ASEE AMERICAN SOCIETY FOR ENGINEERING EDUCATION

Paper ID #27861

Bringing students to real-world training environment through service-learning senior capstone projects with K-12 outreach activities

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Bringing Students to Real-World Training Environment through Service Learning Senior Capstone Projects with K-12 Outreach Activities

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Abstract

Service learning is an innovative training technique where a service project or service experience is incorporated in an academic course and is evaluated as part of the course overall grade. In this paper, we present the design, implementation, and outcomes of a senior project capstone course where service learning content and K-12 outreach activities are incorporated. We collaborated with a community partner, Ganesha High School in Pomona city, to provide students with service learning experiences. The first course project includes an outreach seminar to introduce solar energy to the high school students and an A-to-Z project to build a solar charging station. The second course project includes developing computer programs and teaching the high school students 3-D printing techniques. Both projects aim to motivate participated students to apply engineering knowledge to serve people. The two projects proved to be exciting experiences for the college students. They are highly engaged and motivated to work on the projects. We observed that the senior project teams become more responsible and proactive regarding their work. They applied critical thinking skills and creativeness in developing 3-D printing programs, building the solar charging station, making presentations, and implementation of the entire projects. At the conclusion of the projects, we have donated the solar charging station of $1700 value to the community partner. Overall, the experiences have opened the student eyes and minds to the real-world situations where they interact with people who have specific needs and constraints. These factors motivate them to learn and work responsibly.

Index Terms **—** Innovative training technique, K-12 outreach activity, real-world training environment, service learning, senior project capstone course, solar project, 3-D printing project.

1. Introduction

Service learning has become an important part of teaching pedagogy at the California State Polytechnic University Pomona (Cal Poly Pomona) for a number of years. It provides students with structured opportunities to learn through active participation and organized community involvement. A service learning course is an academic course where a service project or service experience is part of the overall grade[1]. Prior to winter 2018, the service learning courses offered at Cal Poly Pomona are primarily regular courses. In winter 2018, we developed the first service learning senior project course (called ECE 467S Team Project III), which is the final capstone course in a series of three quarter-based courses required for all engineering bachelor degree candidates. The course was first taught in spring 2018. In this paper, we present the design, implementation, and outcomes obtained from the course.

The special feature of the senior project capstone course is that students typically work in teams on different projects under supervision of different instructors. Occasionally, a student is allowed to work alone on a project. Given this feature, a single syllabus would not suit all projects and all teams. Therefore, we developed a general framework for the course. Then, based on the general framework, each instructor develops a customized syllabus for a particular project.

The general framework is as follows:

1) The course is a 1-unit class that comprises a team-based technical project component and a service learning component. It is an activity course, i.e. it may include classroom meetings, lab-based design, service learning, and other appropriate activities to meet the course learning outcomes.

2) The course learning outcomes (CLO) are specific for each project but must satisfy both the technical and service learning requirements. Evaluation/grading procedure(s) must be defined based on these requirements. The technical content includes design and implementation of engineering systems (hardware and/or software) at upper division level. Service learning content includes diverse activities with community partner(s) so as to benefit both the college students and the partner(s).

3) A minimum 10 service learning hours are required for each student. Each project team must work with an external community partner for the service learning experience.

4) Reflective activities are included in the course where students are encouraged to discuss with other team members and the instructor about their experiences with the course and any improvement that they believe is necessary.

5) The common goals for all projects are: (a) college students effectively learn the technical content; and (b) students learn to work with community partner(s) and provide meaningful service to the partner(s).

The course taught in spring 2018 involved two separate team projects, which were independently supervised by two instructors, Ha Le and Zhen Yu. The first project is a solar project and the second project is a 3-D printing project. The projects will be described in details in following sections.

It should be noted that the prerequisite for this final capstone course includes two senior project courses taken in sequence. Therefore, part of the content required for this course may have been covered in those two prerequisite courses, depending on projects. Since the service learning content was officially approved in winter 2018, it was only been implemented in spring 2018.

Looking back at previous work on teaching methods, educators have been trying many alternatives to help students learn course materials better. Learning centered approach (instead of teaching centered) is one such paradigm. Flipping class is another approach being used in different educational institutions. It is known that learning is not a one-way street where educators / instructors / professors talk in class or use board or Power Point while students are simply the receptors. Educators hope that the student-receptors will receive and digest 100% of the written materials and the words that the teacher delivered. However, this is not always the case so other innovative training methods are needed. *"Learn by Doing"* [2] is a motto at Cal Poly Pomona. This motto is especially true for engineering education where practice is a key to comprehend technical theories and skills.

Service learning approach originated from the hands-on learning or experiential education. The power of experiential learning has been pointed out in various work [1, 2, 3, 4]. Specially, in service learning, college students do not only learn by doing, they can also make or produce useful professional-grade product, thereby having the feeling of accomplishment. Alternatively, they can undertake a role as instructor and teach high school students, elementary school students or other people using knowledge and/or expertise they know themselves or they learn from college. In this way they perform community services or do the so-called community-based services [6].

As mentioned previously, in 2018, we, two instructors at Cal Poly Pomona, developed a service learning course called ECE 467S, which is a senior capstone class with the flavor of service learning. We cooperated with the local Ganesha High School where some of the high school teachers and many high school students were involved (about 40 students). We had two teams working on solar power and 3-D printing projects. These are engineering projects where college students learn to design and implement technical systems and at the same time learn to perform community service.

The solar power project designed and built a $1,700-value solar charging station which was donated to Ganesha High School at the conclusion of the project. Additionally, the college students taught the high school students an A-to-Z process to conduct an engineering project through a seminar. The 3-D printing project facilitated the college engineering students to work as instructors. They taught the high school students to use 3-D printers to print materials using 3-D software. A design contest was organized at the end of the project for the high school students to demonstrate what they learned.

The content of our services learning projects is close to what Giles and Eyler [4] described: *"the practitioners of service-learning are more oriented to action than scholarly pursuits"*. It also embraces the idea of constructivism described in Ben-Ari's paper [7]: *"... knowledge is actively constructed by the student, not passively absorbed from textbooks and lectures".* Furthermore, it follows the idea described in Mariappan, Monemi, and Fan [6]: *"Constructivist learning environments emphasize knowledge construction instead of knowledge reproduction*". The ideas are applied to the solar power and 3D printing projects where we do not formally instruct most of the training and practical details in the classroom. Instead, we bring our students to a real-

world environment where our students are given great freedom to create and conduct their activities and learn through them.

We observed that our students learned enthusiastically and vigorously after just a few weeks into the projects and became very productive. They also became very good instructors to the high school students. In Bielefedt and Pearce [3] (page 27) and Butin [8] it was stated that four elements (4R) should be present in all service learning activities: reciprocity, respect, relevance, and reflection. *"Reciprocity"* means that both the (college) students and the community benefit from the activity. *"Respect"* means having a balanced partnership with both sides respecting each other. *"Relevance"* means that the service is relevant to the learning objectives of the course. Finally, *"Reflection"* gives participants a chance to reconsider their activities, then adjust or improve them. From our course content explained above (and more details to be provided later), our service learning projects satisfy the 4R.

Overall, the outcomes and experiences obtained from the projects confirm to us what researchers have found in some previous work [3, 9, 10] that university students are capable and enthusiastic to solve real world problems if they are freed to undertake structured self-directed assignments.

2. Solar project with service learning content

Six college students participated in this project. The project supervisor and advisor is Ha Le.

2.1 Project description

Technical content

The project-based course aims to train students in basic principles of solar photovoltaic (PV) systems, PV array design and installation, user-and-environment-friendly applications of PV systems, promotion of solar power usage for benefits of community, and service-learning work with an external community partner.

The project key technical component is to design, prototype, and test a solar PV stand-alone charging station for consumer portable devices, such as cell phones, laptops, music players, emergency radios, and so on.

A significant amount of preparation was performed for the final capstone course taught in spring 2018. All students who participated in the project have strong background in solar PV systems through taking an upper division course in solar PV systems and/or background training provided by the advisor prior to spring 2018. A major part of the solar-based charging station design was done in winter 2018 and most components to build the prototype of the charging station were ordered at the same time. The thorough preparation is a great advantage for the project final implementation stage because it allows students more time to build and test the charging station prototype, as well as perform service learning tasks.

Service learning content

The external community partner is Ganesha High School (GHS) of Pomona Unified School District, which is located in Pomona city, California. The service learning tasks are designed

based on discussions with the partner such that they meet the partner needs. The high school has a special program to educate their students engineering and science. The solar PV project meets the partner needs well as it demonstrates how engineering and scientific theories can be applied to create an engineering system that is beneficial to many users.

The Cal Poly Pomona student team is to perform two service learning tasks with the partner. The first task is to conduct a workshop to educate GHS students on using solar power for environment protection, and A-to-Z process to implement an engineering project. The second task is to build a prototype of the solar charging station and donate it to GHS for school staff and student use. The team is responsible for the station installation. All students are required to perform a minimum of 15 service learning hours.

Funding for project

The funding includes $1000 obtained by the instructor from the Cal Poly Pomona Center for Community Engagement and approximately $700 contributed by the student team.

2.2 Course learning outcomes and grading procedure

Students are evaluated according to course learning outcomes (CLO) based on 100-percent (100-point) grading scale. The CLO and the respective grade credits are defined in Table 1. The grading procedure was included in the course syllabus and provided to all participated students at the beginning of the course.

Table 1 Course learning outcome and credits

#	Course learning outcomes	Credit, %
1	Determining project scope	5
2	Developing a design with concrete specifications of a solar-based stand-alone charging station for consumer portable devices	25
3	Prototyping of the design and testing to ensure that the solar-based charging station works properly	30
4	Performing service learning tasks	20
5	Writing and submitting the project final report that follows a defined template	20
	Total	**100**

2.3 Implementation

The project has been completed by the end of May 2018. The Cal Poly Pomona student team conducted a workshop for GHS students on solar energy usage and environment protection, and how to complete an engineering project, from theoretical design to software and hardware implementation. The team also brought small electrical devices such as LED, switches, IC (Integrated Circuits), etc. to show the high school students and gave them as gifts. The workshop was a great success. The high school students excitedly listened, talked to the college students,

and handled some hardware. The prototype of the solar charging station was successfully built according to the National Electrical Code (NEC) and tested to work properly.

Reflective activities: Students regularly communicated with the instructor regarding all issues related to the course. The communication was done via regular team meetings, emails, and talks during the project implementation and after the project has been completed.

Fig. 1 Solar charging station of $1700 value donated to Ganesha High School

2.4. Outcomes

The solar charging station valued at $1700 was installed at GHS in June 2018 by the student team. Since then, apart from a minor adjustment, the station has been operating normally. A picture of the installed station is shown in Fig. 1. The student team also completed and submitted the final project report. A paper was written based on the report technical content (not service learning content) and submitted to a journal. At this time, the paper is undergoing a review process.

Course training quality

The training quality exceeds the instructor expectation for a senior project course. Based on the instructor observation and communication with the team, the project was an exciting experience for the participated students. Compared to 15 other teams advised by the instructor for the past 5 years, this team requires the least amount of supervision. Since the students learned that they would do the service learning tasks with the high school, they became highly engaged and motivated to work on the project. For example, they conducted the workshop for the high school students by themselves without the presence of the instructor. They developed software for controlling the charging station. They proactively contacted some local metal shops to investigate options to build the metal enclosure for the station so as to meet outdoor condition requirements. Additionally, they successfully performed a number of trouble-shooting tasks for both software and hardware by consulting various sources beyond the advisor guidance.

Impacts on college students

In terms of hard skills, the project effectively trained the students in essential engineering concepts such as system design, developing software, testing an engineering system, and trouble shooting. They also obtained writing and analytical skills through project report, design and testing of the engineering system.

In terms of soft skills, the students learned communication skill through interaction with the high school students, the local metal shops, and the people they consulted during the project implementation. They also learned how to negotiate and collaborate with other team members to come up with the final design and complete the entire project.

It is difficult to directly quantify the project impact in helping the students find future employment because many factors influence the student ability to find employment. One possible impact is that the project solidifies the student technical abilities and the soft skills, which are advantageous for future engineering jobs. All six participated students graduated after the completion of the project and three of them were employed right after graduation.

Benefits for university and College of Engineering

The service learning project helps improve the reputation of the university and College of Engineering through the community service. It contributed to strengthen the collaboration between the university and the community partner. In August 2018, Cal Poly Pomona Associate Vice President for Research visited the charging station and met with GHS principal. They discussed further collaborative activities between Cal Poly Pomona and the high school. Furthermore, the project advisor, the team, and the university are recognized by GHS and the Pomona Unified School District for the donation and support.

3. Three-dimensional (3-D) printing project with service learning content

Eleven college students participated in this project. The supervisor and advisor is Zhen Yu.

3.1 Project description

Technical content

In this project, the students are expected to learn the technologies of developing new engineering systems and products for mass customization, namely, 3-D printing, additive manufacturing, related application, and community service. The technical component is to learn 3-D modeling software, mechanism, control system, additive processes and quality control, technology of material and the future industry manufacturing processes; design and fabricate objects. In addition, students are to demonstrate 3-D printing real life objects or devices for Electrical Engineering Applications. All students who participated in the project have strong background in 3-D printing techniques through working on a 3-D printing supercapacitor project in fall 2017 and winter 2018, where they developed the 3-D printing of supercapacitor method, taking advantage of the speed and precision of 3-D printing and also avoided contamination during supercapacitor fabrication.

Service learning content

Given the growing importance of 3-D printing in manufacturing sector, there is a strong need to prepare a student cohort who can fulfill the future requirements of industry, government, and academia. This project provides experience for high school students by exposing them to the state-of-the-art in 3-D printing technologies.

The project team includes twelve college students who work with a community partner, being Ganesha High School (GHS). The college students taught the GHS students 3-D printing techniques. The high school students were expected to learn to use a 3-D printer to print or make real life objects or devices. They learned the printer software, designed the product, and demonstrated the skills. The high school students were organized into several groups. The groups practiced with the 3-D printer and software. They tried out different possible products printable from 3-D printer with the help of our college students. Before the completion of the project, they presented and demonstrated their 3-D printer projects and products that they learned.

Funding for project

The funding includes $1000 obtained by the instructor from the Cal Poly Pomona Center for Community Engagement.

3.2 Course learning outcomes and grading procedure

This service learning course prepared our college students with integrated, multi-disciplinary scientific knowledge and professional skills required for jobs in a wide range of industries, government laboratories and new high-technology companies. The students are provided up-to-date knowledge and the importance of serving the community.

Students are evaluated according to course learning outcomes (CLO) based on 100-percent (100-point) grading scale. The CLO and the respective grade credits are defined in Table 2. The grading procedure was included in the course syllabus and provided to all participated students at the beginning of the course.

Table 2 Course learning outcome and credits

#	Course learning outcomes	Credit, %
1	Project Design	25
2	Demonstration	20
3	Community Service	25
4	Final Project & Report	30
	Total	**100**

3.3 Implementation

This project provided technical experiences to high school students by exposing them to the state-of-the-art 3-D printing technologies. The project has been completed by the end of May 2018. Through the service learning course, the Cal Poly Pomona student team traveled over to Ganesha High School and taught students the Onshape CAD platform, how to sketch, resize, extrude, and export their work. After 3 weeks of practice, a 3-D printing contest was organized for the high school students where they demonstrated their skills to create objects or devices and competed for design awards in terms of Aesthetics and Functionality.

Content of 3-D printing contest: We divided the GHS students into groups with freedom to pick their own project to design a 3-D product. They had a week to design, and we print out their design a week later using our materials. The projects were evaluated using the rubrics listed on the web site [11]. The 3-D products created by the GHS students include sickle, trophy cup, glasses holder, and cellular phone case. The ranks for the contest are: winner, first runner up, and all other honorary mentions.

Reflective activities

The instructor encouraged, supported and mentored the students. Our students interacted with the local high school teacher and students happily and proactively. The college students showed enthusiasm and interest in working as instructor, which is new experience for them. The college students communicated with the instructor very well, before, during, and after this service learning period. After the completion of the project, they still showed appreciation of having such experience.

3.4 Outcomes

A Ganesha High School participant expressed the project experience as follows: *"I have learned that your [making your] imagination [reality] is possible. I just want to thank the Cal Poly*

Tech/3D printing team." Figure 2-4 show the pictures of the activities. The college student team completed and submitted the final project report.

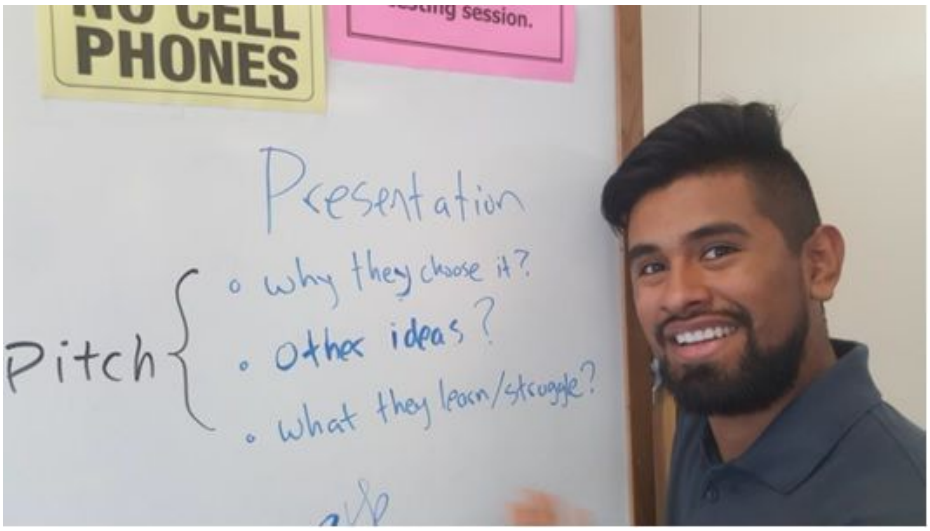

Fig. 2 College student Jose Lopez explaining presentation criteria

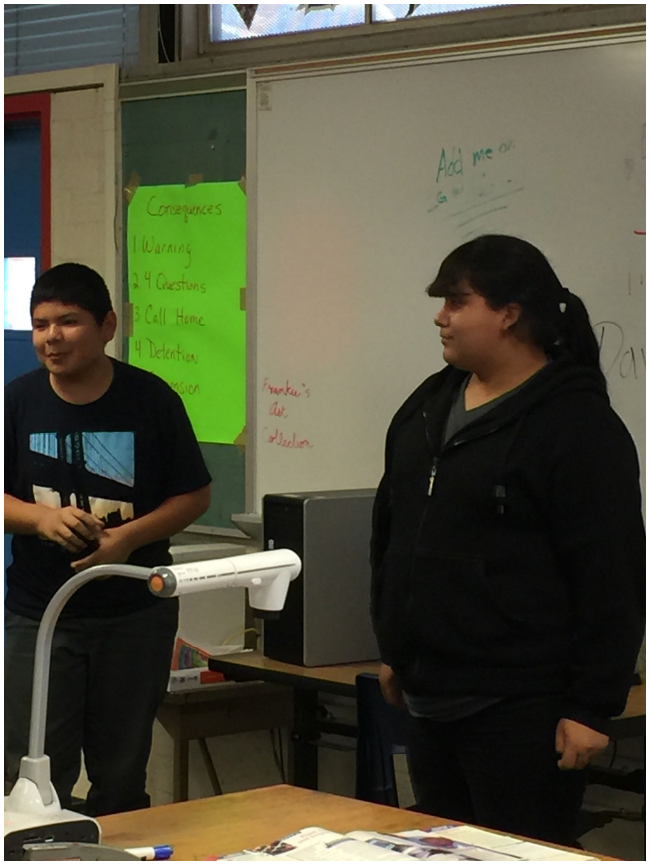

Fig. 3 High school students presenting their 3-D printed object

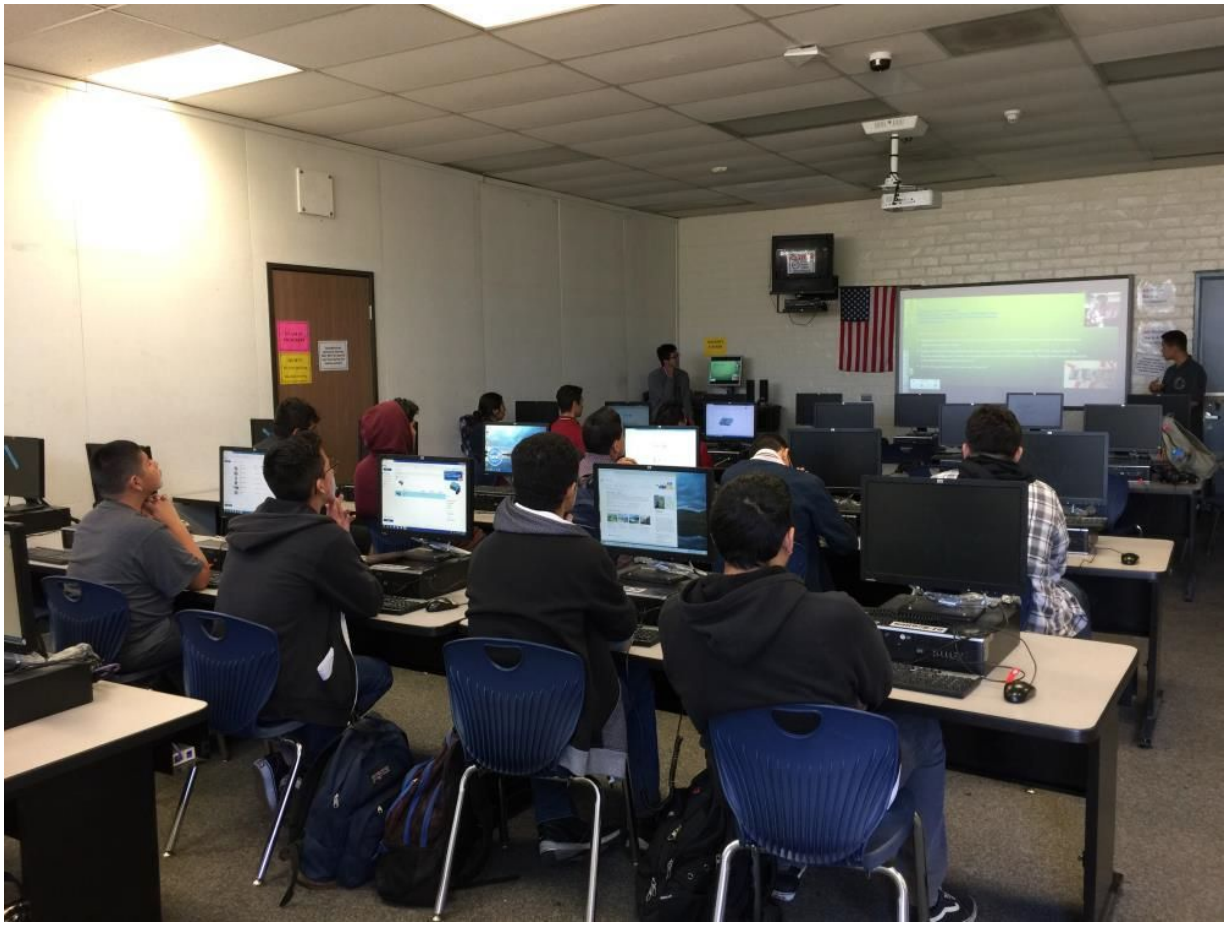

Fig. 4 Classroom view of a presentation session

Course training quality

This course gives students first-hand research experience with faculty members and helped them obtain written and oral communication, collaboration, and time management skills. These are skills that many good STEM students lack. The course quality is high since it inspires interdisciplinary interests in students, and exposes them to the state-of-the-art topics which can be incorporated into existing curriculum and new course development. Our students were highly engaged and very motivated. They realized that engineering study means more than just attending classes or taking exams. The experiences also include meaningful community and society involvement and contributions.

Impacts on college students

Service learning is a very good way to achieve several objectives for the education of engineering students, including:

1) Ensure what the students learned are practical and realistic, applicable to the real world.

2) Guarantee that the students have in mind of serving the community when they are in school and keep that after they graduate.

3) Help the students to start to build good and sustainable community relationships while still in school.

4) Facilitate the students' learning actively through learn-by-doing.

This service learning is a good opportunity to educate students that what they learned in the classrooms is not just academic knowledge, but should be applicable to the society and should serve the community. This project will better prepare the students involved by exposing them to cutting-edge technology, which will prepare them to be successful alumni. This project offers students active, hands on learning experiences in and out classroom, thus following the learn-by-doing paradigm. The project also helps create a collaborative network of community partners that can provide career and internship opportunities to college students.

Benefits for university and College of Engineering

Guided by CPP's signature motto of "learn by doing" and one of the core values of "service learning", the service learning project evaluates the quality of instruction by integrating the state-of-the-art technologies in an interdisciplinary project. It addresses Cal Poly Pomona's recognition of its responsibilities to the community and the importance of applying and advancing sustainable practices in our campus classrooms. It also provides a welcoming environment for prospective students to learn about Cal Poly Pomona.

College of Engineering at CPP has Outreach Offices responsible for community development and outreach programs. The outreach programs enhance the College of Engineering's commitment to support underserved populations by recruiting and graduating increased numbers of historically underrepresented students; by inspiring and empowering K-12 female students to pursue STEM majors and careers.

4. Conclusion

In terms of achievements, this is the first service learning course based on capstone senior design projects at our university. Before the creation of our course, the previous service learning courses are regular lectures or labs. The course learning outcomes are successfully achieved. The college students were highly engaged and motivated to work on the projects. We observed that the senior project teams were very responsible and proactive regarding their work. They applied critical thinking skills and creativeness in developing 3-D printing programs, building the solar charging station, making presentations, and implementation of the entire projects. They learned a lot from the projects with minimum supervision of the advisors.

We provided meaningful services to the community partner, which is Ganesha High School. The services includes teaching the high school students A-to-Z process of conducting an engineering project, solar energy and environment protection concepts, 3-D printing techniques, creative design of products, as well as soft skills as such teamwork and presentation. At the conclusion of

the projects, we have donated the solar charging station of $1700 value to the community partner for staff and student use.

The lessons learned from the project are: (a) Service learning is an eye opening activity for not only our college students, but also for us as faculty instructor; (b) We realized that our college students can be very capable and responsible when given suitable responsibilities and opportunities, and (c) We learned the fun of outreaching to community. We hope that, in the future, different schools or community institutions will be involved in similar projects.

In terms of future plan, there are chances to develop other service learning projects and collaborative activities beyond our projects.

As mentioned in section 2.4 outcomes (Ha Le), in August 2018, Cal Poly Pomona Associate Vice President for Research visited the solar charging station and met with the GHS principal. They discussed further collaborative activities between Cal Poly Pomona and the high school.

The 3-D printing project (Zhen Yu) was not only used in this service learning project (ECE 467S), but was also an integral part of Zhen Yu's other projects on Unmanned Aerial Vehicles (UAV) and supercapacitors. In the future, it is possible to continue the ECE 467S (its semester based version) with the same partner. It can also include different content, such as nanotechnology, with different partners.

References

1. What is service-learning? Center for Community Engagement, California State Polytechnique University Pomona, Available: https://www.cpp.edu/~cce/service-learning/faculty.shtml, 31 October 2017.
2. R. DuFour et al., "Learning by Doing", A Handbook for Professional Learning Communities at Work", 2016.
3. A. Bielefeldt, J. Pearce, "Service Learning in Engineering", Michigan Technological University, 2012.
4. D.E. Giles, J. Eyler. 1994. The Theoretical Roots of Service-Learning in John Dewey: Toward a Theory of Service-Learning. *Michigan Journal of Community Service Learning.* 1 (1): 77-85.

5. J. Dewey, 1938. *Experience and Education,* Collier Books, New York.
6. J. Mariappan, S. Monemi and U. Fan, Enhancing Authentic Learning Experiences through Community-based Engineering Service-Learning, 2005.
7. M. Ben-Ari, Constructivism in Computer Science Education, SIGCSE, 1998.
8. D.W. Butin, 2003. Of What Use Is It? Multiple Conceptualizations of Service Learning Within Education. *Teachers College Record.* 105 (9), 1674-1692.
9. J. M. Pearce and C. Russill, "Student Inquiries into Neglected Research for A Sustainable Society: Communication and Application," *Bul. of Sci. Tech. & Soc.*23 no. 4, (2003), 311-320.
10. J. M. Pearce, "e Use of Self-Directed Learning to Promote Active Citizenshipin Science, Technology and Society Classes", *Bul. of Sci. Tech. & Soc.* 21 no. 4, (2001), 312-321.
11. "TCEA's 3D Design ContestRubric of Judging Criteria", https://tcea.org/student-contests/3d/