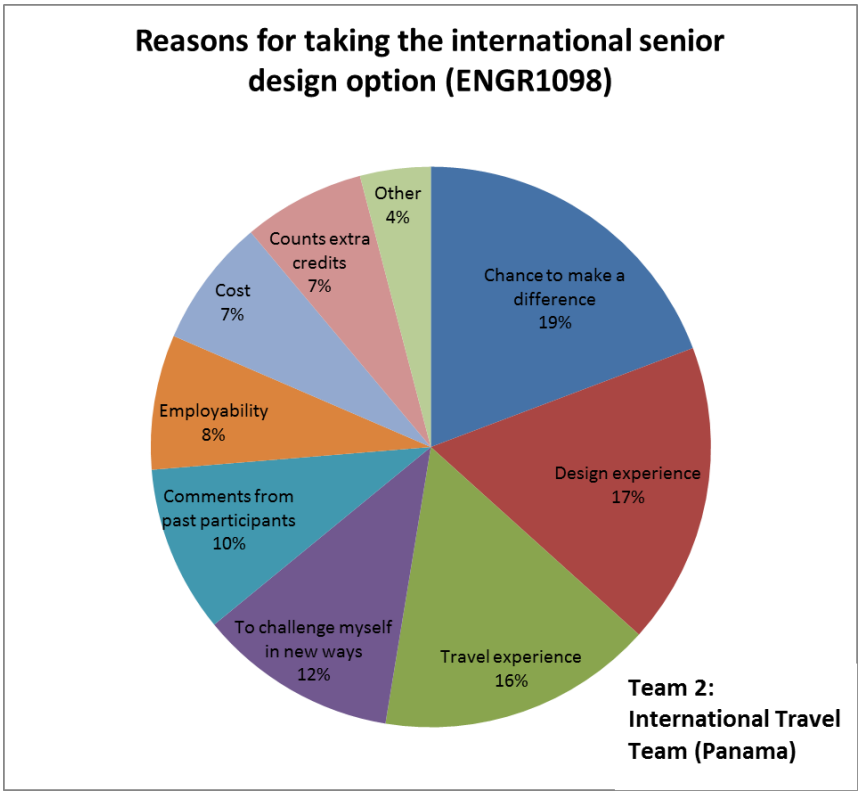

Figure 13: Reasons for taking the international senior design option, ENGR1098

D. Travelled Team:

To test ABET outcome H, and to measure students' motivation within the travelled international service learning team, Question 15 asked them to rank the reasons for taking the international service learning credit, ENGR1098. The overall result for the team is presented in Figure 13. This figure indicates how important each reason was compared to the other 8. It was found that the most important reasons were to have a chance to make a difference (19%), to have design experience (17%), to travel (16%), and to challenge themselves (12%). Students were exposed to the international community, recognized the poverty in other part of the world and understood how their effort can change the life of a community.

Summary and Conclusion

Service learning project courses provide a great opportunity for students to get involved in community service. They improve students' attitude, perspective, and motivations in solving problems. A semester long engineering senior design helps students face challenges that engineers in real world face. International senior design projects tend to increase these benefits to the students. These international projects help students go beyond the typical engineering experience because they are exposed to other cultures and understand real world needs for engineering services within economic and political constraints. Universities also benefit as these projects meet or exceed the ABET Engineering Criteria.

In this study, the one credit course ENGR 1098 that was developed to integrate international service learning into senior design project was found to help administer the international experience into the existing senior design experience. Surveys were conducted to measure and compare international service learning projects to typical senior design engineering projects. While students' performances were satisfying in all senior design projects, the results confirmed that the international component improved students' outcome and met course objectives. Moreover, the one credit course helped the institute and instructors to organize and benefit from international experience. Interestingly, between the two international service learning models, stay at home team and travelling team, better performance was observed from students who travelled to the community. This once more confirms the need and impact of international exposure.

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Appendix A: Senior Design Survey

1. Compared to your previous undergraduate coursework, how educational was your senior design experience overall?
   0 1 2 3 4 5 6 7 8 9 10
   (Strongly Neutral Strongly)
   Disagree Agree
2. How confident are you that you can complete a design within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability?
3. How much has your senior design experience enhanced your understanding of professional and ethical responsibility?
4. To what degree has your senior design experience enhanced your ability to communicate effectively (both written and visually)?
5. To what degree has your senior design experience enhanced your understanding of engineering in a global and societal context?
6. Upon graduation and searching for jobs, within the continuum below, you hope to find a job that is: (financially secure - useful to society)
7. To what degree has your senior design experience increased your knowledge of contemporary issues in the world?
8. Working on this project increased my confidence.
9. I am proud of the quality of our work and final report.
10. I have confidence in my technical problem solving skills.
11. I feel confident in completing team projects in the future.
12. I have confidence in working as a productive team member.
13. I have confidence in leading a project team.
14. The project activities made the engineering subject more interesting.
15. Provide your reasons for taking this *international senior design option* (ENGR1098): (rank them from 1-9: where 1 most important, 2 next most, and so on)
    - __ cost
    - __ counts extra credits
    - __ design experience
    - __ travel experience
    - __ chance to make a difference
    - __ to challenge myself in new ways
    - __ comments from past participants
    - __ employability
    - __ other (please specify, if applicable):
16. I was able to utilize and apply <u>knowledge of engineering design</u> during the project.
17. I was able to utilize and apply <u>knowledge of estimating</u> during the project.
18. I was able to utilize and apply <u>knowledge of project scheduling</u> during the project.
19. I feel that the project <u>enhanced the learning experience</u> of the class.
20. This project gave me an ability to <u>design and conduct experiments</u>, as well as to <u>analyze and interpret data</u>.

21. The project required me to consider _____ on project design.
    (Check all applied)
    - ☐ Economics
    - ☐ The environment
    - ☐ Sustainability
    - ☐ Constructability
    - ☐ Ethics
    - ☐ Health and safety
    - ☐ Social issues
    - ☐ Political issues
22. The project required me to work in multi-disciplinary teams (i.e. people with different professional training).
23. The project activities helped me develop collaboration skills.
24. As a result of the project activities that I completed, I am more comfortable in my dealings with people of diverse backgrounds.
25. This project gave me an ability to identify, formulate, and solve engineering problems.
26. I have confidence in framing a problem and organizing a possible solution approach.
27. I can identify important parameters to be measured to check if our design requirements are met.
28. The senior design project was a good insight into how a typical engineering project research might be conducted.
29. This experience will change what I value in my own life.
30. I am working on this project ____.
    (check ONLY ONE)
    - ☐ for my benefit.
    - ☐ to benefit my "clients" at the project site.
    - ☐ to fulfill degree requirements.
    - ☐ to help solve community problems.

31. As a result of this project I have better insight into what civil and environmental engineers do.
32. This project gave me an ability to communicate effectively.
33. Please check all applied:
    - ☐ I have confidence in my ability to interact with industry mentors.
    - ☐ I am confident about interacting with the local population at my project site.
    - ☐ I have confidence in preparing a complete engineering report.
    - ☐ I have confidence in preparing and presenting a formal oral client presentation.
    - ☐ I have confidence in my ability to interact effectively with my team members.
    - ☐ There were some group members who were difficult to work with.
    - ☐ I identified some problems with my group participation skills.
    - ☐ I would be able to deal with difficult group members better, as a result of this project experience.

34. This project gave me the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context.

35. I feel my senior design project experience ____.
    (Check all applied)
    - ☐ enhanced my knowledge of other cultures.
    - ☐ opened my eyes to social issues in other countries.
    - ☐ opened my eyes to social issues more local to me.
    - ☐ helped my understanding of the political climate in my project site country.
    - ☐ helped my understanding of the socio-economic issues in my project site country.

36. This experience will be greatly valued by prospective employers.
37. This experience will be of great value to me as a person (non-professional reasons).
38. This experience will provide skills that can be transferred to my next/first job.
39. This project gave me recognition for the need to & ability to engage in life-long learning.
40. The amount of effort I put into the service-learning project was greater than what I would have put in for an equivalent made-up project not involving service.
41. This class (ENGR1098) and these types of projects would be beneficial for future Engineering Senior Design students.
42. This project required me to be creative in the project design process.
43. I learned a new technology (i.e. Survey equipment, AutoCAD, EPANet, Primavera 6, BIM, STAAD software) and/or became more experienced with a technology, as a result of the senior design project.