

## **Comparison of Students' Outcome to Different Types of Project Based Service Learning Experiences for CEE Senior Design**

**Dr. Dan Budny P.E., University of Pittsburgh**

Dr. Dan Budny joined the University of Pittsburgh faculty as Academic Director of the Freshman Programs and an Associate Professor in Civil Engineering in January 2000. Prior to that time he served as Associate Professor of Civil Engineering and Freshman Programs at Purdue University. He holds a B.S. and M.S. degree from Michigan Technological University, and an M.S. and Ph.D. degree from Michigan State University. His research has focused on the development of programs that assist entering freshman engineering students, including academically disadvantaged students, succeed during their first year. Of particular note are the highly successful counseling and cooperative learning programs for first-year students that he created within the freshman engineering programs at Purdue University and at the University of Pittsburgh. Dr. Budny has numerous publications and presentations on engineering education. He is widely recognized for outstanding teaching, receiving awards at both Purdue and Pittsburgh Universities, plus national and international awards. Dr. Budny is very active in ASEE within the Freshman Programs and the Educational Research and Methods Divisions, and was on the ASEE board of directors. Dr. Budny can be reached at the University of Pittsburgh, Freshman Engineering, 126 Benedum Hall, Pittsburgh, PA 15261; 412-624-6474. [budny@pitt.edu]

**Mr. Sina Arjmand, University of Pittsburgh**

**Dr. David V.P. Sanchez, University of Pittsburgh**

David Sanchez is an Assistant Professor in the Department of Civil & Environmental Engineering and the Assistant Director for the Mascaro Center for Sustainable Innovation. He directs the Sustainable Design Labs that is currently focused on fusing sustainability principles and design thinking to address the Water and Energy grand challenges in the natural and built environment. Current projects include: Renewable electrode materials for Microbial Fuel Cells and the Electro-Fenton process, Recirculating Aquaponic Systems, Environmental Quality wireless sensor networks, and incorporating Sustainable Design/Innovation into engineering curricula.

He serves as a Faculty Lead for Pitt's Design EXPO and a variety of the Mascaro Center's Sustainability programs including the Manchester Academic Charter School "Green week" and the Teach the Teacher program. Dr. Sanchez teaches Introduction to Sustainable Water Technology and Design, classes in the Civil & Environmental Engineering Department and the Swanson School of Engineering Freshmen program. He works closely with K-12 initiatives and outreach programs including Investing Now, Energy Ties, and the ALCOSAN outreach program.

# **Comparison of Students' Outcome to Different Types of Project Based Service Learning Experiences for CEE Senior Design**

## **Abstract**

Adding international exposure to project based service learning in to undergraduate curriculum has been found to have positive impacts on students' motivation, attitude and experience. ABET engineering criteria require engineering schools to include international exposure in to all undergraduate programs. Our program aims to directly involve half of our students in an international service learning experience. The senior design course in the Civil and Environmental Engineering program has been modified and improved over the past few years to offer international experience in addition to community service. By working on real world engineering projects, students practice their design and calculation skills. They also develop team work, effective communication, and community engagement through service learning experience. Adding the international exposure to senior design further improve students motivation to provide engineering services to communities in need by changing students mindset to engage them to the whole new world with all political, social, environmental and economical limitations. In the past 5 years, international experience teams worked on several engineering design projects such as designing and building a water distribution system and storage tanks to provide potable water, and the design and construction of structures such as small community buildings and bridges to provide access to disadvantaged communities in Latin America. The projects are selected such that there is a design component for any area in Civil Engineering, for example: structures, geotechnical, water resources, environmental, sustainability, or construction. This paper will expand our previous published results that show an improved satisfaction in the design experience for the teams involved with the international experience and also study and compare our observations regarding ABET student outcomes by expanding these types of projects into domestic service learning projects. Moreover, the improvements in senior design project definition, coordination and management will be recommended to help achieve the overall international experience outcomes to any project.

## **Hypothesis:**

A previous study showed that including an international component into a typical civil engineering design project provided improvements in students' motivation, attitude and experience when compared to a typically classroom project. The research questions for this study was whether a local domestic setting project, with the same level of interaction with local communities, can have the same impact on students' outcome as the international projects.

## **Introduction**

The primary goals in offering a service learning project within the framework of a traditional curriculum are to ensure that students understand the impact of engineering projects on society as well as the social contexts within which they operate, to develop confidence in the students' ability to solve problems, to help the students function successfully and comfortably in a

professional engineering environment, and to understand and appreciate what it means to be a professional engineer

Service learning has been shown to do this while also providing an experience that is both fulfilling and enlightening [1-2]. Many engineering students are overwhelmed by the workload of the engineering curriculum, and are not stimulated by the course materials. Some students lack the maturity or experience to understand how the engineering curriculum will be of value to them in the future. They have not yet been exposed to the variety of opportunities that will be available to them upon completion of an engineering degree, nor do they understand the skills they will need to ultimately be effective and of value in a professional work environment. With such an imposing challenge facing them as engineering students and little understanding of how and where their education will take them, many students lack the confidence in themselves to succeed. This can lead to constant anxiety and struggle in their chosen major. Research suggests that service learning can address these issues more efficiently than traditional courses because service projects have an inherent purpose to solve a problem for a community in need [2-3]. Additionally, projects that deal with poverty provide obvious answers to students struggling with the question, "Why am I studying engineering?"

Many Engineering programs are becoming interested in including an international service learning project into the school's curriculum [1-9, 11, 12, 14-22]. There are many components in a typical international service learning experience that can benefit both the students and the school [10, 13]. One of the first and well documented benefits comes from the value that 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 also 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 [40].

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. By working with the local NGO and engineers assigned to the team they can expand their knowledge based by using the expertise of these local engineers as a resource for their design. Finding these local contacts is a very important component of these international projects.

In addition, 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 this 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 in 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 than 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 [40].

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. The local client might have the engineering experience to review the student project and thus act as a typical outside project reviewer. If this is not possible the faculty member working with the student team can provide this design review. In either case the students learn how to incorporate design review comments and adjust their projects. 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.

There are several different methods that can be used to incorporate international service learning experiences into university curriculums [9, 11, 15, 19, 20]. 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 [13]. 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 [7]. 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.

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 [13]. 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 Borders, 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.

### **The Value for Students**

Students benefit in different ways from different aspects of the coursework. We have found it helps to develop students' accountability and self-reliance, to improve student confidence and performance, to help students understand how course materials will be used in their future, and to encourage community involvement. The project based service learning aspect provides real-world experience and a concrete starting and ending point, simulating the real-world project implementation experience. The service-learning aspects introduce the concept of engineering as

a tool for helping society, the importance of understanding customer needs, and introduce an invaluable depth to the experience of engineering. An experience like this early in the professional career is exciting and stimulating, as the most basic assumptions in our daily lives are challenged. Those moments, when students' senses are peaking, are opportunities for transformational educational impacts that can have ripple effects on their future lives and careers.

### *Project-Based Coursework*

The benefits of project-based coursework have been well documented [23-29]. Project based learning can help to develop the higher order critical thinking, life, and self-management skills that are so important for any young adult. The project format also allows students to more actively engage in learning, delve deeper into an issue, makes the content more meaningful, and is an effective way to engage multiple different learning styles into one project. Students are empowered to take initiative and responsibility for their own learning, and ultimately make critical choices as to which part of the project process they wish to explore [30]. One of the key elements of project-based coursework and employment in the engineering field is interaction with and accountability to a client. Designing to satisfy the needs of a client, reporting information clearly to keep your client updated on progress, and dealing with changes requested by the client are all integral parts of the project cycle. Our students have shown, again and again, to rise to these newly introduced challenges and gain a sense of accomplishment that a traditional lecture-based course cannot match. Additionally, project-based learning promotes the development of project-management skills, teamwork, and the ability to effectively schedule around other commitments. These life-skills are important to any working professional, but specifically the engineer of today. As globalization and technical competitiveness are changing the landscape of the job market, a new approach is needed to train these engineers [31, 32]. Project-based learning has consistently been shown to be one of the most effective strategies for this purpose.

### *Service-Learning*

Benefits of service learning to students involved are less documented, as the phenomenon of service-learning has grown out of the project-based learning paradigm, but practitioners of service-learning have become convinced it is an effective tool in many aspects of engineering education. There are also different levels of service learning. Working in a soup kitchen is a different type of experience than performing an engineering design for a community living in a jungle. They can both be defined as charity, but the tasks require different skills. The context of Civil Engineering service learning is a project that allows the students to use their engineering skills to provide a service that impacts the quality of life for the people involved.

Over the years researchers have been garnering evidence of the short and long-term benefits of service learning [33] and urging its addition in standard teaching curriculum. Service learning has a distinct advantage over traditional teaching techniques in that it adds two additional elements to the obvious goal of learning course content: the local community is served by students, and those students are then forced to reflect on the connection between the course educational objectives and the experiences they had in the field. Education ultimately is meant to produce positive results for society, and this point is inherently reinforced through the service-

learning experience. Combining learning and service objectives ensures that both the community partner and the students providing the service receive benefits from the interaction. In a lucrative field such as engineering, service learning is one opportunity for students to give back to their local community, learn about the personal and moral merits of engineering, and gain a understanding of the struggles that underserved populations encounter. Engineering as a field was developed to respond to the needs of the community, and service learning provides an experiential framework for this [34 - 39].

### **The Value for an Engineering Program**

These “soft skills”, which are very effectively taught using a service learning course, specifically address the objectives and program outcome criterion set forth within the ABET Engineering Criteria [39]. The objectives of ABET accreditation are to:

Assure that graduates of an accredited program are prepared adequately to enter and continue the practice of engineering; Stimulate the improvement of engineering education; Encourage new and innovative approaches to engineering education; Identify these programs to the public.

A service learning course for engineers provides a unique methodology for improving engineering education by providing students both a classroom and real world learning environment, thus effectively learning skills beyond the traditional course material. This increases their effectiveness as engineers in the future work force and their value to the world community as problem solvers. Furthermore, by teaching these skills through service to a community organization, not only is the public becoming involved with and benefiting from the student’s education, they are also learning more about the role of engineers in society. Thus, technically oriented students are exposed to non-technical issues, and the general public is exposed to some of the technical aspects of design and problem solving.

The ABET accreditation criterion for program outcomes and assessment include among others: an ability to apply knowledge of mathematics, science, and engineering, an ability to function on multi-disciplinary teams, an ability to identify, formulate, and solve engineering problems, an understanding of professional and ethical responsibility, an ability to communicate effectively, the broad education necessary to understand the impact of engineering solutions in a global and societal context, a knowledge of contemporary issues, and an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

All of these criteria are outcomes of a service learning course for engineers. The outcomes listed above cannot all effectively be reached through a single traditional course. Introducing the concepts and true importance of professionalism, communication, team work and problem solving in a service oriented program forces students to focus on how their engineering education can and will be used following graduation. It prepares students for what to expect when put in a work environment. Furthermore, it results in an improved reputation of an engineering program, as the quality and work-preparedness of its students increases. While experiencing the thrill of solving a problem which is of value to a community partner, students become drawn in to their course material and fine tune the development of their problem solving skills.

In short, a service learning course for engineers results in more engaged students who more deeply appreciate their skills as engineers and the value of their education to themselves and to their community.

### **Typical Senior Design Course Format**

The CEE Senior Design course is setup as a full semester based course. Students normally take the course in their final semester before graduation to be prepared for real engineering life out of school. The course is 15 weeks long and there are two - two hour lecture and presentation sessions in each week. The actual lecture part of the class lasts for 50 minutes, however, two-hour sessions are scheduled so student teams can get together and work on their projects. The course takes advantage of several faculties and mentors. Each faculty member works with one or two teams depending on their project topic and concentration in the field of Civil and Environmental Engineering. In addition, one or two mentors may work with teams in need of additional help with software trainings and analysis. Normally classes start with lectures from faculty and invited speakers, which are followed by students' presentations and results discussions. Students then stay longer if needed to work with their teammates on their next tasks. The course schedule for CEE Senior Design is setup to make students work in a team on a design project. The time in class is not used to work on the design. The students work on the design projects either in the second hour of the class or meet after class as a team. The class time is used for the students to make presentations and for professional development discussions.

Typically the design project is an idea from the students, or a concept proposed by a faculty member. The projects are selected such that there is a design component for any area in Civil Engineering, for example: structures, geotechnical, water resources, environmental, sustainability, transportation, or construction. The students will be assigned to the project based on the need of the project and the interest of the student. Typically the projects are not real, in that they do not provide engineering services to communities in need. Over the past 5 years, one exception to this concept is the result of including some overseas projects that provide help to unprivileged communities through the design and construction of various water related projects. The value of these projects is they typically require some type of design component for all the Civil Engineering focus areas: structural, water resource, environmental, geotechnical, and construction. Thus the project allows the faculty member to create multidisciplinary design teams. For example to provide a simple water system to a community you need to build a storage tank that requires structural and geotechnical designs. The tank and piping needs to meet the needs of the population and involves water resources, environmental, sustainability and construction components. In addition, you need to help the people create a water department to maintain the system. Thus, what looks like a simple water main project can actually impact any Civil Engineering student in the course.

The course starts by dividing students into teams based on their concentration and interests. Typically teams consist of four to eight students, but can be as large as 10 students. In the following two sessions, students get to know each other and discuss their interests and capabilities and their responsibilities in the project that they were assigned to, and meet with any

faculty member assigned to help them. Note, the class meeting is not for the students to perform their design, that task is done outside the classroom.

Project planning and scheduling is one of the first tasks that teams work on and present to the class by the end of the 2<sup>nd</sup> week. The next assignment is the Capability assignment where each student discusses their individual strength and skills that will allow them to perform the tasks required in the design. The concept of a Capability report is to model what a typical consulting firm must do when responding to a RFP. Teams make their presentations in weeks 3 and 4. In session 8, week 4, students learn about Value Engineering, Constructability Review, and Risk Analysis. This process is better explained by doing Value Engineering on one of the projects as a demonstration. Students then discuss and present their take on Sustainability in their projects in week 5. In week 6, students are introduced to the concept of political and ethical issues and get familiar with issues and limitations they would face during an engineering project. The first Progress Report is due by session 12 in week 6. Invited speakers from engineering companies and/or project clients explain design process and engineering team work to students. The 2<sup>nd</sup> project report is due during sessions 14 to 17, when each team presents its work, discusses their engineering efforts, and their next steps to the class. As a unique experience, all teams are required to attend these sessions where they can interact with other teams and discuss the issues. In the next four sessions, teams work on their response to the political and/or ethical issues assignment, and share their thoughts with the class. They also have to work on their next progress report. In the next session teams learn about the Design Expo, Life Long Learning and its promotion. Teams present their 3<sup>rd</sup> and final progress report in Week 13. During each progress report members of the other teams make up Value engineering teams to assess each progress report. In week 14, teams prepare their final project deliveries, and submit their course evaluations. Session 29 is designed for teams to present their work in the Design Expo conference held every semester by the University of Pittsburgh. The Design Expo is a school-wide poster session involving every senior design project in all 6 departments. During the Expo the students present the design and are evaluated by corporate judges. The CEE Department also requires an additional presentation where all the senior design students present their final work in a one-hour presentation for all students and faculty. Table 1 shows the general schedule for CEE Senior Design course at the University of Pittsburgh.

Those students who enrolled in ENGR 1098 for the international exposure are required to work on a specific topic and travel for approximately 10 days to the country of the target project. This requires extra effort, coordination and scheduling from the instructor. Therefore, one instructor (and maybe a mentor) has to work closely with the travel team and prepare them for the trip. The instructor who is in charge of international service learning projects has to be well experienced to make sure the students can fulfill the requirements for both the Senior Design and the International Experience courses. The faculty member also has to travel with the students and be available to the students.

In this course, students and teams are evaluated through their team-work and collaborations, project deliverables and final product, presentations throughout the semester, feedback and evaluations from their project clients, Expo judges and instructors. Moreover, student outcomes and team efforts are analyzed by this research and the surveys conducted in 2014 and 2015.

**Table 1: Senior Design Course Schedule in Civil and Environmental Engineering program at the University of Pittsburgh**

<b>WEEK</b>	<b>SESSION</b>	<b>SCHEDULE</b>
<b>Week 1</b>	Session 1	Assign teams
	Session 2	Teams talk to each other
<b>Week 2</b>	Session 3	Teams talk to each other
	Session 4	Project management - Work your Plan, Discuss Capability presentation
<b>Week 3</b>	Session 5	Student Capability presentations
	Session 6	Student Capability presentations
<b>Week 4</b>	Session 7	Student Capability presentations
	Session 8	Define Value Engineering, Constructability Review, Risk Analysis
<b>Week 5</b>	Session 9	Value engineering on one of the projects
	Session 10	Sustainability presentation, Assign political issue
<b>Week 6</b>	Session 11	Progress report
	Session 12	Progress report
<b>Week 7</b>	Session 13	Guest Speakers
	Session 14	2nd phase progress report
<b>Week 8</b>	Session 15	2nd phase progress report
	Session 16	2nd phase progress report
<b>Week 9</b>	Session 17	2nd phase progress report
	Session 18	Political response 1
<b>Week 10</b>	Session 19	Progress report
	Session 20	Political response 2
<b>Week 11</b>	Session 21	Political response 3
	Session 22	Define Presentations
<b>Week 12</b>	Session 23	Design Expo Update - Sustainability, Life-long Learning and the promotion of it
	Session 24	Value of Engineering
<b>Week 13</b>	Session 25	3rd Progress report presentation
	Session 26	3rd Progress report presentation
<b>Week 14</b>	Session 27	Prepare for final project and courses evaluations
	Session 28	Prepare for final project and courses evaluations
<b>Week 15</b>	Session 29	Design EXPO
	Session 30	Senior Design Department Presentations

*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.

### **Designing New Service Learning Projects based on our Previous International Experiences**

During academic year of 2010-2011, the first international engineering service learning project within the University of Pittsburgh was developed. The pilot project was collaboration between the senior design course and local chapter of Engineers Without Borders. Gradoville et al [10, 11] evaluated the project outcomes by conducting surveys and evaluating students' performance throughout the course. A review of that study, given below, shows 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 teamwork, 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 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].

We have continued to provide international design experience because of this positive outcome and last year in the Fall 2014 we repeated the survey to determine if we could get the same results or was the 2011 outcome just a result of the specific project. There were four projects 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 Panama trip had an in country component while the Ecuador project did not include any travel. Students self selected themselves into each of the projects. 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. Plus, the questions used in the 2011 survey were repeated [40].

A review of the data given in Figures 1-3 shows the same basic trends between last year and 2011, supporting the concept that the international experience is what makes the difference, thus

we able to repeat the results even with different projects in a different country. The results are included in the results section of this paper as a comparison. The positive results are very encouraging, however, sustaining a group of international projects is very difficult. The cost of travel and the time away from campus during the semester makes it difficult to recruit students. The interesting result from last year was the international team that did not travel scored about the same as the team that did travel. Meaning there is something in the nature of these experiences that makes the difference. Thus, this past Fall 2015 we decided to see if we could take the basic components from an international design and apply it to a local domestic project. We have over 100 students that have been involved with our international projects over the past 5 years, so we asked them to explain what was the major difference between their projects and the other senior design projects. Their comments covered a large range of topics but the two main issues were that the projects were real and that they got to work with a real client.

So in the Fall 2015 semester we had 4 projects, The Midway Hotel at Conneaut Lake, The Bigelow Boulevard Reconfiguration Project, The Trinity Acres Youth Camp Master Plan, and A Water expansion project in Kuna Nega, Panama. The first two projects were made up projects, the hotel was basically the cost estimate of a possible hotel, and the Bigelow Boulevard project was the redesign of a road that cuts through our campus. The last two were real projects with actual clients. Trinity Acres was a non-profit organization that was looking for a concept analysis to use as a starting point to expand a site for a youth camp, and the Kuna Nega project was a water system expansion project outside Panama City, Panama. In each projects the students had to collect data for their actual site and thus had to contact outside people for help. However, the two projects with clients had people that were actually vested in the project. In the case of the camp, the students concepts would be the starting point for the non-profit organization to hire a consulting firm to complete the design and in the case of Kuna Nega the students actually traveled to Panama and installed part of their design.

## **Results/Discussion**

### **A. Result Validation**

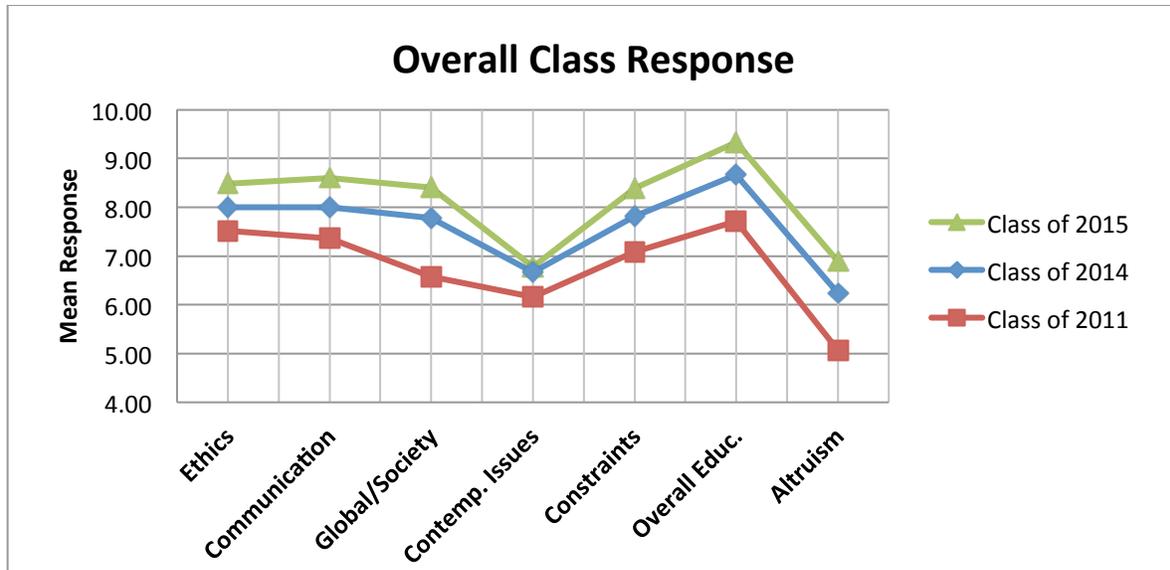
To better evaluate the outcomes and to compare students' responses, results from Gradoville et al [10] are adopted as our reference. Gradoville et al studied the service learning in Ecuador as part of senior design course in spring 2011, and developed a survey to measure students' outcome. The same survey questions (seven questions in Table 2) were included as part of our survey. The questions were answered on a scale of 1 – 10, from not at all to very much.

It is very difficult to compare data between the various design projects over this time frame because each design project is unique. Each semester we may have 4 – 6 design teams of between 6 – 10 students and each project is different. In addition, different students within the same project perform different tasks, and each project has different focus areas, thus each student has their own unique experience. In addition, we have noticed that 100% of our students have some type of unique co-op or work experience background that typically enters the design process and impacts the final design. Therefore, when you consider all these variables it is difficult to perform a numerical comparison for our results. Instead we are looking for patterns in the student responses. To analyze the data we will display the responses of different teams as a subgroup and compare them against a different subgroup. The goal is to determine if there is any noticeable difference in the average responses between groups.

**Table 2: Survey questions adopted from Gradoville et al 2011**

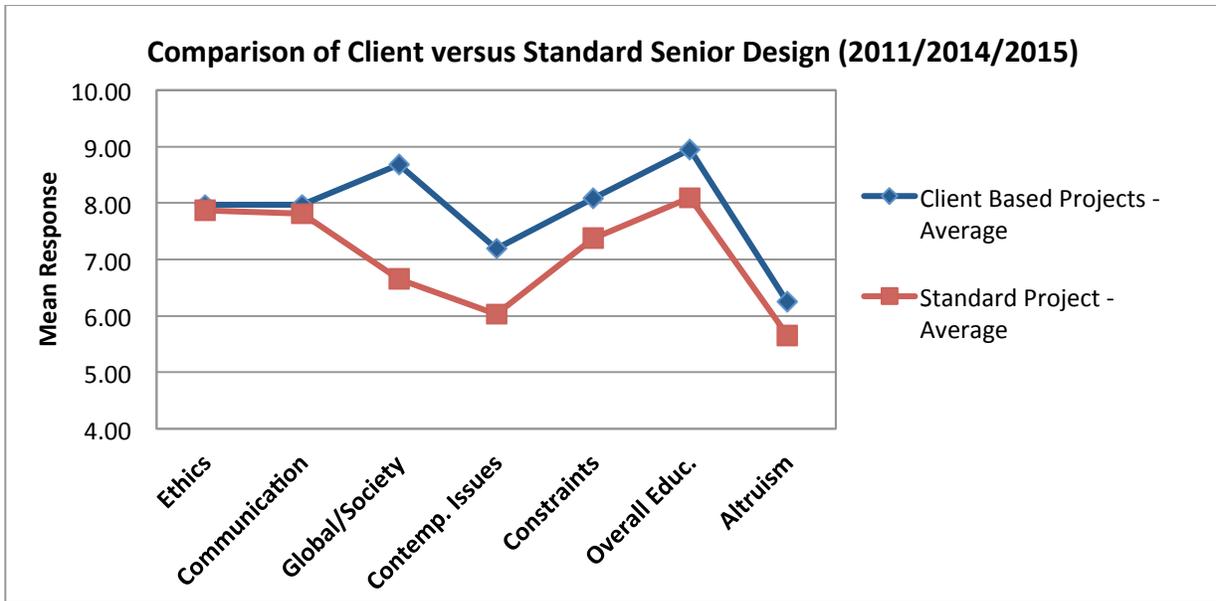
<b>OUTCOME</b>	<b>QUESTION</b>
Ethics	How much has your senior design enhanced your understanding of professional and ethical responsibility?
Communication	To what degree has your senior design experience enhanced your ability to communicate effectively?
Global/Society	To what degree has your senior 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 2015 was 8.12, while the 2014 population was calculated to be 7.60 while the 2011 score was 6.78. This indicates that the overall score among all students has increased as a result of us including more content into the syllabus as shown in Table 1. Figures 1 compares the classes' response to each question. It was found that the overall response pattern was consistent between our 2014 and 2015 classes and class 2011, while the mean response from class continues to increase each year for every single question as we expand the content in the class lectures. The maximum difference between mean scores (1.80) was discovered when asking about students experience in a global and social context, and when they were asked if they were more interested in selfless jobs (altruism). This overall increase shows that the continues improvements we put into the class lectures to get the students more involved 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 and 2014, thus supporting the concept that the 2011 findings were not a one year result.



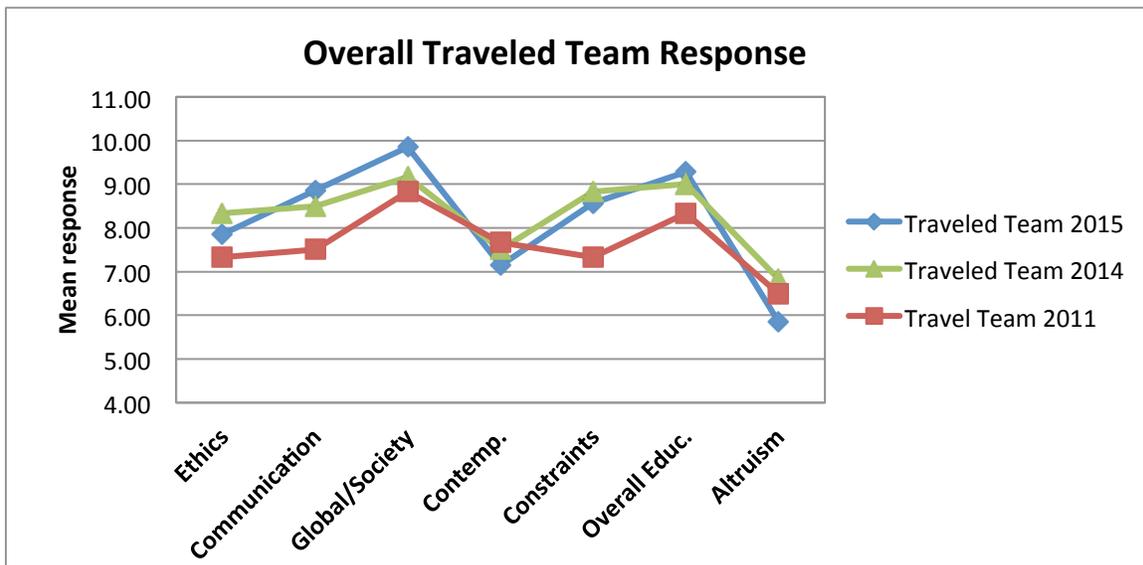
**Figure 1: Comparison of our results to class 2011 from Gradoville et al 2011**

In addition, we were interested in comparing responses of international and domestic service learning teams to see if adding the concept of clients and real projects made a difference. In 2015 Team 2 was the Panama international service project, and Team 3 was the domestic Camp master plan project. The other 2 projects in 2015 were standard domestic projects. In 2014 Teams 1 and 2 (Ecuador and Panama) were international service learning projects. The other two 2014 teams (Glenwood and Davis bridges projects) were local 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 three different years. Comparison of responses in Figure 2, from the client based “real project” teams for 2011, 2014, and 2015 indicates that the overall outcome above the non-client based projects. Then, the data just for the Client teams is shown in Figure 3, which compares the teams from 2011, 2014 and 2015. This data basically shows similar trends, thus, the nature of the project is not what is important. The travelling and getting exposed closely to the community culture was the common experience and what is important. However, the overall average score of the international teams continues to get higher each year. The largest difference was found to be the highest when students were asked about realistic constraints in design, such as global, society, economic, and ethical issues.

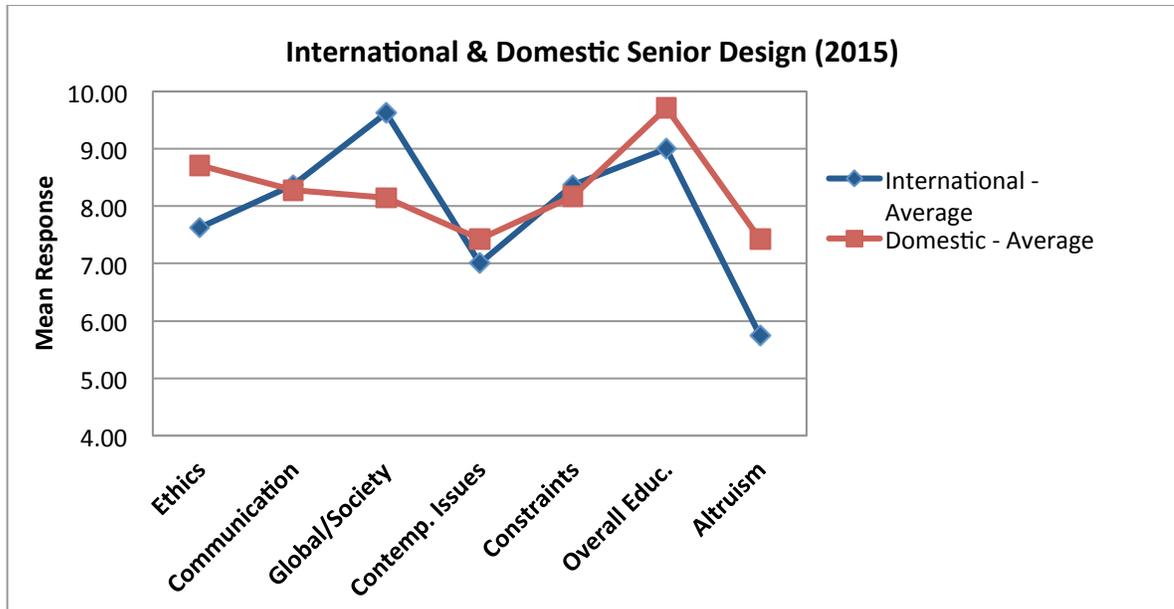


**Figure 2: Comparison of Client and non-Client based service learning projects in 2014 and 2011.**

Finally, Figure 4 plots the 2015 groups with the real clients, one being international and one domestic. They are basically the same showing the importance of interacting with an actual client and working on a project that is actually going to happen. Note, the international team scores higher on global issues and then they also appear to understand that money is not everything.



**Figure 3: Comparison of travel teams 2014/2015 and 2011**

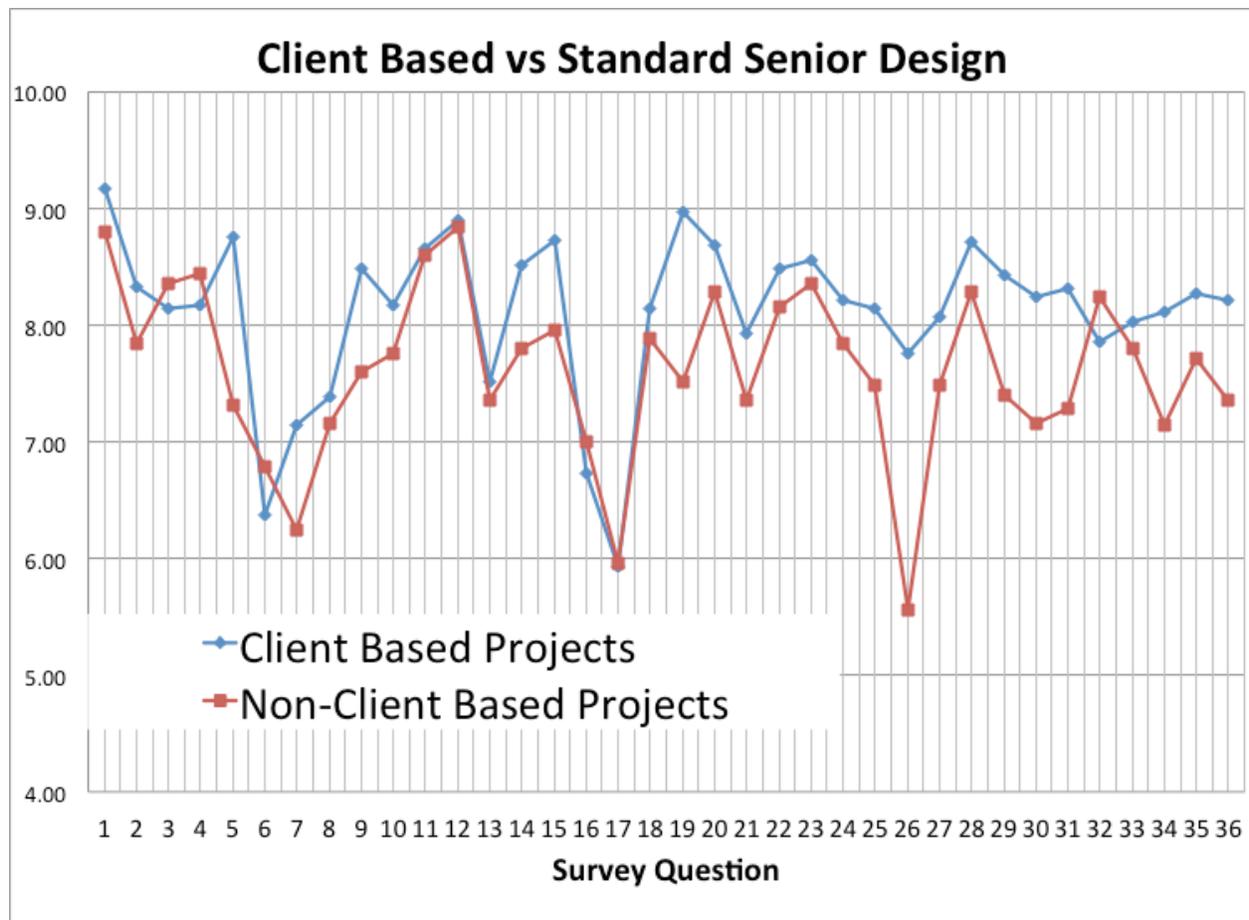


**Figure 4: Comparison of Client Based teams Domestic versus International**

## 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 and 2015 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 7.89 out of 10. The average score was calculated to be 8.40 for client based teams, which was well above 7.60 for the remaining team. This emphasizes how exposure to client based 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.

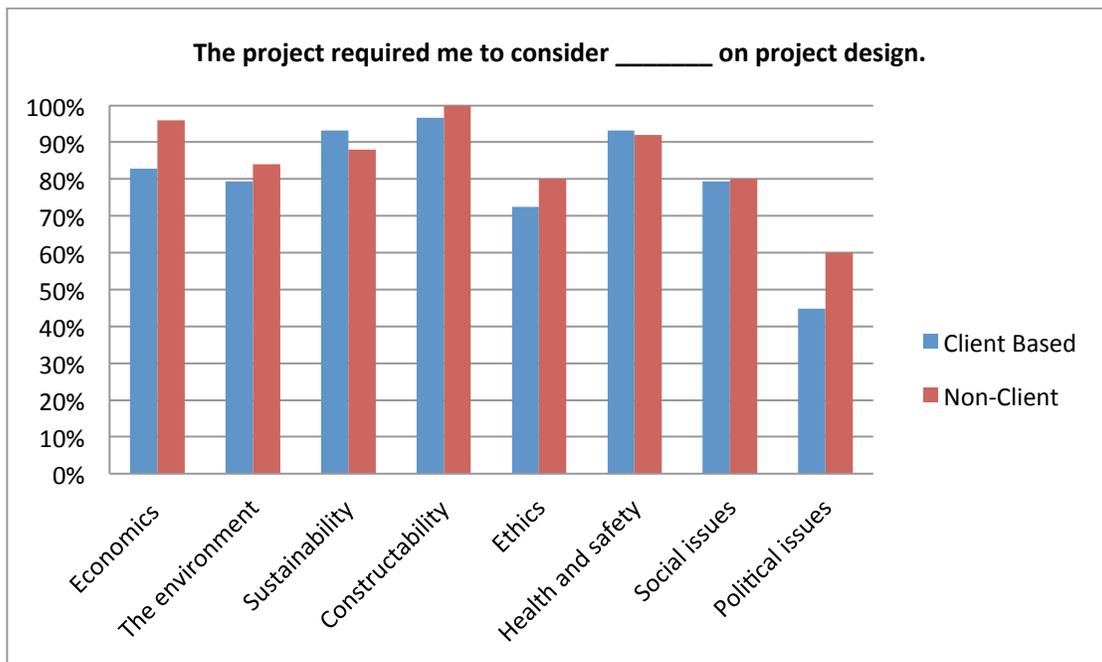
Figure 5 shows all 38 questions and compares the average ratings for the client based and standard senior design projects. It was observed that the overall patterns of responses were consistent. However, in almost all questions, the students in client teams rated their experience higher than students in the non-client teams. This could be an indicator of a general positive improvement in students' attitude and perception.



**Figure 5: Response comparison of international and domestic service learning teams**

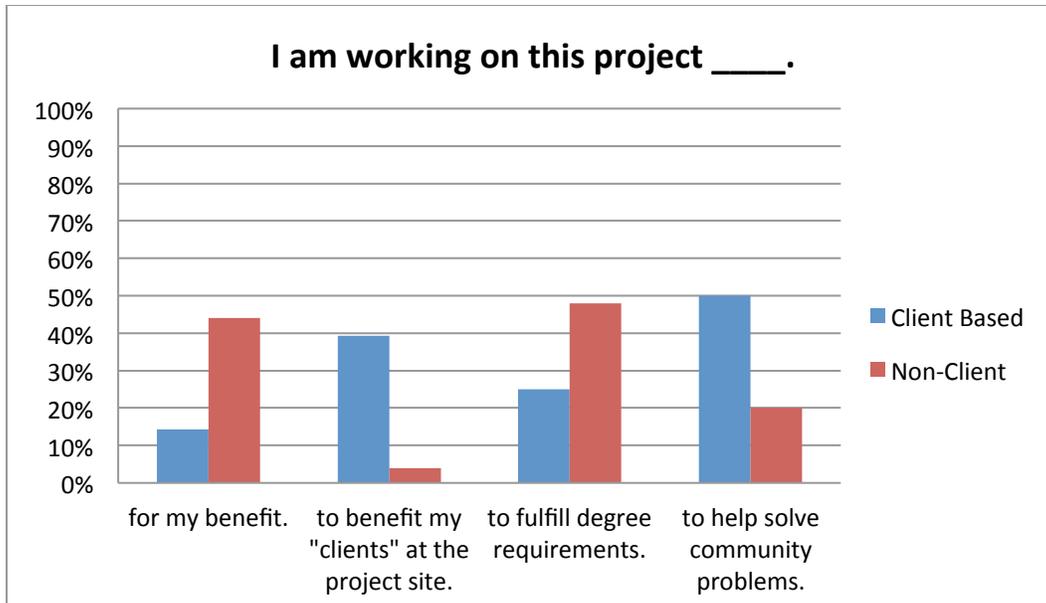
The maximum differences between responses from the client versus non-client based teams are in Questions 5, 19, 26, 30, 31 when the average responses differences are above 1. Question 5, understanding of engineering in social and global context, is already discussed. Question 19 “The project required me to work in multi-disciplinary teams (i.e. people with different professional training)”, shows that the students on these teams understand the value of team work more than the other groups. Question 26, “This experience will change what I value in my own life” once again shows the added value these projects give to understanding the needs of society. Question 30, “This experience will be greatly valued by prospective employers”, shows the students are understanding how their education fits with the needs of future employers and the value of working with a client before they graduate. Finally Question 31, “This experience will be of great value to me as a person (non-professional reasons)”, also addresses the gain related to showing the students the connection between their lives and their profession. In summary, these service learning projects expand their overall experience, attitude, and perception regarding the senior design course changing the values in their life. This indicates how understanding the needs of their client could change students’ perspectives and make them feel better about their profession and its impact.

When students were asked what aspects of their project required them to consider “blank”, there were some interesting outcomes (see Figure 6). It was found that international service learning teams did not consider the political issues into their design. This makes sense since both teams worked on designing a water distribution network for a poor community in another country, or a park for a church organization, 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 also interesting that the client teams did not focus on money and the cost of the project as much and were more concerned about meeting the needs of the client. Money was an important factor, but not as important as designing something that completed the task. It is observed that domestic team, and especially the Bridge teams (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 client based students had a better understanding of sustainability and they considered it in the project.



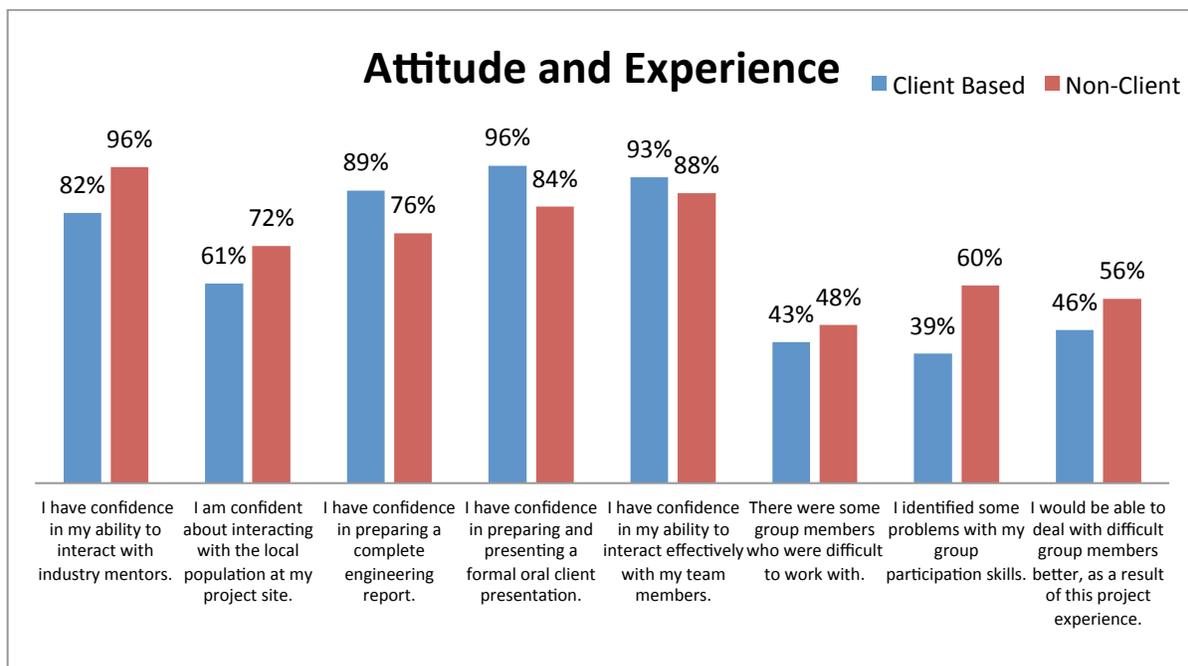
**Figure 6: Student responded what aspects the project required them to consider in project design**

Figure 7 shows the results of the question that tested the 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 the service learning students considered to help solve community problems the most (50%), and then to benefit their clients at the project site (40%). 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 the other projects indicated that the most important reason was to fulfill degree requirements (50%), and then for their benefit (45%), and very few of them considered working on the project to benefit their clients.



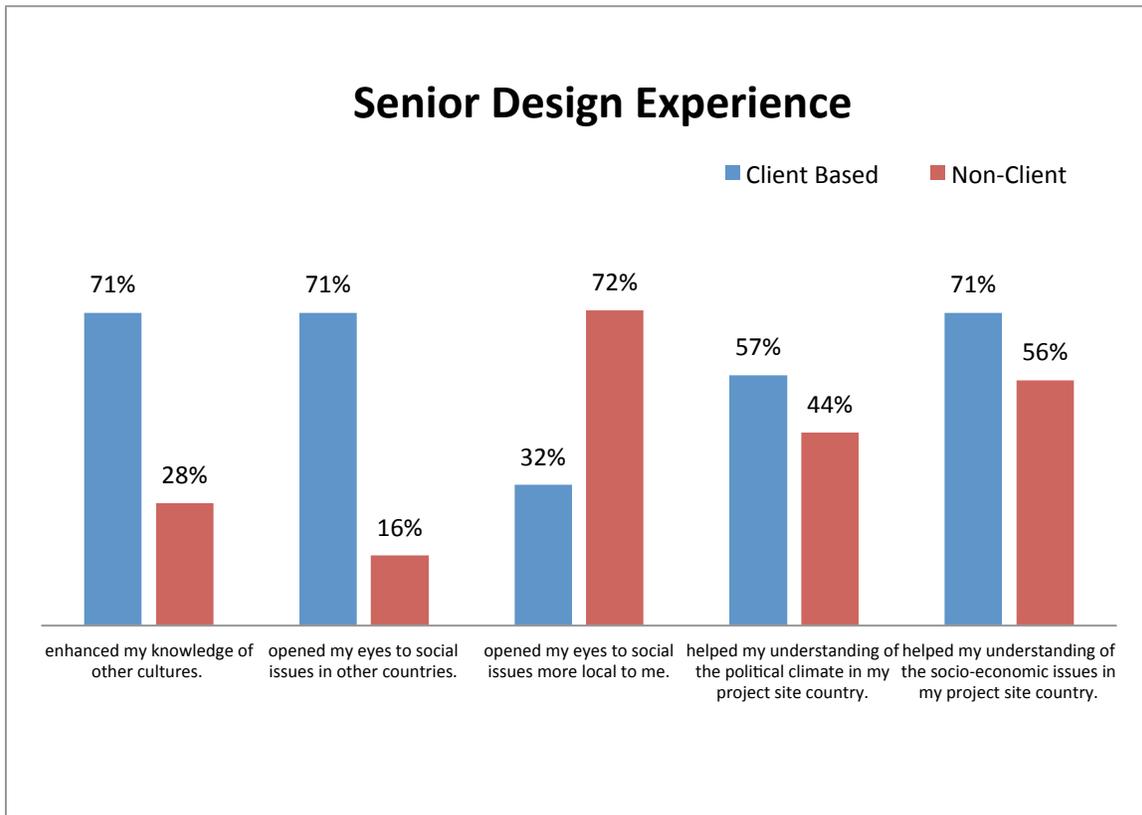
**Figure 7: Motivations behind working on the project**

In another question students were tested for their motivation and experience. They were asked to check as many as applied. The summary of the results for the service learning teams versus the standard senior design teams is presented in Figure 8. Because the client based teams were more exposed to their community they showed more confidence in report preparation, presentation, and effective communication. They also showed less indication of problems within the team members. Client teams in overall showed less confidence in interacting with the local population. It is interesting to find that teams who was exposed and interacted with the local community were less confident while the other teams were more confident.



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

Finally, Figure 9 evaluated the students overall experience in the senior design course. Interestingly, it was found that the 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 the teams. Figure 10 shows the average score (out of 10) by service learning vs non-client based projects. It was found that in all ABET outcomes students involved with client based service learning projects rated their experience higher. The motivation and experience of working on an real project appears to raise the experience for the students. We observed similar patterns in responses to almost all ABET criteria except ABET B and H. ABET B is asking students about experience with design and analysis. There is a distinct difference between client and non-client project teams. We observed more confidence and attitude among students when they felt the project is real. Five different questions were designed to test ABET H. The results indicate that mainly the design experience and value of client based service learning increased students

response. These results show a great advantage by including an real world service learning experience within the typically Capstone design course.

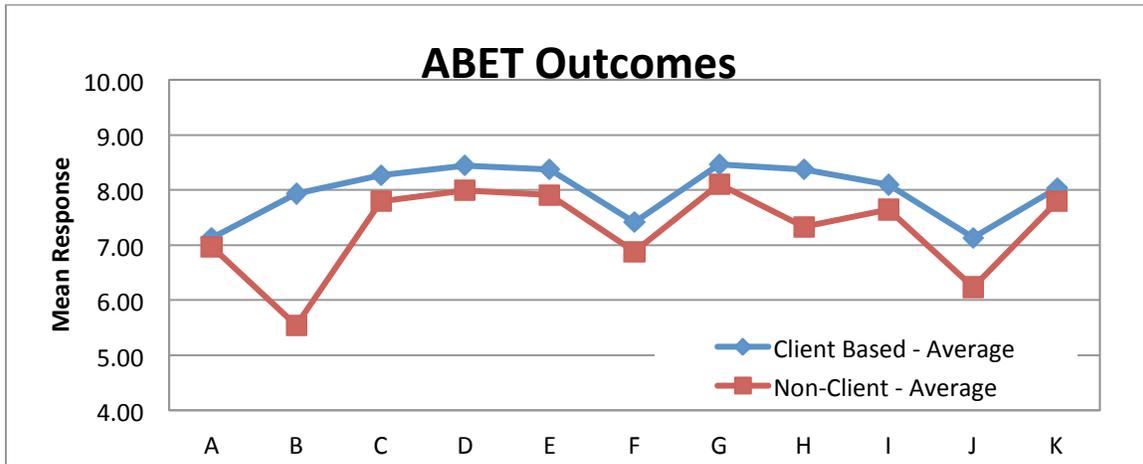


Figure 10: ABET outcomes of client based and domestic teams

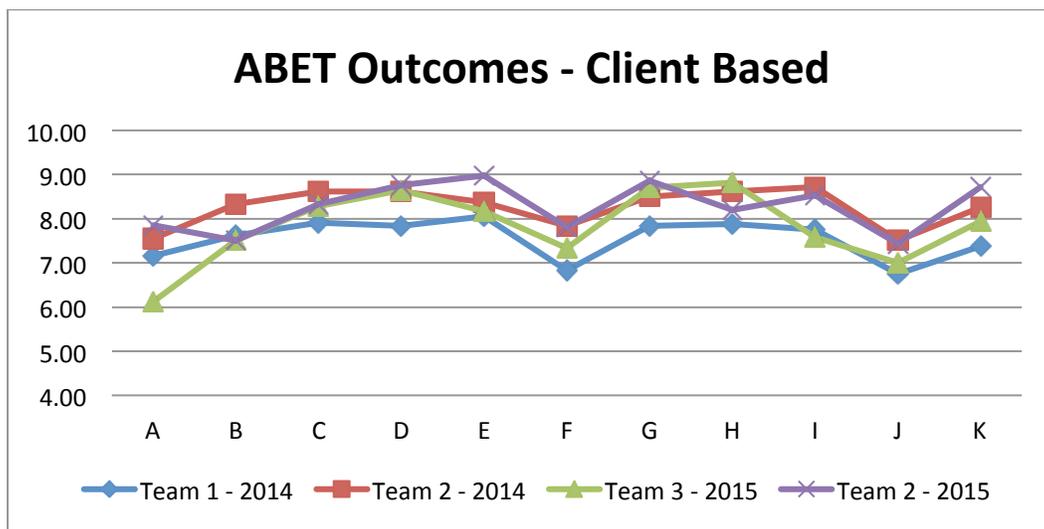
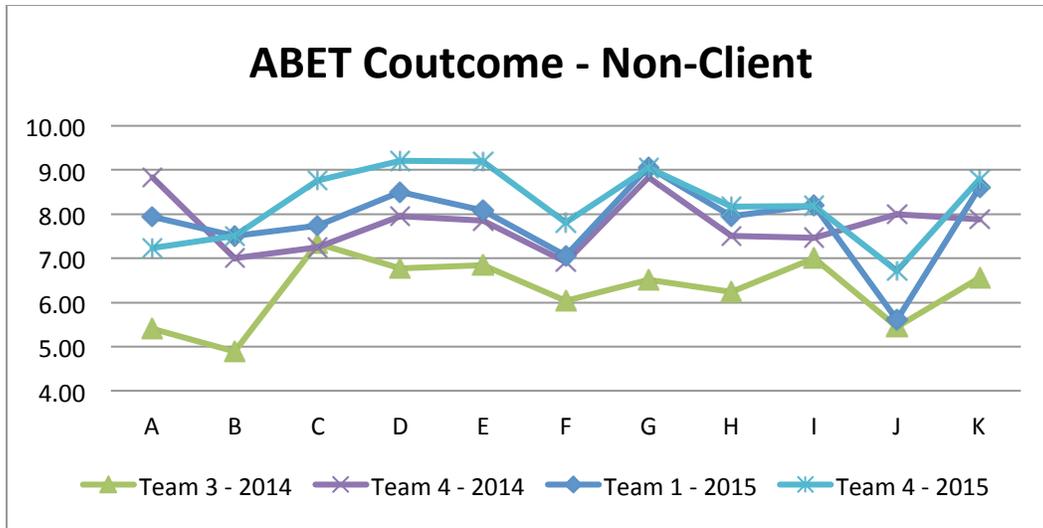


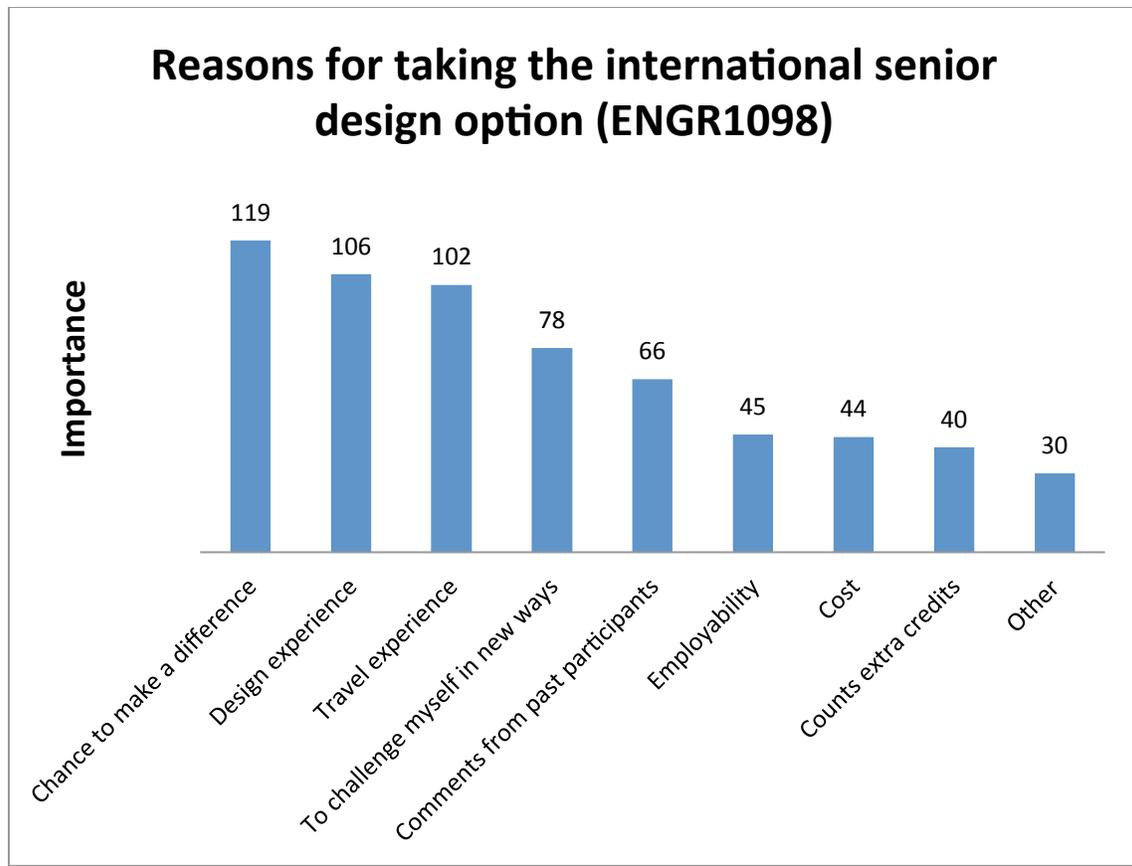
Figure 11: Comparison of international service learning teams

It is found that all the international teams and the domestic church camp team responded fairly similar to all ABET outcomes. The results in Figure 11 shows there is basically no difference between these teams. The same data is plotted in Figure 12 for the non-client based teams. As shown in Figure 10 the numerical values between the client and non-client teams are close to the same. However a comparison of Figures 11 and 12 shows that the non-client based teams have a larger range in the values. This could mean that the selection of the non-client based teams must be made with more caution since the student outcome varies more with these types of projects.



**Figure 12: Comparison of domestic service learning teams**

The final question we studied was why did students want to do the international experience. This is not a cheap option. Each student must purchase his or her own airline ticket, passport, and medical insurance. In addition, there was a Study Abroad fee that covered room and board, transportation, etc. Typical cost is on the order of \$2000. So why spend the money if you don't have too? Over the past 5 years we have had over 130 students travel on these projects and their responses are given in Figure 13. The results show that one reason is just to travel, but the general theme is they want to do something to challenge themselves and do something that will make a difference.



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

## 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. We found that our semester long engineering senior design helps students face challenges those engineers in real world face. If you compare the experiences of our students who did an international and/or domestic service learning senior design project against those who did a typical make believe project, our real world project members appeared to have a more complete design experience. Giving the students access to a real client tend to increase the student understanding of the big picture of engineering and was a benefit to the students. These projects help students go beyond the typical engineering experience because they are exposed to projects that force them to understand the real world needs for engineering services within economic and political constraints. Universities also benefit as these projects meet or exceed the ABET Engineering Criteria.

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