

Evaluation of International Experiences in Sustainability Education in Civil and Construction Engineering

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Abstract

Sustainability in civil and construction engineering is practiced globally in a variety of ways that are dependent on regional customs, available resources, governmental policy, and local building and design practices. Thus, the ability to examine the practice of sustainability internationally may be considered to enhance student learning outcomes in a course on sustainable engineering and construction. This paper examines the impact of incorporating a study abroad component to such a course, as compared with a traditional on-campus offering. In particular, a study abroad program was conducted for two summers in Australia, and application of practices and rating systems in that country were used to develop projects that could be certified through the LEED (Leadership in Energy and Environmental Design) rating system in the U.S. Several offerings of a traditional on-campus course were then made, with a similar project development aspect at the conclusion of each. The learning outcomes from each type of offering are compared using similar assessments, and an evaluation of the differences is made. Besides considering the benefits of study abroad programs in sustainability education, a reflection on the benefits of bringing an understanding of the global aspects of sustainability to on-campus course offerings is also made.

Introduction

Sustainability is, as stated in the United Nations Report on the World Commission on Environment and Development [1], the consideration of impacts to and preservation of the economy, the environment, and social equity (often referred to as “the three ‘E’s” of sustainability) in the execution of any plan or project. Its growth as a field of study and as a standard of practice is understandable in light of concerns about dwindling resources, population and developmental growth, and environmental sensitivity based on global warming and other natural phenomena. Engineering in general, and civil and construction engineering in particular, is a field uniquely well-equipped to tackle the issues of incorporating sustainability into project execution. Indeed, the study of sustainability in engineering programs in the United States has grown dramatically in response, with Syracuse University’s Center for Sustainable Engineering reporting that approximately 80% of all engineering programs have incorporated sustainability into their curricula to some degree [2].

Although sustainability is usually studied locally, it is, by nature a global issue. Thus, it would assumingly lend itself well to being studied from a global perspective. The benefits of studying abroad in general are well-researched. An example of the enhancement of educational benefits is put forward by Cisneros-Donahue et. al. [3]. Particular aspects of student learning they examined that would be pertinent to sustainability include global interdependence, interpersonal accommodation, and cultural sensitivity. They found that benefits in these areas were

significantly greater after participation in study abroad programs. Similar benefits were found in less formal surveys by the Institute for the International Education of Students [4] and the American Institute for Foreign Study [5]. The Handbook of Practice and Research in Study Abroad [6] also considers that, through study abroad, students become global participants in the areas of “cosmopolitanism” (i.e. openness to other cultures), activism, reform, management, and capitalism. Sustainability is a topic that is well-addressed by students aiming to have global impacts in these areas.

In order to try to harness the potential of study abroad programs to enhance student learning in a burgeoning and increasingly critical area, I began a short-term (one month long) study abroad program at The College of New Jersey (TCNJ) through Australearn, a subsidiary of GlobalLinks Learning Abroad. The program was begun exclusively with TCNJ students in the summer of 2011, and expanded to a nationwide offering in the summer of 2012. Before starting the program, I researched several provider- and university-based compendia (e.g. IIE Passport [7], StudyAbroad.com [8], UCLA [9], etc.) and found a minimal number of programs that combined the benefits of study abroad with the application of civil and/or construction engineering in addressing sustainability issues. It was thus felt that the implementation of such a program could be used, not only to improve the learning outcomes of the participants of the program, but to evaluate the benefits of such programs in general.

Development of the Program

The program was developed on the basis of two fronts: development of the course to be embedded into the program and selection of a site. Since I had not taught a course in sustainability before developing the study abroad program, I decided that the course should be able to exist independently of the program, should the international aspect of the program become unavailable or unviable, due to cost or other issues. This also would allow me to incorporate the study of sustainability on a continuous basis into the College’s Civil Engineering curriculum.

The two aspects of course development I will consider herein are the course objectives and the assessment tools used in the course. The course objectives, as with most engineering courses, were selected to map to the program outcomes for Civil Engineering curricula put forth by the Accreditation Board for Engineering and Technology [10]. This mapping is meant to show that the course, by having students meet the course objectives, is achieving the goal of meeting the ABET program outcomes. The mapping of the course objectives seen in Table 1 is based on the ABET program outcomes of the 2011-2012 evaluation cycle. These outcomes have changed somewhat since the origin of the course in 2011. However, the current outcomes are similar enough to those of 2011-2012 that the mapping should clarify the goal of the course objectives. (A primary difference is that ABET program outcomes now specifically call for the inclusion of principles of sustainability in design in the curriculum, which is actually a direct objective of the course itself.)

Table 1. Mapping of course objectives to ABET program outcomes.

Course objectives	ABET program outcomes										
	a	b	c	d	e	f	g	h	i	j	k
1. <i>explain</i> the meaning of sustainability and the different areas in which it is practiced						X	X	X	X	X	
2. <i>discuss</i> the ways in which sustainable engineering practices are applied					X		X	X			
3. <i>analyze</i> a project or site in terms of sustainability and the degree to which it is applied	X				X						
4. <i>determine</i> ways in which a project or site can be made more sustainable	X		X	X	X						X
5. <i>apply</i> sustainability concepts to the development of a new project or site	X		X	X	X	X	X	X	X		X
ABET program outcomes (a) an ability to apply knowledge of mathematics, science and engineering; (b) an ability to design and conduct experiments, as well as to analyze and interpret data; (c) an ability to design a system, component, or process to meet desired needs; (d) an ability to function in multidisciplinary teams; (e) an ability to identify, formulate and solve engineering problems; (f) an understanding of professional and ethical responsibility; (g) an ability to communicate effectively; (h) the broad education necessary to understand the impact of engineering solutions in a global and societal context; (i) a recognition of the need for and an ability to engage in life-long learning; (j) a knowledge of contemporary issues; (k) an ability to use the techniques, skills and modern engineering tools necessary for engineering practice.											

Since the course is intended to show that students are able to address the issues of sustainability, the assessment tools were selected to reflect assessment of the achievement of sustainability objectives in the field. One of the more common and long-standing means of assessment of Civil and Construction Engineering projects, buildings in particular, is the LEED (Leadership in Energy and Environmental Design) rating system, promulgated by the U.S. Green Building Council (USGBC) [11]. Practitioners considered to be skilled at the implementation of sustainability principles in building projects are certified by the USGBC through the LEED AP (Accredited Professional) credential. Since the main requirements for earning this credential were examination and project experience (the experience aspect has since been changed to be strongly recommended rather than required) [12], I felt that similar tools to evaluate the achievement of the course objectives should be used in the course. The exams in the course are modeled after LEED credentialing exams, and the culminating project in the course allows students to implement sustainability principles with the goal of earning LEED certification.

The other front that needed to be considered for the program was the selection of a site for the international experience aspect. Based on discussions and informal surveys of desired locations, Australia was chosen as the site. Several other factors led to Australia being a sound choice for international study of sustainability issues:

- Australia is the driest continent on earth in terms of average annual rainfall overall, and has, in recent years, suffered from a number of droughts that have restricted supplies of fresh water. [13]
- Australia is a well-developed country, where different methods of sustainability engineering can be examined rather than having students seek to implement measures with which they may already have been familiar.
- Despite Australia's size, the vast majority of its population is concentrated in large cities along the coastline [14]; this creates issues with concentrated air and water pollution, transmission of energy, and transportation of goods and raw materials.
- Australia has been engaged in serious debate of policies (e.g. water use restrictions [15], a carbon tax [16]) that will likely spur further developments in sustainability.
- As the site of an introductory program, the cultural similarities of Australia to the United States would allow engineering students to feel a sense of familiarity while maintaining the academic rigor of an engineering-focused course.

Framework of Evaluation

The sustainability course I have taught, under various titles and incarnations, has run several times since 2011. The course offerings evaluated are listed below, with some of the individual aspects of each:

International Offerings:

- 1) Summer 2011: ENG/IDS 470 – “Sustainability Australia” at The College of New Jersey
- 2) Summer 2012: ENG/IDS 470 – “Sustainability Australia” at The College of New Jersey

Domestic (on-campus) Offerings:

- 1) Summer 2013: 14.466 – “Introduction to LEED” at The University of Massachusetts Lowell
- 2) Spring 2015: CNET 4900/MSET 5900 – “Sustainability Principles and LEED” at The University of North Texas
- 3) Spring 2016: CNET 4900/MSET 5900 – “Sustainability Principles and LEED” at The University of North Texas

Despite some of the different characteristics of these offerings, there are three primary consistencies that make the evaluation of student learning across them worthwhile:

- a) the course objectives (outlined in the previous section) were maintained through all offerings
- b) the assessment tools (LEED-modeled exams and projects) were maintained through all course offerings

- c) the characteristics of the students enrolled (mostly upper-division and/or graduate Civil and/or Construction Engineering students) were generally consistent through all course offerings

To capitalize on these consistencies, the results will be presented in the next section on the basis of achievement of the course objectives based on review of the assessments made using the tools. However, because of the some of the inconsistencies of the course offerings, it is understood that these results are not intended to define a rigorously scientific study of the objectives. Rather, it is meant to make a general consideration of the benefits of international experiences to the study of sustainability, with an eye towards, perhaps, implementation of strategies to improve on-campus sustainability study based on those experiences. (Indeed, I have already attempted to implement some of these, as I will discuss in the “Review of Results” section, which may skew results of later on-campus offerings of the course.) To make further consideration of the impact of some of the differences in the offerings on the results, I will present the results both in aggregate (international vs. domestic) and broken out for each offering and tracked over time.

Results of Evaluation

Figure 1 shows a comparison of the assessment results of the course objectives outlined in Table 1. These are based on achievement of the participants on exams and projects, as described in the “Development of the Program” section. In Figure 1, the results are aggregated, with the results of all study abroad offerings combined for each objective and the results for all domestic offerings combined. The results paint a picture of the overall comparison of the performance of students studying abroad versus those studying on campus. The most evident conclusion is that there is a consistently higher achievement of the course objectives for students studying sustainability abroad versus those studying sustainability on campus.

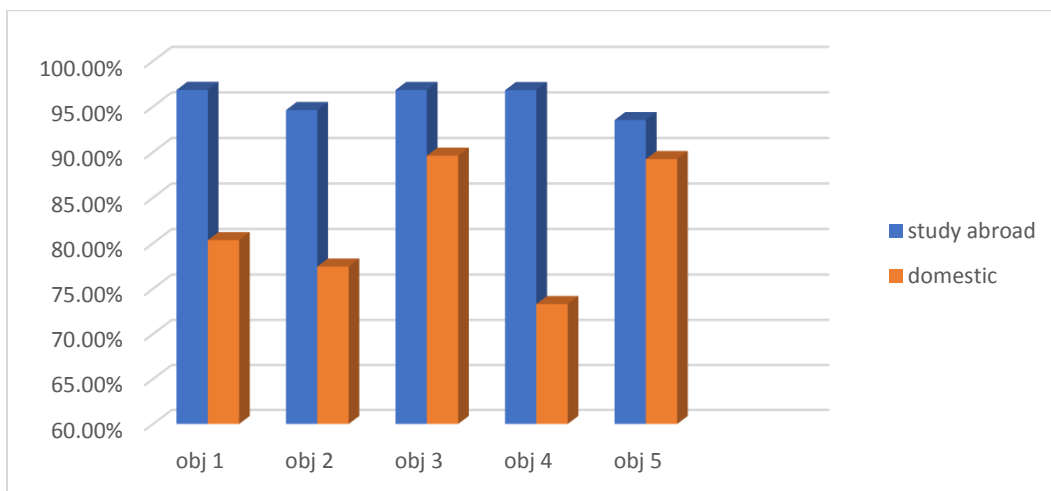


Figure 1. Comparison of assessment of course objectives aggregated for study abroad and domestic course offerings

As considered earlier, it is likely that differences in each individual course offering may have contributed to differences in performance in the course objectives. For this reason, a tracking of the assessment of course objectives for each individual course offering is depicted in Figure 2. It should be evident from Figure 2 that, although there is some variation from one offering to the other in performance, achievement of the course objectives in the individual study abroad offerings is, again, consistently higher than any of the individual domestic (on-campus) course offerings. Of course, there is enough variation from one course offering to the other, especially for the domestic offerings, that it is worth considering characteristics of those course offerings that may have led to those differences. This consideration will be made in the “Review of Results” section.

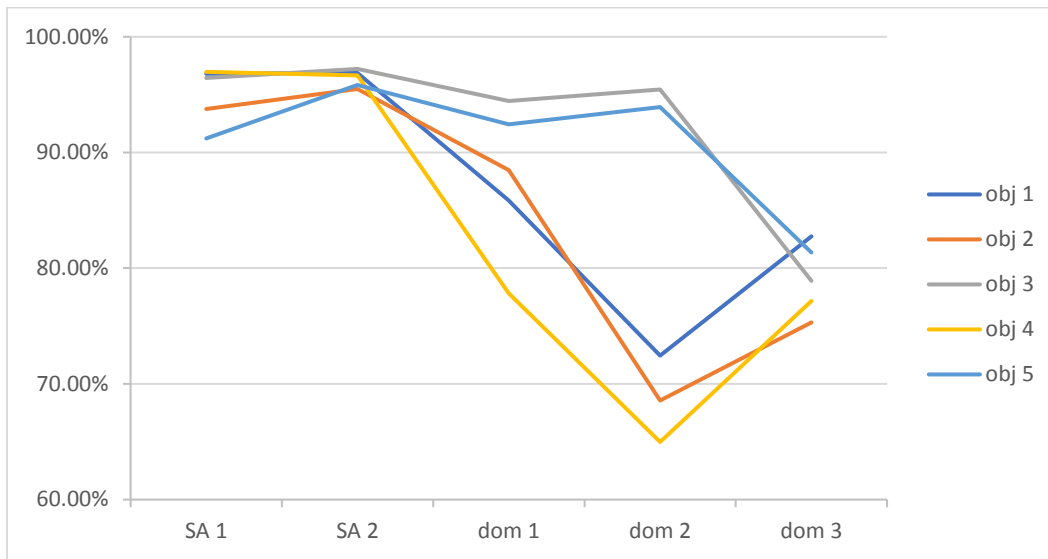


Figure 2. Tracking of assessment of course objectives over individual study abroad and domestic course offerings.

Review of Results

As stated in the “Results of Evaluation” section, the most straightforward conclusion from the results is that achievement of the course objectives outlined in Table 1 is consistently higher for students participating in study abroad offerings than for those in domestic (on-campus) offerings of the sustainability course. This is true both in the aggregate and across individual offerings. This conclusion is also likely the most significant one, as it speaks to the idea that there is great benefit to participation in study abroad programs, especially for Civil and/or Construction Engineering students studying sustainability. However, a slightly deeper review of the performance on the course objectives is helpful for two reasons: (1) not all students will have the ability to study sustainability on an international basis (based on cost, availability, personal and/or curricular constraints, etc.), and (2) factors that can lead to improvement in achievement of course objectives should be considered, whether for study abroad or domestic offerings of sustainability courses.

The first area of variation to consider is the variation from one course objective to another. The greatest divergence in performance from study abroad to domestic offerings is for two objectives: (a) Objective 2: *discuss* the ways in which sustainable engineering practices are applied, and (b) Objective 4: *determine* ways in which a project or site can be made more sustainable. These are also the objectives for which performance across the domestic offerings is consistently lower than that of the other objectives. I would conjecture that the reason the difference in performance on Objective 2 would speak most highly to the benefit of a study abroad program, which is a sense of immersion in the subject matter. It would naturally be easier for students to discuss sustainable engineering practices after the nearly daily visits to sites, projects, and other examples of those practices experienced during the study abroad program. The performance deviation for Objective 4 is likely born of the higher level on which the objective falls on Bloom's Taxonomy for educational objectives [17]. Higher-order objectives should generally have lower performance than lower-order ones, and the level of the objectives increases for this course from Objective 1 (*remember/understand* level) to Objective 5 (*create* level). This should imply that the performance and/or deviation for Objective 5 should be greater than that for Objective 4 (*evaluate* level). However, the assessments for Objective 4 were a combination of individual (exam-based) and team (project-based) ones, while those for Objective 5 were strictly team assessments. It might be reasoned that it is easier for students to perform better in achieving course objectives as a team than individually, leading to the observations of performance on Objective 4.

The second area of variation to consider is from one offering to another. This variation is most pronounced from Domestic Offering 1 to Domestic Offering 2. This difference probably arises from two factors: (a) a greater time lag between the two offerings than any other pair of offerings and (b) offering the course at a different institution. The variation, based on these two factors, should be understood to be more instructor-based than student-based. That is, the variation was likely based on a need for me, as the instructor, to adjust the course on the basis of an absence from teaching the course and an understanding of the new institution and the student body thereof. This should be evidenced by: (1) extremely low variation in performance from Study Abroad Offering 1 to Study Abroad Offering 2, despite the difference in the students to whom the course was taught (as discussed in the "Development of the Program" section) and (2) the convergence in performance (with performance in some objectives increasing and in others decreasing slightly) from Domestic Offering 2 to Domestic Offering 3 (which had very similar characteristics in format, institution, student makeup, etc., but with adjustments made by the instructor).

Informal Evaluations

It was understood, with the inception of the study abroad program in sustainability, that there were benefits to be had by studying the topic on an international basis. With this in mind, an informal survey was taken of the participants of the first study abroad offering upon their completion of the program. Three questions were asked: (1) students' perception of their performance on the course objectives (shown in Table 2), (2) students' satisfaction with the

program overall (shown in Figure 3), and (3) aspects of the study abroad program that students felt were most beneficial to their understanding of sustainability. This survey was only conducted after the first offering, as it was not intended to track performance, but merely to gain insight as to students' thoughts about the study abroad experience. Nevertheless, the results are somewhat instructive, and so are provided herein.

Table 2. Survey results of student perception of meeting course objectives.

	very well (1)	reasonably well (2)	not very well (3)	poorly (4)	mean
Objective 1	11	5	0	0	1.31
Objective 2	14	2	0	0	1.13
Objective 3	12	4	0	0	1.25
Objective 4	9	6	1	0	1.50
Objective 5	11	3	2	0	1.44

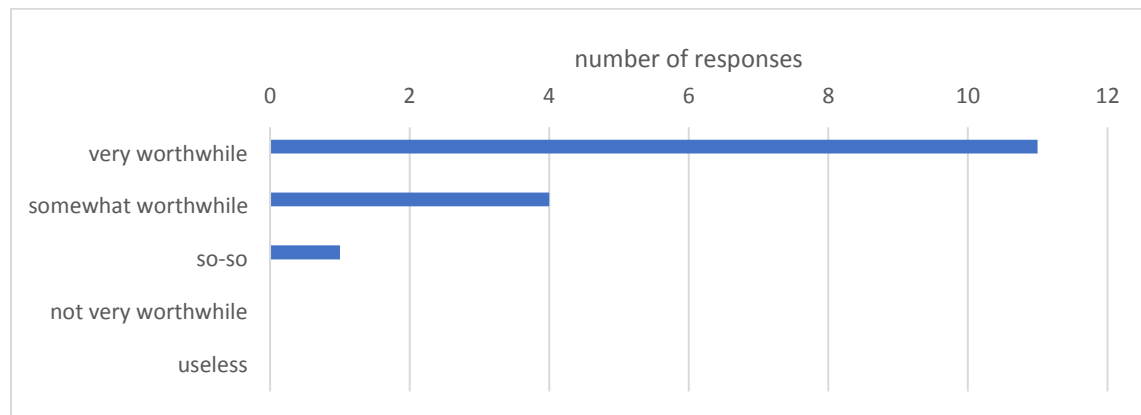


Figure 3. Survey results for student satisfaction with study abroad program.

The results in Figure 3 show that students generally were highly satisfied with the study abroad program, and the benefits provided by it. Table 2 reflects similarly high levels of satisfaction with their own performance, although there is, as considered in the “Review of Results” section, slightly lower perception of performance with the higher-level course objectives.

As to the third question, the most common responses included:

- travel, including traveling abroad and traveling to a number of cities
- site visits, including the range of sites overall as well as specific sites mentioned
- university visits, including tours of university facilities, visits with Australian students also studying sustainability, and lectures given by guest faculty from those universities

These responses, in particular, along with the review of results, not only speak to the benefits of studying sustainability through international experiences, but can lead to further considerations for improvements in sustainability education for Civil and Construction Engineering students.

Conclusions and Further Considerations

The evaluation presented herein is not entirely scientific, and thus variability in performance due to a wide variety of factors, including number of students, background knowledge, minor adjustments to the assessments, etc., is not accounted for. However, the results, from both formal and informal standpoints, point to a conclusion that international experiences lead to higher performance towards and greater student satisfaction with the objectives of sustainability education in Civil and Construction Engineering. The difference in performance is significant across the course objectives, and both the difference in the characteristics of the course offerings and the participants' informal responses point to the conclusion that study abroad aspects are strong contributors to this.

Improvement in performance for sustainability education objectives is certainly desirable, whether through international experiences or on campus. As indicated in earlier sections, it is difficult to recreate the immersive, intensive experiences that come with study abroad program in domestic on-campus offerings. Nevertheless, there are tactics that can be drawn upon from the study abroad program studied herein, like increases in number and variety of site visits, interactions with students and faculty working with sustainability on an interdisciplinary basis, and work with local or on-campus projects with real-world impacts, that can be implemented in domestic programs. Indeed, when I was able to incorporate such elements into my domestic offerings, like Domestic Offering 1 and Domestic Offering 3, I was able to come closer to having students replicate the performance of study abroad participants. Although one might say that there is no substitute for an international educational experience, a greater richness of experiences in domestic offerings can bring some of the benefits of study abroad programs to those domestic offerings.

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