5-Year Evaluation of a Course Model for Student-Initiated Engineering Service Learning

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Abstract – Student-initiated projects in engineering service learning represent an opportunity to educate engineering students on topics of sustainability, motivate new engineers to work on humanitarian focused projects, and provide impact on projects for underserved populations in partnership with community organizations. Based on iterations of an engineering design course operated by student participants of Engineers for a Sustainable World at Stanford University, we provide an analysis and discussion of the structural and operational components of a student-initiated engineering design course created to support international service projects. Course ratings demonstrate overall improvement through time in student satisfaction, indicating continued improvement of the course structure and execution despite yearly turnover in personnel. The current two-part course model consists of a one-unit lecture series followed by a three-unit design course, with classroom components complemented by opportunities for international service including project and community assessments and a summer internship program. Overall, course evaluation results were comparable to or better than faculty-led engineering design courses in mechanical, civil and environmental engineering at Stanford. While concerns over consistency persist, overall performance demonstrates successful integration of student-initiated design into the engineering curriculum.

Index Terms – student-initiated courses; engineering service learning; sustainability; design curriculum.

INTRODUCTION

Project-based service learning in engineering education has recently been lauded for its positive impacts on student participants, performing at least on par with more traditional project-based learning in terms of knowledge and skills gained.ⁱ Engineering service learning couples academic subject matter with service to community, fostering civic responsibility in students while yielding a functional product or service to satisfy the needs of the community partner.ⁱⁱ Such programs have been successfully integrated into departmental curricula, helping to communicate the responsibility of engineering students to contribute to solving community development problemsⁱⁱⁱ while meeting accreditation criteria.^{iv}

While many engineering students recognize the importance of sustainable development, widespread knowledge gaps persist in many core aspects of this field, and students frequently encounter difficulties in directly linking the theory of sustainable development with engineering practice.^v Although more than 80% of respondents in a recent survey of engineering faculty indicated some level of sustainable engineering course activity at their institution, university efforts for education in sustainable engineering remain “grass-roots,” with little overall organization at a national level.^{vi} Opportunity is ripe for the development of project-based service learning courses that address issues of sustainability and sustainable development. Engineering educators must continue to find new ways to integrate societal and economic issues with environmental science,^{vii} and service learning can play a role in enhancing ethics education in engineering.^{viii}

International service learning in engineering provides numerous educational benefits, including real-world project experience, improved social and cultural awareness, enhanced desire for service, and increased international exposure.^{ix} However, in such courses and projects, careful reflection concerning the challenges and drawbacks of international service learning projects must be conducted. Despite positive intentions, international service learning projects in engineering may provide the most benefit to participating students rather than project communities, with potential costs to the community resulting from uneven power relationships and the creation of dependencies.^x Instructors, students, and project participants in international engineering service learning courses must be cognizant of such challenges, utilizing effective project planning and developing strong and consistent relationships with community partners.

Extra-curricular engineering organizations such as Engineers for a Sustainable World (ESW) can serve as a platform for integrating service learning throughout the student experience and for development of effective course curricula. In this paper, we provide a five-year update on a model for learning sustainable design through service, based on a course developed and implemented by the Stanford University chapter of ESW.^{xi} This course has been entirely student organized since its inception, providing a unique opportunity to evaluate the performance of a student-initiated service learning course over time. While student initiated courses are a component of many university curricula, concerns over quality, student acceptance, and consistency of these courses have not been addressed to any degree in peer-reviewed literature. The objective of this study is to provide discussion and evaluation of the iterations on the course model, weighing the effects of adaptations in the model on the student experience. The course program is documented, including student evaluation results, and recommendations are presented on development and implementation of student-initiated courses. By observing the evolution of this course over a five year period, we are able to evaluate not only the success of the course model in specific cases, but also the ability of a student-initiated course to maintain consistency and effectiveness over time despite annual turnover in key volunteer personnel.

COURSE MODEL

Design for a Sustainable World is a student-initiated service learning design course at Stanford University in which students address engineering problems facing underserved communities worldwide. Each course offering is based around a partnership with a community organization facing a specific engineering challenge. Working in teams, students approach these challenges by applying principles taught in the course as well as prior knowledge. The course targets upper level undergraduate and graduate students, with engineering students comprising a majority of enrollment. The course is offered as a technical elective in the Department of Civil and

Environmental Engineering (CEE), such that students receive general engineering credit towards graduation requirements. Although there are no explicit prerequisites for the course, acceptance is by application only, with relevant coursework and outside experiences factored into the selection process. While the class is open to and marketed towards students of all majors, efforts to increase the number of non-engineers enrolled have met with limited success, with most classes largely comprised of engineering students. Class sessions include a mixture of outside lectures, student presentations, and facilitated design work.

Course Organization and Project Selection

Design for a Sustainable World is managed by the Stanford chapter of Engineers for a Sustainable World (ESW-Stanford). As a student-initiated course, faculty advisers are engaged as volunteers on a project-specific basis, advising projects applicable to their area of expertise. Graduate student course instructors, selected by ESW-Stanford and supported as teaching assistants by CEE, are responsible for curriculum development as well as management of class sessions. These instructors work with faculty advisers and former instructors to develop an academically rigorous syllabus and appropriate student evaluation mechanisms. Student project leaders enrolled in the course are responsible for managing design work, as well as overseeing assessment trips and other activities crucial to the design process. Course instructors and project leaders are selected by the Director of Projects, an elected member of the ESW officer corps responsible for overall management of the design course and outside partnerships. The Director of Projects works in conjunction with the remainder of the ESW officer corps, who are responsible for fundraising, publicity, outreach, and event management. The organizational structure of the course, which may be conducted more than once in an academic year with different project foci, is depicted in Figure I.

Selection of partners and design projects is managed by ESW-Stanford, specifically through the Director of Projects. The selection process begins prior to the school year, at which time all proposed projects are evaluated for compatibility with the design course. The majority of project opportunities are developed organically through student, faculty, and alumni networks. Course projects are typically conducted as research and development for project partners, such that students in the course provide recommendations to the partner based on needs outlined by the organization. The partners assume responsibility and liability for final project design and implementation. By interfacing with reliable partner organizations as opposed to directly with communities, long-term community involvement, relevance of student design tasks, and overall project success remain the function of the partner, rather than student teams directly.

FIGURE I

STRUCTURE OF STUDENT-INITIATED SERVICE LEARNING COURSE PERSONNEL.

Student Travel and Funding

Most course projects have included opportunities for student travel, including assessment trips and summer internships. For those projects including assessment trips, 2-3 students undertake one week trips to the project sites during winter or spring break prior to the course. These students are responsible for gathering on-site information, finalizing the scope of the class projects, and cementing relationships and communication mechanisms with international partners. Students taking part in assessment trips are designated as project leaders, taking on additional responsibilities for the remainder of the course. Project leaders communicate directly with foreign partner organizations via telephone, email, and video conferencing, and through aggregation of questions from course participants. For projects involving domestic project partners coordinated with additional international partners, communication was primarily with the domestic partner. Funding for assessment travel is provided by ESW-Stanford.

Summer internships are offered as 8-12 week programs, in which selected students from the class travel to project sites to continue work in close collaboration with partner organizations. In this arrangement, day-to-day activities of student assessment teams and summer interns are facilitated by the partner organizations, rather than by ESW-Stanford. Summer interns are selected competitively with 2-3 internships typically offered per class project. Interns are responsible for developing deeper relationships with new and existing partners, progressing and/or implementing designs developed during the course, and evaluating potential for continued involvement in future years. Limited funding for summer internships is provided by ESW-Stanford. Where funding is insufficient, interns are asked to raise additional funds through grant writing or solicitation of donations. Project partners are asked to support interns through in-kind donations, generally including housing and transportation.

The total course and projects budget ranges from \$10,000-\$35,000 per year including departmental funded teaching assistantships. This total is supplemented with in-kind

contributions, including donations of time, student housing, student transportation, and materials. This budget is used to offset travel costs, provide prototyping materials, fund student internships, and arrange for events and publicity surrounding the course. Funding sources include small grants from university departments and centers, grants from outside agencies, and corporate donations. Most funding is issued on a one time only basis, with extensive grant writing required each year to ensure continued financial support. Annual grant writing is coordinated by the ESW leadership team, specifically the Director of Fundraising, and is supplemented by individual grant applications submitted after the selection of summer interns.

COURSE AND PROJECT ITERATIONS

Courses led by the ESW-Stanford chapter leaders over the five years following publication of the original course model^{xiii} are documented in Table I. One to three courses or projects were conducted during each academic cycle, with a total of nine courses completed in the five-year period. The course format has undergone a series of iterations based on formal and informal feedback from course participants and project leaders, faculty and staff advisers, and course instructors. Formal feedback solicited by course instructors includes official university course evaluations, unofficial course evaluations conducted by course instructors, and project evaluations solicited from course partners and faculty advisers following final presentations. Several examples of course modifications implemented or important course components retained through time are described below.

Course modifications

The need for pre-course assessment trips became evident during the spring 2006 ecological sanitation course. Without appropriate contextualization of the community issues associated with ecological sanitation in Haiti, student progress in design work was severely handicapped, despite the ability to test designs at an on-campus location. To address the need for site-specific information, an assessment trip was conducted for the first time prior to the autumn 2006 project in Nicaragua. This trip proved extremely valuable for the site visitors as well as the course participants, who gained information and developed greater empathy for the project beneficiaries through improved communication with project partners. Although such assessments require substantial fundraising and preparatory work, the visits have been effectively replicated in subsequent courses when resources have allowed.

The ability to thoroughly and efficiently document and communicate findings has proven essential for maintaining effective partnerships and for project continuity and improvement over multiple years. This is especially true for student-led courses, in which instructors and project leaders change frequently. Communication of findings, methodologies, and pedagogical strategies prevent duplication of efforts and allow improvement of the course structure through time. These improvements are implemented through the evolving course syllabus, which is periodically updated by past and incoming course instructors, project leaders, and the Director of Projects. Particular emphasis on the quality of project portfolios submitted by design teams has been introduced into the course through mid-term design reviews, multiple presentations for which community partners (in person or by video) and the public are invited, and reviews of draft and final portfolios. Project portfolios containing recommendations for project partners and summer interns are retained in ESW-Stanford physical (on-campus) and electronic archives for future reference and are provided to partner organizations.

Most course offerings have focused on one project topic or community partner. Experience from numerous courses indicates that small teams of 3-5 students assigned to particular sub-topics and working in coordination are more effective than larger groups. In 2009, two different projects, ecological sanitation and tsunami preparedness, were conducted in parallel within the same course, with joint lectures on topics of mutual concern. The increase in the number of participants in the course was accompanied by an expanded leadership team to coordinate the course and integrate project teams in new ways, including the introduction of project leaders. These project leaders address the need for communication between subgroups and remove the burden of team management from the instructors, allowing the instructors to focus primarily on course administration. Although interactions between multiple disciplines in the 2009 course were ultimately beneficial for student projects in this course, limited resources may hinder the ability of students to sustainably operate such a course model. In the following year, courses were once again separated by project, but the institution of project leaders was retained.

Feedback from the spring 2009 course also indicated frustration with the 10-week structure of the original course model, in which certain crucial lectures occurred too late to be of use in the design process. In the updated model, a compulsory single unit, 10-week seminar series precedes a three-unit design course, with the seminar-design series operating over two consecutive quarters. The seminar series conveys background information in full prior to the start of the design phase, allowing design work to begin earlier in the subsequent quarter and additional attention to be paid to project content, team formation, mentoring sessions, and coordination between teams. During the design component, class sessions may also include guest lectures on a limited basis, working sessions with local experts, communication with outside partners, and course presentations. This two-part structure was first implemented in 2010 for the tsunami preparedness project, and generated overall positive feedback. Similar courses developed at institutions on a semester system may find that one semester is sufficient to incorporate a seminar component prior to the design work.

TABLE I
COURSE AND PROJECT ITERATIONS

Qtr, Year	Project or Course Topic	Project Location	Partner Organization(s)	Enrollment	Faculty Adviser	Course Format	Assess- ment Trip (# students)	Summer Internship (# students)
Spring 2006	Ecological Sanitation	Milot, Haiti; Stanford University Farm	Sustainable Organic Integrated Livelihoods (SOIL)	20	N*	Design course with guest lectures. One project topic with two project locations and 5-8 students per team.	N	Y (1)
Autumn 2006	Green School Design	Ocotol, Nicaragua	Centro Nueva Segovia (CNS)	Data not available	N*	Design course with guest lectures. One project topic with multiple sub-teams.	Y (2)	N
Spring 2007	Indigenous Technologies for Earthquake Resistant Construction	Pan-Himalayan Region	SEEDS India	Data not available	N*	Research-based project with guest lectures. Results directly applicable to summer internship.	N	Y (2)
Winter 2008	Sustainable Technology for School	Iringa, Tanzania	Bahati Education	4 (7-9 including auditors)	N	Independent working groups with project leader for discussions. Informal sub-teams by topical interest. Offered for-credit if desired.	N	N
Spring 2008	Water Quality Testing	General Application	N/A	6	N	Research-based project with guest lectures. Results useful for ESW-Stanford projects and student workshops on water quality.	N	N
Spring 2009	Earthquake and Tsunami Preparedness	Padang, Indonesia	GeoHazards International (GHI)	29	Y (2)	Design course with guest lectures. Integrated two project tracks into one course. General lectures and design reviews conducted with full class; specialized lectures held for separate project teams. Eight teams consisted of 3-5 students each.	Y (2)	Y (2)
	Ecological Sanitation	San Miguel Suchixtatepec, Oaxaca, Mexico	SARAR- Transformacion (SARAR)		N*		Y (3)	Y (2)
Winter 2010	Solar Refrigeration***	Tanzania	Dissigno	12	N	Design course with guest lectures. Three teams consisted of 3-5 students.	N	Y (2)
Winter 2010	Earthquake and Tsunami Preparedness	Padang, Indonesia	GHI, Andalas University	14	Y	Weekly seminar series in preparation for design course. Participation in course compulsory for design class.	Y**	Y (2)
Spring 2010	Earthquake and Tsunami Preparedness	Padang, Indonesia	GHI, Andalas University		Y	Design course with limited guest lectures. Four design teams with 3-4 students.	Y (2)**	Y (2)

* No single dedicated adviser identified; however, considerable faculty and/or staff involvement on a consulting basis.

**Fall quarter reconnaissance team, including past interns, project partners, and faculty adviser, visited project site after earthquake, prior to seminar course. Spring break assessment trip participants returned to project site prior to participation in spring quarter design course.

***Ratings for “overall level of satisfaction with the class” were obtained from course instructors directly, outside the university archive system.

Student ratings

When available through the university online system and course archives, course participant ratings of overall course quality were collected for the Design for a Sustainable World and related classes. While course ratings cannot capture the entirety of the classroom experience, their administration is identical across all Stanford courses, and favorable evaluations across universities are strongly correlated with positive student achievement.^{xiii} Ratings on a scale of 1-5 for “the quality of the course content” for the ESW course and three upper-level undergraduate engineering design courses in mechanical, civil, and environmental engineering are displayed in Figure II. The ESW course performed competitively with these established capstone project classes. The course was also compared to a graduate level faculty-led design course sponsored by the mechanical engineering department and the school of business that similarly incorporates service oriented design projects through a two-quarter program. While the initial ESW course ratings were somewhat low, the course exhibits dramatic improvement through time, with evaluation marks approaching those for the mechanical engineering course after implementation of recommended course improvements.

FIGURE II

STUDENT RATINGS THROUGH TIME FOR OVERALL COURSE QUALITY OF THE ESW SERVICE LEARNING DESIGN COURSE (●) COMPARED WITH THREE UPPER-LEVEL UNDERGRADUATE (UG) CAPSTONE ENGINEERING DESIGN COURSES IN ENVIRONMENTAL (△), CIVIL (◇), AND MECHANICAL (□) ENGINEERING (LEFT). WHEN COMPARED TO A HIGHLY RATED GRADUATE-LEVEL (GR) MECHANICAL ENGINEERING SERVICE LEARNING DESIGN COURSE (×), THE ESW COURSE RATINGS (●) IMPROVE THROUGH TIME ($R^2 = 0.03$ AND 0.88 , RESPECTIVELY, ON LINEAR REGRESSIONS) AND APPROACH THE RATINGS OF THE FACULTY LED COURSE (RIGHT).

Project Implementation

All service learning courses must balance the educational mission of the university with a desire to create positive community outcomes. Generating positive community impact, particularly in an international context, requires a degree of sensitivity and committed effort that is difficult to achieve in a remote volunteer setting. For this reason, care is taken to integrate with effective partner organizations to mitigate for the short span of student involvement. Overall, the experience of both partners and interns has been positive. Most partners have requested continued involvement with the ESW-Stanford program through additional classes, projects, and internships, while many interns have returned as project leaders, instructors, or advisers. While the project outcomes themselves are worth examining in detail, final implementation is in

large part determined by the project partners, and this study therefore focuses on the effect of the course structure itself on the student experience.

Proposed Timeline and Best Practices

Each of the projects completed to date has included a combination of assessment travel, student internships, faculty mentoring, professional mentoring, interdisciplinary collaboration, multi-year commitments, international partnerships, and domestic partnerships. The project focused on tsunami preparation in Padang, Indonesia, is unique in that it has integrated each of these elements with the combined impact reflected in student course evaluations, outside awards, and positive project outcomes. Using this project as a model, we have developed a recommended full cycle project timeline that includes the course itself, project development, student travel, and a schedule for knowledge transfer and personnel turnover (Table II). To complement this idealized timeline, we suggest a series of best practices to guide successful implementation of the model. The following recommendations concerning personnel transitions, project selection, course structure and knowledge transfer, student evaluations, fundraising, and student travel are based on formal and informal course evaluations, consultations with faculty and project partners, and our own experiences as instructors and projects director.

TABLE II
RECOMMENDED TIMELINE

	Personnel development	Project development	Course progression
Spring quarter (academic year -1)	ESW officer elections, Director of Projects selected	Solicitation of potential projects	
Summer quarter	Solicit course instructors	Due diligence and new project selection	Solicit faculty input
Fall quarter (academic year 0)	Finalize course instructors and project leaders	Fundraising, recruit faculty advisers	Publicize course offerings, confirm seminar speakers, submit syllabus to faculty advisers for review
Winter break		Assessment travel (winter option)	
Winter quarter	Accept and review applications for summer internships, accept and review design course applications	Fundraising, finalize scope of work and determine subgroup tasks	Seminar series, finalize design course syllabus
Spring break		Assessment travel (spring option)	
Spring quarter	Knowledge transfer to incoming Director of Projects	Design course; includes submission and review of project portfolios, recommendations for project partners and summer interns, and public presentations	
Summer quarter		Summer internships	Evaluate student feedback
Fall quarter (academic year +1)		Intern presentations, report submission, and debriefing, evaluate projects for continuation	Knowledge transfer to incoming instructors

Smooth personnel transitions and a multi-year outlook are critical to building and maintaining organizational capacity. Whenever possible, students chosen for key projects positions (e.g., ESW president, Director of Projects, project leaders, and Director of Fundraising) should not be in their final year before graduation, and students exiting key positions should be engaged in an advisory role. Course instructors may be selected from all levels of graduate study, with technical proficiency beneficial but not a necessary prerequisite, as the project leaders and course participants will be more engaged in design decisions. Organizational ability, leadership skills, enthusiasm and a desire to work independently are required qualities in both instructors and project leaders. Working with the Director of Projects, the course instructor,

project leaders, and summer interns form the core leadership team responsible for execution of each project. These teams function most effectively when engaged with faculty, and students are therefore strongly encouraged to seek formal faculty advisers.

Lessons Learned

A variety of challenges were experienced in project development over the five year period, including inability to fund travel to project sites, poor communication or lack of understanding with partner organizations, and inability to incorporate the proposed scope of work into a short term off-site course. To avoid such malfunctions, the projects selection process has grown to consider technical merit, community benefit, suitability for design course participation, suitability for intern participation, partner reliability, ease of communication, expected cost, and potential for multi-year collaboration. Due diligence should be conducted with all partners before the initiation of any partnership, with participation contingent upon third party recommendation. When in-kind benefits are to be conferred, these benefits should be codified as early as possible in a memorandum of understanding (MOA) to avoid conflict as the year progresses. In general, domestic partners have proven especially successful for the service learning course structure due to ease of communication, but these partners must also have a strong connection with organizations at the project site.

One-quarter classes are often too brief to both convey necessary background information and incorporate an effective design component. A two-quarter setup is recommended, with one quarter consisting entirely of lectures, taken for one unit on a pass/no pass basis. This lecture series can be opened to all students, and serves as a prerequisite for the application-based design component. A binding application process allows ESW personnel to select a qualified group of students for each course while avoiding overcrowding. The most effective courses conducted generally enrolled between 12 and 18 students per project.

Although each course must be tailored to the specific project and to the skills of the available personnel, a common series of assignments can be implemented for a variety of project topics. These assignments are the basis for evaluation of student progress and for final course grade assignments. The most important evaluations occur through midterm and final design review presentations and project portfolio submissions. An in-class midterm presentation provides a forum for feedback from other project teams, advisers, and project partners, when available. The final design review is an opportunity to showcase student projects in a more formal environment and is commonly open to the public. All audience members are asked to provide direct written reviews of presentations, yielding rapid and diverse feedback for presenters. The purpose of these sessions is to facilitate interaction both within the class and with outside experts. Additional tools utilized for assignments and evaluations have included a team charter assignment, for teams to establish goals and expectations in working as a group, and a project scope of work, to define project objectives, key tasks, and a timeline and budget. Individual grades are based on a combination of the overall team grades, class participation, and confidential evaluation forms in which students are asked to describe and numerically rank the contributions of each team member. A full description of mechanisms for student evaluations in student-led project courses is beyond the scope of this paper but warrants attention, as fair and effective evaluation of peers is a non-trivial issue.

Fundraising requires continuous effort focused on mitigating both total project cost and funding uncertainty. Uncertain funding hinders planning decisions at all levels, leading to delayed or cancelled travel opportunities or even cancellation of entire courses. Mitigation of this uncertainty requires securing funds well in advance and seeking multi-year funding commitments. Controlling total costs requires judicious allocation of available funding. General funds, including department grants and grants from university

research and public service centers, are most useful when set aside for new projects. Established projects are better supported through outside grants and corporate donations. Travel costs can be consolidated by limiting reimbursements to a lump sum agreed upon during the application process. Total project costs can also be mitigated through project selection, by seeking projects with low transportation costs, low materials demand, and donated on-site housing.

Student travel in the form of assessment trips and summer internships represents an important component of successful classes, cementing relationships with project partners, providing real-world context, and helping students become more connected to the projects. Project leaders and course instructors are generally chosen for assessment trips, as these students will be expected to lead during the class itself. Assessment trips may take place either immediately before the lecture series or immediately after, depending on the logistics of the particular project. Overall, trips of 2-3 students were found to provide a desirable combination of effectiveness, cost, and flexibility. Summer internships are the capstone of the program, in which the designs and knowledge generated in the class are transmitted to outside partners. Qualities for successful interns are considered similar to those required of successful course instructors, with particular emphasis on an ability to adapt and work independently. As with assessment travel, internships are limited to 2-3 students, to allow for successful integration into the operations of partner organizations. Interns must deliver updates throughout their summer experience, compile a detailed final report, and present their findings to the public during the upcoming school year. While it is in many ways unfortunate that a large number of students from each class are unable to visit project sites, financial constraints and the limited capacity of partners have generally prevented larger teams. Smaller student teams tend to increase flexibility while requiring that students interface outside of their own community, and may therefore be preferential even when larger teams are possible.

For each project, evaluation steps are required to iterate the course structure and determine which projects should be continued for additional years. Multi-year participation in projects can be extremely fruitful and should be pursued when possible, as long as meaningful work remains to be done. In the event of less successful or single year projects, continuation may still be arranged in a lesser form, possibly including extracurricular student working groups or independent summer interns. Metrics including official course evaluations, unofficial surveys, and exit interviews with key personnel and partners should be used at a minimum to evaluate the year's progress and determine necessary iterations.

CONCLUSIONS

One of the greatest challenges, and a necessity to achieving course learning objectives and project goals revolves around the need for long-term community interactions and effective communication. We have established several long-term partnerships with NGOs that have the human and resource capacity to ensure extensive and continuous community involvement. These organizations serve as intermediaries to student project implementation and community participation. In many ways, the partner organizations are relied upon for feedback on the success of student placement, the direction of future design and project work, and in defining the scope and needs of the community of interest. Strong relationships between the students and the community as well as positive learning attitudes and humility are essential for each involved student to gain an understanding of how she or he can credibly contribute to community needs. Students placed in international service projects must initiate adaptations to the needs and particulars of the community, understanding that the course-derived results are fluid and must be improved by local knowledge and expertise.

Additionally, project leaders and course instructors must be cognizant of potential dangers associated with technological interventions in another culture such as the loss of indigenous knowledge and the creation of unsustainable dependencies. In our experience, the support of an engaged faculty member and

consistent community partner through several years of a particular topic, coupled with a commitment to positive impact on the community by the course leaders and participants, are more likely to lead to successful engineering service learning courses and course satisfaction. However, this faculty engagement is not compulsory, as success has been demonstrated without strong faculty involvement. Dedicated and mature graduate, and sometimes undergraduate, students have served as both competent and highly-successful course instructors. Effective student instructors complement their own expertise by seeking out technical expertise, promoting faculty and professional involvement, and establishing strong communication lines with the community partners.

Running a service learning course as a student-led initiative presents a number of challenges. In particular for student-led projects and courses, continuity and quality of leadership is a persistent issue. From the perspective of students and faculty, acceptance and perceived legitimacy can suffer from the resultant inconsistencies. These inconsistencies can be magnified by yearly turnover in projects and partnerships, with some projects ultimately proving more fruitful than others. Despite this yearly turnover of organizational capacity and project partners, institutional knowledge has been maintained and developed throughout the lifetime of the course, with performance improving significantly over time. When run using best practices, course ratings for Design for a Sustainable World have met or exceeded those of comparable faculty-run courses.

When the tradeoffs in consistency are effectively mitigated, student-initiated courses create benefits extending well beyond the experience of the participating students. Student interaction is fostered across all levels, including seminar enrollment, student design, student travel, project evaluation, teaching, and curriculum development, allowing for the development of leadership skills across a broad spectrum of students. Engaged participation by students at all levels, from freshman to PhD candidates, results in a degree of integration that is highly unusual in the university environment. Without the presence of an organizing faculty member, students are forced to make decisions in a real-world environment, in which the scope of their responsibilities and the consequences of their decisions are greatly expanded. When properly designed and implemented, such courses can play a valuable role in the university curriculum.

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- ⁱBielefeldt, A. R., K. G. Paterson, and C. W. Swan. 2010. Measuring the Value Added from Service Learning in Project-Based Engineering Education. *International Journal of Engineering Education* 26 (3):535-546.
- ⁱⁱCoyle, E. J., L. H. Jamieson, and W. C. Oakes. 2005. EPICS: Engineering Projects in Community Service. *International Journal of Engineering Education* 21 (1):139-150.
- ⁱⁱⁱBauer, E. H., B. Moskal, J. Gosink, J. Lucena, and D. Munoz. 2007. Faculty and student attitudes toward community service: A comparative analysis. *Journal of Engineering Education* 96 (2):129-140.
- ^{iv}Dewoolkar, M. M., L. George, N. J. Hayden, and D. M. Rizzo. 2009. Vertical Integration of Service-Learning into Civil and Environmental Engineering Curricula. *International Journal of Engineering Education* 25 (6):1257-1269.
- ^vAzapagic, Adisa, Slobodan Perdan, and David Shallcross. 2005. How much do engineering students know about sustainable development? The findings of an international survey and possible implications for the engineering curriculum. *European Journal of Engineering Education* 30 (1):1-19.
- ^{vi}Murphy, Cynthia F., David Allen, Braden Allenby, John Crittenden, Cliff I. Davidson, Chris Hendrickson, and H. Scott Matthews. 2009. Sustainability in Engineering Education and Research at U.S. Universities. *Environmental Science & Technology* 43 (15):558-5564.
- ^{vii}Mihelcic, J. R., L. D. Phillips, and D. W. Watkins. 2006. Integrating a global perspective into education and research: Engineering international sustainable development. *Environmental Engineering Science* 23 (3):426-438.
- ^{viii}Pritchard, M. S. 2000. Service-learning and engineering ethics. *Science and Engineering Ethics* 6 (3):413-422.
- ^{ix}Johnson, Peter E. 2009. Direct and indirect benefits of an international service-learning design project: Educational effects on project members and their peers. *International Journal for Service Learning in Engineering* 4 (1):15-30.
- ^xVandersteen, J. D. J., C. A. Baillie, and K. R. Hall. 2009. International Humanitarian Engineering Who Benefits and Who Pays? *IEEE Technology and Society Magazine* 28 (4):32-41.
- ^{xi}Al-Khafaji, Karim, and Margaret C. Morse. 2006. Learning sustainable design through service. *International Journal for Service Learning in Engineering* 1 (1):1-10.
- ^{xii}Al-Khafaji and Morse. 2006. Learning sustainable design through service. *IJSLE* 1 (1).
- ^{xiii}Cohen, Peter A. 1981. Student ratings of instruction and student achievement: a meta-analysis. *Review of Educational Research* 51 (3):281-309.