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Including Non-Engineering Students in an International Service-Learning Engineering Project – A Case Study

Kenneth W.K. Lo[1], C.K. Lau[2], Stephen C.F. Chan[3], Grace Ngai[4]
[1,2,3,4]Office of Service-Learning, [4]Department of Computing
The Hong Kong Polytechnic University
Hong Kong
{kenneth.wk.lo, chi-kin.lau, stephen.c.chan, grace.ngai} @polyu.edu.hk

***Abstract* — Service learning, which addresses human and community needs through engagement in community activities, has been proven to have a high educational impact in many disciplines. Integrating engineering expertise into service learning can not only lead to particularly impactful community service, especially in developing countries where engineering expertise is not always available, but also provide an effective way for students to apply their theoretical knowledge to solve real-world problems. Service learning in engineering has been documented in the past 20 years. Following its extracurricular implementation, it has now been integrated into core curriculums. However, most of the programmes are only offered to engineering students rather than being implemented as a form of general education applying a multidisciplinary approach. This article examines how to integrate students from very different disciplines into a single project. Our case study is from a credit-bearing service-learning subject offered by the Department of Computing that is open to all undergraduate students. The projects were conducted in Rwanda and Cambodia in 2015 and 2016.**

Keywords— Education; Service-Learning; Training.

I. INTRODUCTION

International service learning is a structured academic experience in another country in which students apply theoretical knowledge and hands-on field experience to address human needs in an organised service activity [1]. Service-learning projects require students to leave their communities and be immersed in a different culture and environment for a certain period of time [2]. Together with structured reflection and direct interaction with others, students can not only reflect on the experience to gain further understanding of course content, the global situation and intercultural issues, but also to appreciate their discipline [3] and improve their awareness of community-civic responsibility. In engineering terms, integrating appropriate technology into service-learning projects can bring in different engineering solutions in a global and societal context. It also helps engineering students to develop a greater sense of professional skill and ethical responsibility, especially concerning the use and deployment of technological solutions.

Since the 1990s, universities and engineering organisations have developed engineering-related service-learning projects that bring students from first world countries to serve in developing regions, often as part of first-year design courses or capstone projects [4,5,6]. For example, in 2013, a freshman-level mechanical engineering course was offered at Mississippi State University in which students were required to participate in one of five engineering projects [7]. Gannon University has integrated service-learning into a first-year seminar in engineering [8]. Service-learning has also been used in courses at George Washington University [9], Purdue University [10] and the University of Massachusetts [11]. Riding on the success of positive experiences, a substantial body of literature exists on student learning outcomes [4,6], community impacts [12], pedagogy design [9] and the integration of service-learning into engineering education [4,13]. Research has shown that a key to maximising student learning outcomes and community impacts is to involve different disciplines in the same project [14,15,16]. In engineering service-learning, a multidisciplinary approach not only enriches engineering projects with complementary skills such as community assessment but also empowers non-engineers to work in engineering projects, which is particularly satisfying for non-engineers who thought such skills were beyond them. However, existing programmes are generally carried out by engineering students trained in relevant skills.

In our case study, we implemented service-learning in engineering programmes using a general education approach that makes service learning available to all undergraduate students. The challenges that we encountered are discussed below, followed by an outline of the course model and the teaching activities involved. We believe that our experience will be of value to other educators who wish to develop a course to maximise students' potential in international engineering service-learning programmes. We compare the learning outcomes of engineering and non-engineering students by conducting a series of paired-sample t-tests. We conclude this paper with a discussion of the benefits of integrating a multidisciplinary approach into an engineering service-learning project.

II. COURSE DESCRIPTION & PROJECT DESIGN

The Hong Kong Polytechnic University has a long tradition of organising engineering-related service learning projects in local and overseas communities. Since 2005, our students have contributed over 15,000 man-hours to underprivileged communities in China, Cambodia, Rwanda and Myanmar, and service learning has been a mandatory general education requirement at the university since 2012. Since then, increasing numbers of non-engineering students have taken service learning subjects offered by the engineering departments and worked on engineering projects alongside students majoring in engineering. This is especially significant for international projects in developing regions.

Our case study is a 2-semester service-learning subject offered by the Department of Computing called ‘Technology Beyond Borders: Service Learning across Cultural, Ethnic and Community Lines’, which is open to all undergraduate students and enrols around 120 students each year. The objectives of this course are as follows:

1. To increase our students’ awareness and knowledge of communities that are culturally, ethnically or socially distinct from their own.

2. To acquaint students with significant issues of social need, justice and ethics related to the information age, such as the concept of the information divide and how technology may be used to meet needs.

3. To cultivate an awareness of information ethics and professional responsibility in our students.

4. To nurture a sense of civic responsibility and engagement in our students.

In 2015 and 2016, 237 students enrolled in this subject and were grouped into two teams, one undertaking STEM-related teaching projects in primary or secondary schools and the other undertaking infrastructure improvement projects in rural villages. As the nature of the projects, the course outline and the learning outcomes were different, in our case study, we only consider the infrastructure programmes that were implemented in Cambodia and Rwanda. In total, 85 students (36%) were involved in these projects. Of these 85 students, 51 (60%) were in year 1, 30 (35%) were in year 2, and the remaining 4 (5%) were in year 3. Only 32 students (38%) were studying engineering; the others were from a variety of disciplines including health sciences, pure sciences and the humanities. Table 1 shows the distribution of the students’ academic disciplines. This diversity poses extra challenges to the running of such projects but also makes additional learning gains available to the students.

TABLE I. ACADEMIC DISCIPLINE DISTRIBUTION

	Total number of students	**Department**	
Engineering-related Discipline	32 (38%%)	Faculty of Engineering	29 (34%)
		Faculty of Construction and Environment	3 (4%)
Non-engineering-related Discipline	53 (62%)	Faculty of Business	18 (21%)
		Faculty of Applied Science and Textiles	15 (18%)
		Faculty of Health and Social Sciences	11 (13%)
		School of Design	5 (6%)
		Faculty of Humanities	4 (5%)
Total:	85		

The main goal of this service-learning project was for the students to bring aid to local Cambodians. This initiative had two principal and correlated aims. First, our students provided solar power to rural villagers, a task that involved building the panels themselves and wiring up homes with necessary electrical appliances. Second, the team built a zero-carbon community learning centre and computing lab for a local Cambodian school.

1. Solar Energy System for villagers: Following the principle of appropriate technology, the solar power solutions took the form of a public charging station shared by a group of nearby households. Families could recharge their batteries from the station, and each station could charge up to six batteries at once.

Fig. 1. Solar Charging Station (Left); Community Learning Centre (Middle); Computer Library inside the Learning Centre (Right)

Our students assembled the solar panels and wired up homes with basic electrical appliances. Using local sustainable materials such as coconut or palm branches, LED lights were assembled for the villagers.

2. Community Learning Centre: The objective of the community learning centre project was to provide an informal learning space for village children and youths, both to supplement their regular school education and to serve as a resource for continued education and self-guided study. Two 20-foot-long shipping containers were transformed into a computer learning centre and library. This learning centre, in the playground of a local school, has improved the educational facilities of the school. We anticipate that the community learning centre will also provide a platform for the local people and enhance the cohesion of the community. A rooftop photovoltaic generator, a rainwater collection system and ten low-cost computers were installed. In conjunction with the learning centre, students deployed a customised computer library with electronic learning resources to teach the local children about science and engineering.

To emphasise long-term gains and ensure the projects' sustainability, we involved local institutes from Cambodia and Rwanda. Orientation and intensive training were provided to them before work in the field began. Local youths have been empowered with relevant skills, which have been transferred to communities where skills are scarce and sorely needed.

III. Challenges

A service-learning project can be divided into three phases: preparation, execution and evaluation. Prior to beginning a project, the students study the communities involved and prepare project proposals. Their training usually starts at the beginning of the preparation phase and is a critical factor that directly affects the results of the project, especially when engineering solutions are involved and non-engineering students are participating.

Throughout the project execution, the students reflect upon their experience in discussion groups and are required to write three reflective journals. After the completion of the projects, the students are required to write a reflective report that summarises the impact the service-learning project has had on them personally, and reflects on the linkage between their observations from the service project and the academic topic.

Key challenges for teachers throughout the project include the following:

1. Equipping students with the necessary knowledge, technical skills and hands-on experience. As most of the students are not from engineering disciplines and do not have any prior technical training, the teaching context must start from an elementary level. Given the time limits and the technical knowledge gaps within the team, training must be practical.

2. Empowering the non-engineering students to work on the different aspects of the projects, such as product design and system testing, that are more human-oriented and multidisciplinary.

3. Strengthening the teamwork between students from different disciplines and cultural background. As working practices and modes of communication can differ between one discipline and another, conflicts may arise. Developing team spirit and encouraging the team to work towards the same goal is a challenge for the teaching team.

IV. Course and Training Outline

Recent observations suggest that typical lecture-based learning is not the most effective and efficient way to equip students, engineering or otherwise, with knowledge and hands-on skills within a short timeframe. Therefore, we use a problem-based learning pedagogy. This is an instructional learner-centred approach that encourages students to conduct research, integrate theory and apply knowledge and skills to develop a solution to resolve a defined problem [17]. For example, when we taught students about the abstract concept of electrical circuits, such as series and parallel connection, they were easily confused by the concepts of voltage and current. However, they could easily associate the concepts with the phenomenon of light after experimenting with real circuits and real connections.

Therefore, in addition to lectures, various components were integrated into the training, such as discussions on various case studies, practical workshops, site visits and intensive training. The students were divided into groups by the teaching team, and each group consisted of students with different disciplines, nationalities, and seniority. Each team included students with an engineering background, who acted as mentors to the others. Those students without technical experience contributed in other areas, such as community assessment, system testing, product design or preparation of the training material. With clear responsibility and task allocation in a team, each member can complement the others.

Lectures included case studies from the university and international organisations and covered the digital divide and appropriate technology as well as the culture, social issues and history of the service location. These educated the students on the social aspects of the project and provided them with concrete ideas and reasons to conduct the projects. At the same time, to help students understand the concept and practices of service learning and to equip them with the necessary knowledge and attitude to plan and conduct the projects, a 10-hour eLearning module covered these general background concepts. From March to May, the following six workshops were conducted, focusing on the technical knowledge and hands-on skills:

1. Use of power and mechanical tools;
2. Basic electronic circuitry;
3. Laser cutting, soldering and assembly of LEDs;
4. Safety precautions when conducting an engineering project in a rural area, such as risk assessment;
5. Installation of a solar system; and
6. The introduction of Raspberry PI, a single-board computer used as a server hosting eLearning resources such as electronic books.

Fig. 2. Intensive Training and Preparation at the University in Cambodia

During the workshops, instructors presented a problem statement to the students; this was followed by 30–45 minutes of instruction. Then, each team had 90 minutes to conduct experiments or practice the skills. For example, for the solar panel tutorial, after the instructor introduced the installation procedures and presented the basic construction of the station, each team had to identify flaws and problems and come up with solutions that used local resources, such as using palm leaf mats to prevent rain water contact and using water pipes to construct a frame to direct rainwater off the surface of the solar panels. As the international students arrived in Hong Kong 2 weeks before the project, they only participated in the 2-week intensive training and completed the eLearning module. During the intensive training, with the guidance of instructors, each group attended five sessions, during which they implemented, tested and evaluated their designs for the solar charging system, LEDs and learning centre accessories.

Taking the Cambodia project as an example, 46 hours of training were conducted in Hong Kong and another 39 hours of preparation were completed in Cambodia. For the training in Hong Kong, the lectures, eLearning module, workshops and case studies were conducted between February and March, 3–4 months before the Cambodia trip. The outline of the training for the students is shown in Table 2.

Once the team arrived in Cambodia, the second phase of training was put into motion with the local students. In 2015 and 2016, 11 and 33 Cambodian students joined the team, representatively. Their majors were either English or Development Studies. Even though they had not previously had contact with the team from Hong Kong, working in the same group for 7 hours a day and participating in various orientation and site visit activities strengthened the team spirit and helped them to understand the situation in the target community. The team spent four days testing and training in a local university to finalise the design, assemble the solar system and LEDs and test all the deliverables. This on-site training allowed the Hong Kong students to transfer their knowledge and skills to the Cambodian students.

TABLE II. OUTLINE OF THE TRAINING SCHEDULE

		Hong Kong Students	**Cambodian Students**
Hong Kong	Lectures & Case Studies (6 hrs)	√	
	eLearning module (10 hrs)	√	
	Workshops (15 hrs)	√	
	Intensive Training & Preparation (15 hrs)	√	
Cambodia	Orientation (3 hrs)	√	√
	Site Visit (4 hrs)	√	√
	Intensive Training & Preparation (32 hrs)	√	√
		85 hours	39 hours

The training was followed by the project in which the deliverables were deployed, and the target community was trained to use the new equipment. The community was pleased with the project, and the facilities were put to use almost immediately. During the project execution, Hong Kong students worked alongside local youths to install the solar system and set up the learning centre. Through teaching by demonstration, most of the local students were able to master the technical skills, and some of them were able to help maintain the equipment with the local NGO in the long run.

V. STUDENTS' LEARNING OUTCOMES

The student learning outcomes were fully evaluated using three approaches: grading by the teaching team according to the subject rubrics, a self-reported post-experience survey and reflective journals submitted after the completion of the projects. The subject grading was divided into three subgrades corresponding to the three phases of the service (preparation, execution, and reflection). Each student was assessed by two subject teachers and two tutors individually, and a meeting was organised to finalise the overall grade.

Additionally, a standard post-experience survey was administered at the end of the course. This survey comprised two sets of questions pertinent to the research questions, including the following:

- One set of questions in a pretest–posttest design asking students to indicate their level of agreement with 15 statements pertinent to the following four common intended learning outcomes of service learning at PolyU on a seven-point scale (1 = strongly disagree; 4 = neutral; 7 = strongly agree):

    1. Apply the knowledge and skills they have acquired to deal with complex issues in the service setting;
    2. Reflect on their role and responsibilities both as professionals in their chosen discipline and as responsible citizens;
    3. Demonstrate empathy for people in need and a strong sense of civic responsibility; and
    4. Demonstrate an understanding of the linkage between service learning and the academic content of the subject.

- One set of questions asking students to rate, on a 7-point scale (1 = very little; 4 = a fair amount; 7 = very much), their attainment of the intended learning outcomes relating to their intellectual (4 items), social (2 items), civic (5 items) and personal (1 item) development as a result of attending the service-learning subject.

Students were also required to submit a reflection report that summarised the services in three dimensions: social, personal and academic. For the social impact, data and examples were presented to illustrate the community impact. In the personal dimension, students needed to demonstrate self-reflection on their personal, social and professional changes. In the academic dimension, they reflected on the linkage between their observations from the service project and the academic topic, such as the digital divide or appropriate technology.

The descriptive statistics for the variables are summarised in Table 3. Cronbach's alphas were computed on the question sets of the post-experience survey to check for internal consistency [18]. Empathy, intellectual and civic learning outcomes scales were found to be highly reliable, with alpha values ranging between 0.81 and 0.86 [19]. Application of knowledge and skills and understanding of the linkage between service learning and academic learning showed acceptable reliability. Two of the learning outcomes (self-reflection and social) had an alpha value below 0.70, suggesting that the reliabilities of those subscales are not acceptable.

The engineering students received slightly higher grades than the non-engineering students, with the difference ranging from 0.08 to 0.18. However, the standard deviation in all aspects of the non-engineering group was higher. Among the top 20% of the students, 11 were non-engineering students and 6 were engineering students. In the bottom 20% of the team, 3 students had a non-engineering background and 14 were technical students.

TABLE III. OUTLINE OF THE TRAINING SCHEDULE

Variables included in the study	**Group[1]**	**Min**	**Max**	**Mean**	**Std Dev**	**No. of items**	**Cronbach's aplha**
GRADING (Scale from 1-4)							
Preparation	E	1.70	4.00	3.11	0.65	-	-
	NE	1.30	4.00	2.97	0.68		
Execution	E	2.45	4.00	3.15	0.44	-	-
	NE	1.70	4.00	3.07	0.53		
Reflection	E	2.25	4.00	3.11	0.51	-	-
	NE	2.00	4.00	3.00	0.52		
Overall	E	2.38	4.00	3.13	0.39	-	-
	NE	2.02	3.90	3.02	0.47		
LEARNING OUTCOMES (Scale from 1-7)							
Application of knowledge and skills	E	4.50	7.00	5.71	0.66	4	0.70
	NE	4.00	7.00	5.64	0.61		
Understanding of the linkage between SL and academic learning	E	4.00	7.00	5.53	0.78	4	0.75
	NE	4.00	7.00	5.67	0.86		
Self-reflection	E	3.67	7.00	4.93	0.62	3	0.58
	NE	3.67	7.00	4.93	0.56		
Demonstration of empathy	E	4.50	6.75	5.73	0.67	4	0.81
	NE	4.25	7.00	5.68	0.65		
Intellectual	E	4.25	7.00	5.96	0.72	4	0.85
	NE	4.75	7.00	6.04	0.68		
Social	E	4.00	7.00	6.09	0.77	2	0.65
	NE	5.00	7.00	6.24	0.66		
Civic	E	4.40	7.00	6.09	0.58	5	0.86
	NE	4.20	7.00	6.09	0.71		
Personal	E	4.00	7.00	6.22	0.79	1	-
	NE	5.00	7.00	6.32	0.64		

[1] E – Engineering; NE – Non-Engineering

Among the eight learning outcomes, the personal aspect had the highest mean for both engineering students (6.22 on a 7-point scale) and non-engineering students (6.32), whereas self-reflection had the lowest (4.93 for both groups), which is still significantly higher than the mid-point of 4. The standard deviations of the scores ranged from 0.58 to 0.79 for the engineering group and 0.56 to 0.86 for the non-engineering group. Four learning outcomes had a higher rating from non-engineering students and two outcomes had a higher rating from engineering students. However, the differences were small, ranging from 0.05 to 0.14.

TABLE IV. INDEPENDENT T-TEST BETWEEN ENGINEERING STUDENTS AND NON-ENGINEERING STUDENTS

Variables included in the study	t	df	Sig. (2-tailed)	Mean Diff	Std. Err. Diff	Effect Size
GRADING (Scale from 1-4)						
Preparation	1.18	68.49	0.24	0.17	0.15	0.14
Execution	0.72	83.00	0.48	0.08	0.11	0.08
Reflection	0.93	66.72	0.36	0.11	0.11	0.11
Overall	1.09	83.00	0.28	0.11	0.10	0.12
LEARNING OUTCOMES (Scale from 1-7)						
Application of knowledge and skills	0.53	83.00	0.60	0.07	0.14	0.06
Understanding of the linkage between SL and academic learning	-0.74	83.00	0.46	-0.14	0.19	0.08
Self-reflection	-0.03	83.00	0.98	0.00	0.13	0.00
Demonstration of empathy	0.34	63.87	0.73	0.05	0.15	0.04
Intellectual	-0.53	83.00	0.60	-0.08	0.16	0.06
Social	-0.90	83.00	0.37	-0.14	0.16	0.10
Civic	0.00	83.00	1.00	0.00	0.15	0.00
Personal	-0.65	83.00	0.52	-0.10	0.16	0.07

A series of independent *t*-tests were conducted to examine differences in the grading and learning outcomes between the engineering and non-engineering students. The results depicted in Table 4 show that the two-tailed value of p is between 0.24 and 1, which is greater than 0.05, and so there were no statistically significant differences in the grading and learning outcomes between the two groups of students. Furthermore, the effect size in all dimensions was less than 0.14, which represents a small effect [21]. These results suggest that subject results and learning gains are independent of the disciplines of the students in an engineering service-learning project.

The students' reflective journals reflected the advantages of integrating a multidisciplinary approach into an engineering service-learning project and how this can benefit students. Many of them suggested that the tangible nature of the engineering-type project was rewarding and that this motivated them to continue working on the project:

> *"As a physics student, I had learned the circuit diagram before. If I had not participated in the service learning, I would never know how the circuit diagram is different from the real situation. In the diagram, all I need to do is to draw lines to connect electronic elements in series or parallel as long as it will not lead to a short circuit. When I did the indoor wiring for a house or solar panel installation, I realised the real situation was much more complicated. The diagram is only two-dimensional, but the indoor wiring is three-dimensional. I had splitters, wires, clippers, lights, displays and switches in my hand, some of which I hadn't even seen in an electric diagram before. I needed to design where I would place this stuff and connect them together to make all the lights function."*

Fig. 3. A student from Faculty of Business was teaching a local volunteer to install a solar controller on the charging station

The engineering students felt that they had learned more about the human aspects of technology:

> *"We were acting as a human factor in three layers: utilisation, development and popularisation. First, to act as the utilisation layer, we were trying to adapt the technology into a practical form that could benefit the villagers. Secondly, I had a responsibility to help develop the current technology to make it friendlier and bring more benefit to us. The last point, which is also the most important thing, is that this factor should help ordinary people who have no engineering or science background understand how to use those technologies properly. The last step is the most important one. When I worked with my groupmates from Design or Business, they helped me to understand how non-engineers think about the solutions, which made me think outside the box."*

Moreover, one of the students from a Design major reflected on the teamwork and personal changes in the project:

> *"I used to doubt what I could contribute to the team. Being a Design student, I did not have any technical or science background. At the beginning of the course, I could barely understand the circuit design and could not even connect the components on the breadboard. I relied on my teammate and tried my best to work on the design of the solar station. Following the instructions from the*

engineering students, I drew the three-dimensional diagram with precise measurements. With discussions and revisions, we finally completed the design. Throughout the execution, I became the only one who understood the whole setting and measurement; therefore, I stepped beyond my comfort zone and took the role of leader to build the solar station. My teammates appreciated what I did and felt grateful that I was part of the team. Engineering to me is an auxiliary to other dimensions and an important way to make a difference, both to the rural villagers and to me."

The students' work in multidisciplinary teams and integration into an engineering project was found to positively impact not only the project but also the students. With a structured training schedule, clear task classification and substantial support from the teaching team, engineering and non-engineering students achieved the same learning outcomes. Also, this mixed group approach can offer other learning experiences to the teams, including tolerance for diversity and interpersonal development, and stimulate them to think differently about engineering.

VI. Conclusion

This paper presents the challenges and solutions of guiding a mixed group of engineering and non-engineering students to conduct an engineering project. We describe the necessary teaching and learning activities that were used to help students understand the theory and concept of service learning, motivate them to conduct the projects and workshops and equip them with the necessary technical skills while strengthening intra-team communication and rapport. The results of an independent *t*-test to examine differences in course grading and learning outcomes are presented followed by some student reflections. No significant differences were found between the groups or in the reflection journals, indicating that a multidisciplinary approach can benefit both engineering and non-engineering students.

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