Exploring the Expanding Impact of a Sustainable Development Engineering Course Through a Critical Evolutionary Review

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The Expanding Impact of a Sustainable Development Engineering Course Through a Critical Review over its Offerings

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Abstract

The Sustainable Development Engineering course has evolved over its seven offerings at a research university in which interdisciplinary groups of graduate students engage in critical thinking, problem solving, and collaborate with community partners. Students provide on-site skilled labor, multi-media presentations, and project proposals for the community; in return, the students create project deliverables that display the technical knowledge and skills they developed. In addition, each deliverable integrates varying levels of partnership with the community, sharpening students' teamwork and cross-cultural competencies. The purpose of this paper is to 1) understand the evolution of the course, 2) compare its outcomes to existing engineering education standards and benchmarks, and 3) consider its increased impact over time to students, instructors, and community stakeholders. This will be achieved through a critical reflection upon the seven previous years' syllabi and course outcomes alongside popular engineering education criteria. The results show that students understood the necessity of a global context in engineering design when they developed appropriate projects that met the needs of a culturally diverse community. In addition, students exercised global competencies such as language and cultural skills or teamwork and group dynamics to produce these designs. Furthermore, benefits were also realized by other affiliates of the course such as graduate student instructors who formulated, adapted, and executed innovative lectures and field work and by community partners who built skills in construction and operation and maintenance of a new greenhouse and rainwater harvesting system.

Keywords

Sustainable Development, Global Competency, Engineering Education, Community Engagement

Introduction

Engineers are currently working in increasingly complex, globalized environments. The expectations of their abilities to work efficiently within group dynamics, effectively on new multimedia platforms, and professionally through cross-cultural awareness have increased[1-4]. Some programs, anticipating these trends, are altering their engineering education to meet the needs of global industries, commercial ventures, non-governmental and government sectors, and academic research[5]. Though the Accreditation Board for Engineering and Technology (ABET) has stated through Criterion 3(h) that all engineering graduates should have a "broad education necessary to understand the impact of engineering solutions in a *global*, economic, environmental, and societal context," the training of engineering students to think globally has been traditionally left to the realm of humanities and social science coursework[6]. Accordingly, a growing number of engineering departments and colleges are going beyond this baseline standard to reflect their university's goals and interests in innovative engineering curriculum.

Classroom-based teaching, albeit foundational for an introduction to fundamental concepts, is now being coupled with collaborative projects, experiential learning, multimedia assignments, independent research, international learning opportunities, cross-cultural competence, and open-ended problem solving to foster a deeper understanding, particularly of globally focused material[2-4,7]. In order to outline areas and methods for deeper learning on this topic, Widmann and Vanasupa developed a Global Competency Framework that overlays three categories (knowledge, skills, attitudes) atop Fink's taxonomy of significant learning to evaluate university curriculum that seeks to cultivate globally minded engineers[4]. Fink's taxonomy is a hierarchical system that reflects increasing levels of learned concepts[8] and has been used in previous studies to evaluate other engineering curriculum [4,9]. Widmann and Vanasupa's 2008 study assessed the California Polytechnic State University (Cal Poly) at San Luis Obispo's capstone design experience and revealed areas where subsequent offerings could incorporate more projects and student partnerships to better instill global awareness[4].

The Cal Poly study justified and operationalized a self-reflective assessment that critically evaluated the benefits of an innovative educational experience[4]. While the assessment is of value, the sample size reflects only a single year. When a study presents results associated with a single data set there are limitations to an author's ability to compare, contrast, or potentially extrapolate their findings to a wider application. The Cal Poly study remains of value as it demonstrates the importance of publishing to aid other researchers in keeping abreast of current educational experiences and innovations to (1) understand the most current learning tools, (2) disseminate best practices to allow for quick replication, and (3) explain the pitfalls of curriculum changes that are not worth repeating.

As such, the first goal of this paper is to understand and communicate the evolutionary and adaptive experiences that the university's Sustainable Development Engineering course has undergone during its seven offerings. Secondly, the paper compares the course's outcomes to existing engineering education standards and benchmarks, including the Global Competency benchmarks depicted in Table 1 and ABET engineering educational standards[2,6,10]. Lastly, the broadened impact and deepening influence of the Sustainable Development Engineering course will be considered by bringing together the products of both the first and second goals as they beneficially pertain to students, instructors, and community stakeholders.

Table 1: Four Requirements for an Engineer to Achieve Global Competency [2,10]

Language and Cultural Skills
Teamwork and Group Dynamics Skills
Knowledge of the Business and Engineering Cultures of Counterpart Countries
Knowledge of International Variations in Engineering Education and Practice

Prior to the Fall of 2008, the Sustainable Development Engineering course (cross-listed in the College of Public Health as Water Pollution and Treatment) was not offered at this campus, but existed in a different form at another university[11,12]. When the lead faculty member for this course moved, the inaugural class engaged graduate students in critical thinking and problem solving by considering economic, social, and environmental limitations of engineering projects within a global context. Throughout its offerings, this course has had no prerequisite requirements or mandatory international field component. While the university touts a long-standing history of international service, collaborations with local community partners, rigorous interdisciplinary research, and a commitment to sustained, appropriate growth, there had been no engineering or interdisciplinary course that synthesized these initiatives prior to that the implementation of this course. Consequently, it is now included as one of the core courses for a master's degree in environmental engineering and in the interdisciplinary Water, Health, and Sustainability graduate certificate.

The stated objectives of the Sustainable Development Engineering course are to:
1) apply engineering fundamentals and appropriate technology in design, construction, operation, and maintenance of engineering projects that serve people living in the developing world and smaller communities in the U.S.,
2) learn how community-based engineering projects fit into larger, global issues of sustainable development,
3) develop an understanding of the important interrelationship of public health and engineering;
4) incorporate environmental, societal, and economic considerations and community participation into engineering practice.

Over the years, these objectives have guided the course's curriculum to effectively provide a platform for infusing sustainability concepts into an interdisciplinary atmosphere that considers a global context to engineering problem solving. However, the Fall 2014 curriculum has proven to be particularly unique in the ways that students' knowledge of engineering solutions in a global context has also influenced their practical skillsets. These alterations and the ways in which they are executed warrant further explanation and justification.

For the Fall 2014 course offering, interdisciplinary groups were expected to actively collaborate with community partners and produce a valuable suite of deliverables, including a construction project, a multimedia presentation, and a project proposal to community stakeholders. The relationship is mutually beneficial—students provide high quality project proposals for the community, visually powerful multimedia presentations, and on-site labor. In return, the students create project deliverables that act as a professional product to display the technical knowledge and skills, teamwork, and social context of the project they have developed during the course. These deliverables situate their projects in a larger context as mentioned in ABET's Criterion 3(h). Furthermore, each course deliverable integrates varying levels of partnership with the community, sharpening their teamwork and cross-cultural global competencies. Furthermore, a reinforcing loop has emerged over the years of the course's evolution, as former students have become instructors for the course, grafting their global field experience (through participation in the Master's International program[12]) into lectures and community partnership development. This affords instructors opportunities to improve skills in lesson planning, teaching, and classroom management.

Methods

This research employed a mixed methods approach to address the paper's three objectives:
1) to understand the evolution of the Sustainable Development Engineering course,
2) to compare its outcomes to existing engineering education standards and benchmarks, and
3) to consider its impact to participants, instructors, and community stakeholders.
The syllabi and outcomes of the Sustainable Development course from 2008 to 2014 were assessed and compared to engineering education criteria using critical reflection methods.

Critical Reflection upon Sustainable Development Course Syllabi
Syllabi from the seven offerings of the Sustainable Development Engineering class were collected, beginning with the 2008-2009 academic year through 2014-2015. For each semester the course was offered, information was obtained from the syllabi, consolidated into a table, and systematically compared: course activities, deliverables, goals, topics, instructors who taught the course, and academic disciplines of the students that enrolled. Through documentation, comparison, and critical reflection of the syllabi, trends were discovered as the course's curriculum began to broaden its impacts to students, instructors, and community partners.

To understand the impact of the Sustainable Development Engineering course over the past seven years, the following information was documented and analyzed in the Results and Discussion section: disciplines of the students enrolled, course goals, topics, and deliverables. In order to compare the course's potential impact to engineering education, the characteristics of the course and the syllabus were compared with standards and globally-focused benchmarks, such as the 2014-2015 Criteria for Accrediting Engineering Programs, particularly General Criterion 3 for Student Outcomes, to reflect engineering education standards and the outline of global competencies provided in Table 1 as the benchmarks[2].

Results and Discussion

Course Majors

The course started in the spring of 2009 and at first was offered to primarily Civil and Environmental Engineering graduate students[13]. Seven of the 15 students of the course in 2009 were preparing for the Peace Corps as part of the Master's International program, a three-year Master's degree program incorporating one year of coursework and two years of training and service in the Peace Corps. To promote interdisciplinary collaboration between the related fields of environmental engineering and global and public health,, the course was offered in 2010 as an elective for global health graduate students and as a requirement for public health graduate students in the environmental and occupational health program through the connections formed by the course instructor during the first year on campus in 2009[14]. Starting in 2010 and continuing to the present, the course is cross-listed for Global and Public Health Students[14-19]. Of the 31 students in the Fall 2014 course, 15 were registered under the global and public health listing and 16 students were registered for the course as engineers. The students met together in the same classroom and formed interdisciplinary teams to work on homework assignments and projects. The increased collaboration between engineering and health students provided more opportunities to achieve the course objective of developing an understanding of the important interrelationship of public health and engineering.

Course Objectives

From 2009 to the present, the four course goals have remained largely the same. In 2009, the first objective addressed the service to people in the developing world. To acknowledge and address the needs in our own country for sustainable development engineering, in 2010 the objective added service to smaller communities in the U.S. [14]. The other three objectives have remained the same: (1) learn how community-based engineering projects fit into the larger, global issue of sustainable development; (2) develop an understanding of the important interrelationship of public health and engineering; and (3) incorporate environmental, societal, and economic considerations of the developing world into engineering practice. The addition of service to smaller communities in the U.S. emphasized the application of course objectives to both local and global contexts and was evident in the local course activities discussed below in the course activities section.

Course Topics

In earlier semesters, the course included a wide variety of developing world topics found in Mihelcic's *Field Guide to Environmental Engineering for Development Workers* [20] such as water quality and treatment, wastewater treatment, and community participation. Because of evolving doctoral research in developing world applications, additional course topics were taught by the doctoral students who conducted the field research. With a desire to equip students with communication tools, a Multimedia Crash Course was added in Fall 2014[19]. Course instructors used classroom lectures, case studies, reports, personal experience and concurrent homework assignments to examine variations in engineering practice encountered during international research. The ability for doctoral students to instruct course topics pertaining to their international research topics provided increased opportunities for students to learn how community-based engineering projects fit into the larger, global issue of sustainable development and how engineering fundamentals and appropriate technology can be applied in the developing world. A table providing a breakdown of course topics taught by year is provided in the Appendix.

Course Activities

In 2009, the course activity was a construction materials lab in which a composting latrine was built on the campus and subsequently deconstructed[13]. Starting in 2010 with the arrival of a PhD student with extensive experience with manual well drilling, a manual well drilling laboratory was added to the course activities[14]. With a desire to provide long-term community benefit in addition to the learning experience for students, Fall 2014 course activities included three construction materials laboratories, including the construction of a greenhouse, rainwater harvesting system, and drip irrigation system at a local farm owned by an Ethiopian church and used by refugees from Burma[19].

Course instructors managed the greenhouse construction near the beginning of the semester. Students designed, managed, and installed the rainwater harvesting and drip irrigation as part of their semester projects. Through this experience, students applied engineering fundamentals and appropriate technology in the design, construction, operation and maintenance of an engineering project serving people living in smaller communities in the U.S., learned how the project incorporated environmental, social, and economic considerations through research and extensive communication with the Burmese refugees and other project partners. Working with the project allowed students to apply their knowledge and skills to develop global competencies of language and culture, teamwork and group dynamics with both fellow students and refugees at the farm, and international variations in engineering education and practice by working with refugees at the farm. Many students also shared their knowledge at two local schools as a part of the Great American Teach-In, a district wide opportunity for members of the surrounding community to engage with K-12 students on engineering and/or health topics. This activity was integrated with one of the group projects. All of these activities gave students an opportunity to assess their personal attitudes by experiencing the complex process that is needed to accomplish engineering projects outside of their own culture. This outcome is perhaps the most significant benefit that the students receive because these types of scenarios are difficult to simulate in an educational setting.

Course Deliverables

When the course began at the university in Spring 2009, the course deliverables included a literature review and homework assignments[13]. To provide exposure to more developing world topics during the second year, the course deliverables added course presentations in addition to a literature review and homework assignments[14]. Course presentations were completed by a pair of students on 2-3 research topics related to sustainable development engineering. Examples include small-scale anaerobic biogas production, disinfection in community water systems, gender and water usage, evolution of septic tank technology, and self supply. Literature reviews were completed by each student on similar topics[13-18]. In Fall 2014, the literature review was replaced by a mid-term project presentation, multimedia presentation, and final project portfolio[19]. Mid-term project proposals were presented by teams of 3-4 students reflecting a sustainable development engineering idea suitable for the farm or other partners. Examples include rainwater harvesting and drip irrigation. Multimedia presentations were 5-8 minute videos completed by teams of 3-4 students on the same topics as the mid-term project presentations. The multimedia presentations could include a how-to construction video, operation and maintenance instructions, or background information that would further an understanding of their proposed project. Final project portfolios included project materials such as an advanced version of the mid-term project proposal, budget, and video script completed by the teams of 3-4 students on the same topics as the mid-term and multimedia presentations[19]. The course deliverables for the projects at the farm (5 farm projects out of 9 course projects) were presented to the stakeholders on topics including drip irrigation, rainwater harvesting, greenhouse construction, cattail flour production, and chicken coop construction; another group met with teachers at a local middle school. The stakeholders gave feedback to the students in regards to their mid-term project presentations and three projects were implemented later in the semester. The opportunity to receive and incorporate feedback from real project stakeholders provided a valuable learning opportunity for students and helped conform the students' projects to the stakeholders' desires. A review of course deliverables over time is provided in Table 2.

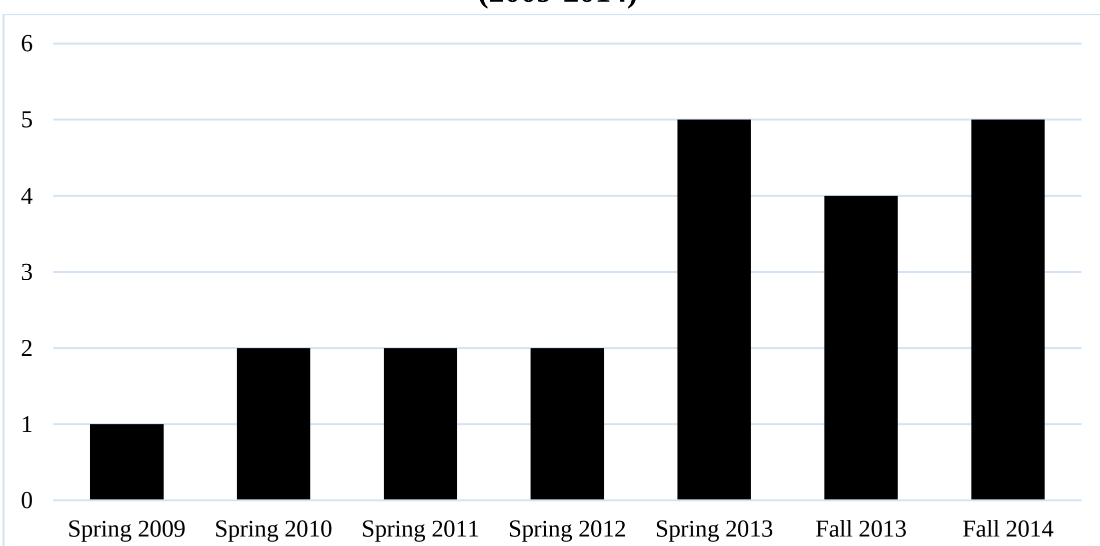
Table 2: Sustainable Development Engineering Course Deliverables (2009-2014)

	Spring 2009[13]	Spring 2010[14]	Spring 2011[15]	Spring 2012[16]	Spring 2013[17]	Fall 2013[18]	Fall 2014[19]
Homework Assignments (Approximately Eight)	x	x	x	x	x	x	x
Course Presentations		x	x	x	x	x	
Literature Review	x	x	x	x	x	x	
Mid-Term Project Presentation							x
Multi-Media Presentation							x
Final Project Portfolio							x

Course Instructors

The founder of the Master's International Program at this university taught the course from 2009-2013. During the professor's sabbatical in Fall 2014, a different professor taught the course. To help provide experience from Returned Peace Corps Volunteers (through the Master's International program) who were continuing their research as PhD students, one PhD student taught the construction materials laboratory and other in-class lectures on water supply and community participation in 2009[13]. From 2010 to Spring 2013, two PhD students taught multiple courses on groundwater hydrology, wells, gravity-flow water systems and facilitated field laboratory sessions on topics of construction materials and manual well drilling[14-16]. In Fall 2013, five PhD students continued to teach course and field laboratory sessions on topics of drilling and construction materials[18]. In Fall 2014, all courses and field laboratories were taught by five PhD students according to their respective expertise based on their research in the Peace Corps and PhD studies[19]. The expansion of course instructors allowed for increased opportunities to learn how community-based engineering projects fit into larger, global issues of sustainable development and how to incorporate environmental, social, and economic considerations of the developing world into practice through the instructors' direct experience in conducting research and living in international settings. A review of course instructors over time is provided in Figure 1.

Figure 1: Number of Sustainable Development Engineering PhD Course Instructors (2009-2014)



Analysis of Course Evolution using Global Competencies

The following four global competencies are used as a framework to evaluate the course and its increasing relevance to students as they encounter today's global challenges in engineering.

Language and Cultural Skills

From 2009-2013, the course did not specifically address language or cultural skills. In 2014, a community service element was added to the course that involved partnership with an Ethiopian Orthodox pastor whose church's land was offered for farming use to refugees from Burma. Interactions with the Ethiopian pastor and Burmese farmers increased the cultural skills of students as they were required to adapt their technical language to better communicate with the pastor, whose daily work and prior experience did not include these types of projects, and to the Burmese farmers that had limited English abilities. Reading material and feedback on mid-term and final presentations from a professor of Anthropology who works with the Burmese farm also contributed to student training on cultural skills. Though a translator was not sourced to produce multilingual videos for the Burmese garden projects, this was done for the one student project that partnered with faculty from Bolivia.

Teamwork and Group Dynamics Skills
Beginning in 2009, the primary evidence of teamwork and group dynamic skills was the field laboratories in latrine construction and well drilling. As the course evolved in 2010 to include public health and engineering students, many homework assignments involved interdisciplinary teams that allowed for collaboration and interpersonal skills development. In 2014, these skills were developed in a broader scope through midterm and final group project demonstrations and a multimedia presentation.

Knowledge of the Business and Engineering Cultures of Counterpart Countries
The two professors who taught the course each brought extensive experience in business and engineering in international contexts. The professor who taught the course from 2009-2013 has conducted extensive research in Bolivia and has directed graduate students who performed research in over 24 countries[21]. The professor who taught the course in 2014 has taught courses with associated field experience in Guyana and Barbados, and has research partnerships in Guyana, Barbados, Belize, Trinidad and Tobago[22,23]. The international experience of the professors has been increasingly complemented through the use of graduate student instructors, all of whom have shared knowledge of the business and engineering cultures of counterpart countries based on previous experiences in the Peace Corps or other international development opportunities in the following countries: Barbados, Belize, Bolivia, Cameroon, Dominican Republic, Honduras, Madagascar, Mali, Mexico, Panama, and Uganda. A guest speaker in 2012 shared an experience related to the evaluation of natural wastewater treatment and reuse systems in Latin America, which benefitted students in the course who were involved in research on wastewater reuse systems in Bolivia. One guest speaker in 2014 previously conducted research on developing world water treatment technologies in Burma, which was particularly relevant to the Sustainable Development Engineering students as they worked on the course's community service projects with Burmese refugees living in Tampa. A second guest speaker in 2014 shared research on using local materials for rainwater catchment.

Knowledge of International Variations in Engineering Education and Practice
To share knowledge of engineering education and practice in the developing world, course

readings and homework assignments in all seven years of the course' existence at the university draw upon resources with an international context. The textbook for the course is *Field Guide to Environmental Engineering for Development Workers,* which has case studies and examples from a variety of international contexts[19]. In 2014, the graduate student instructors provided lectures detailing engineering practice for spring capture in Panama, wastewater lagoon systems in Bolivia, appropriate technology for handwashing in Mali, and indoor stoves in Uganda. These lectures underscored the variations and trends in drinking water systems, wastewater management, hygiene, and cooking methods in developed and developing countries to expose students to the different economic, environmental, and health implications. Of the nine course projects in 2014, three included construction activities: greenhouse construction, drip irrigation installation, and rainwater harvesting installation. These projects required coordination and construction at the property owned by an Ethiopian church that is farmed by Burmese refugees. Students reflected on the projects and stakeholders' feedback throughout the semester and produced oral and multimedia presentations based on these experiences. These deliverables highlighted the unique attributes associated with the variable engineering education and practices experienced in the semester's interdisciplinary, multi-national field site.

Conclusions

Evolution of the Sustainable Development Engineering Course

The Sustainable Development Engineering course evolved through adaptations and alterations made in the students enrolled, instructors teaching, and objectives, topics, activities, and deliverables required for submission. Initially the course was composed of primarily civil and environmental engineering students but expanded to public and global health students. The objectives evolved to include operation and maintenance of engineering projects and applications in smaller communities in the U.S. Topics expanded over time to include instruction from PhD students with personal experience in developing world contexts. Deliverables in 2014 included multimedia components and direct interaction with Burmese refugees in the Tampa area which provided language, cultural and engineering experience as well as construction of appropriately designed technologies that were suitable for long-lasting benefits to the farmers.

Comparison to Existing Engineering Education Standards and Benchmarks

When considering engineering education standards and benchmarks, the course has adapted and evolved to address each of these areas. First, this study referenced ABET's General Criterion 3: Student Outcomes, particularly subsection 3(h), as a proxy for an engineering education standard that reflects the awareness students should have about the way engineering solutions fit into a global context. The course curriculum also adapted to the growing expectations of engineers to demonstrate global competencies through language and cultural skills, teamwork and group dynamic skills, knowledge of business and engineering cultures of counterpart countries, and knowledge of international variations in engineering education and practice.

Consequently, there is a need to differentiate between awareness of a global context and practice of global competency. Both are targeted through the course's evolution in objectives, topics, activities, and deliverables. However, the primary distinction comes through the differentiation of knowledge from skill. As students improve their abilities to situate their (practically implemented or hypothetically proposed) engineered solutions into a global context, they are demonstrating knowledge required by an engineering educational standard. On the other hand, when students exercise and apply globally-focused knowledge in a way that enables them to problem-solve with others that define and address engineering challenges differently, they are demonstrating global competencies[2]. As such, the following section discusses specific developments in the students' globally-focused knowledge and skills.

Impact to Students

The Sustainable Development Engineering course impacted students through hands-on field laboratories and through lectures, homework, and projects. In addition to a construction materials lab, a manual well drilling laboratory was added in 2010 and continued to 2013. In 2014, students developed cultural and language skills by engaging with the Burmese farmers, Burmese pastor, and Ethiopian pastor through field visits, construction activities, interviews, and other forms of correspondence. The students engaged in a diverse array of hands-on experiences including the construction of a greenhouse, drip irrigation system, and rainwater harvesting system. The conversations and field laboratories that took place at the farm allowed for the development of formal and informal connections to be made between students and project stakeholders.

Lectures, homework assignments, and projects created a framework for students to become more globally competent. Since 2009, the number of graduate students involved in course instruction increased from one to five, providing PhD students with international experience the opportunity to share technical and cultural information to the students. In 2014, multimedia presentations expanded the students' skills at disseminating technical information to a broader audience. One student group produced their video with Spanish translation for Bolivian professors to use in their curriculum. Cross-cultural presentations by course instructors exposed the students to diverse topics that captured the diversity of engineering practices and public health concerns encountered in global contexts.

Impact to Community Partners

From 2009 to 2013, students participated in hands-on laboratories in construction materials or manual well drilling, but the objects built were subsequently deconstructed. In 2014, the Sustainable Development Engineering course expanded its potential for impacting the community partners through the construction of physical infrastructure, the creation of technical reports, the development of knowledge sharing environments and the beginning of networks and long-term partnerships. In the three months of the course, students and community partners constructed a greenhouse, drip irrigation system, and rainwater harvesting system. Other projects, including a chicken coop, cattail flour production, and the expansion of drip irrigation system, were not constructed but have produced plans to be used in construction in the upcoming months. Deliverables from each project group include technical reports that can be incorporated into the farm's Future Planning Portfolio. The course also created opportunities for knowledge transfer and networking between community partners, students, and faculty. Students produced multimedia presentations for operation and maintenance of the drip irrigation system, rainwater harvesting system, and greenhouse. Challenges included difficulty in coordination of construction or educational meetings and the logistics of coordinating meaningful participation and knowledge transfer to project stakeholders.

Impact to Course Instructors

With guidance from the advising professors, the graduate students were able to gain experience in a diverse set of skills including curriculum development, lesson planning, and project management. First, the semester began as they re-formulated the syllabus to incorporate a multimedia component, adapted the hands-on field laboratory, and expanded the lecture topics to a broader range of global engineering applications. Next, each graduate student was required to develop his or her own lectures, formulate reading assignments, course activities, and homework to effectively disseminate their topics.

During the multiple on-site lectures in the field, the course instructors worked together to plan and orchestrate the construction projects where they coordinated materials' delivery and safety sessions, acted as project managers and facilitators, and mediated interactions between students and project stakeholders. These on-going interactions between students and community stakeholders also required the course instructors to act in an advisory role to groups on the technical and cultural challenges concerning their projects, actions that had not previously been necessary of instructors but further exercised their cross-cultural and communication skills.

Limitations

While this paper highlights the expanded impacts to all those associated with the course through an objective comparison between what has been done with the course in the past and what is being practiced now, a significant limitation is the lack of a systematic survey or evaluation of the course's effectiveness. As such, the 2014-2015 offering has prompted the course instructors to begin work that quantitatively and qualitatively evaluates the course's impact to students through an assessment of their learning. This parallel research study (*Improving the Global Competency of Graduate Engineers Through Peace Corps Partnership and Long-Term International Service*) will complement the research presented in this paper to holistically evaluate this Sustainable Development Engineering course and understand its impacts to all involved.

Recommendations

As the Sustainable Development Engineering course moves forward, future planning may be

considered ideal when the course topics overlap with the following:
1) graduate student instructors' international fieldwork or domestic research experiences,
2) topics that appear in the *Field Guide in Environmental Engineering for Development Workers* textbook, and
3) projects that can be conducted with community partnerships.
This provides greater depth to students as they are exposed to first-hand experiences from research and field expertise, have the opportunity to reference the subject in a textbook, and can practice the skill on a local level.

In addition, there are other recommendations that the authors gleaned from the course offerings and may be of value to curriculum planners for similar teaching purposes. The interdisciplinary blending of engineering and public and global health students can broaden the scope of group discussions and partnerships, but must be addressed with care to ensure all students are taught at an appropriate depth of knowledge. For example, the technical aspects of water and sanitation systems should be introduced as relatively new features for some public and global health students, refraining from discipline-specific jargon. Furthermore, when innovating a diverse array of learning methods and deliverables, it is most valuable to do so with a prior knowledge of the resources one's individual university already possesses. By doing so, students will have ample resources to use to develop quality course deliverables.

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Appendix

Table A1: Sustainable Development Engineering Course Topics (2009-2014)

	Spring 2009[12]	Spring 2010[13]	Spring 2011[14]	Spring 2012[15]	Spring 2013[16]	Fall 2013[17]	Fall 2014[18]	Activity	Objective
Global Sustainable Development	Week 1	Week 1	Week 1	Week 1	Week 1	Week 1	Week 1	Lecture	1,2,3,4
Public Health	Week 1	Week 1,12	Week 1	Week 1	Week 1	Week 1		Lecture	3,4
Community Participation	Week 1	Week 1	Week 1	Week 1	Week 1	Week 1	Week 1	Lecture	2,4
Water Supply	Week 2	Week 1	Week 1	Week 1,7	Week 1	Week 1	Week 5	Lecture	1,2,4
Role of Women	Week 2	Week 1	Week 1	Week 1	Week 1	Week 1		Lecture	2,4
Water Demand	Week 2	Week 1	Week 1	Week 1	Week 1	Week 1	Week 5	Lecture	1,2,4
Life Cycle Thinking	Week 2	Week 3	Week 3					Lecture	1,2,4
Engineering Materials	Week 4	Week 6	Week 12,13	Week 12	Week 13,14	Week 11	Week 12	Lecture, Laboratory	1,2,4
Springboxes, Spring Development	Week 5	Week 5	Week 5	Week 6,7	Week 6,7	Week 9	Week 5	Lecture	1,2,4
Rainwater Harvesting & Storage	Week 5	Week 5	Week 5	Week 7	Week 7	Week 9	Week 5	Lecture, Project	1,2,4
Gravity Fed Water Supply Systems	Week 6	Week 4	Week 4	Week 6,7	Week 6	Week 9	Week 5	Lecture	1,2,4
Wells	Week 7	Week 8	Week 6, 7	Week 8,9	Week 10,11	Week 6, 7, 8		Lecture, Laboratory	1,2,4
Water Treatment	Week 8	Week 9	Week 9	Week 11	Week 8	Week 10	Week 4	Lecture	1,2,4
Wastewater Generation and Composition	Week 9	Week 10	Week 10				Week 8	Lecture	1,2,4
Wash Areas and Soak Pits	Week 9	Week 10	Week 10	Week 4	Week 4	Week 4		Lecture	1,2,4
Latrines	Week 10	Week 10	Week 10	Week 4	Week 4	Week 4	Week 8	Lecture, Laboratory	1,2,4
Solid Waste Management	Week 11,12	Week 13	Week 14	Week 14	Week 9	Week 14	Week 13	Lecture	1,2,4
Indoor Air Quality	Week 15	Week 14	Week 15	Week 15	Week 15	Week 15	Week 13	Lecture	1,2,4

Flow Through Pipes		Week 4	Week 4	Week 6	Week 6	Week 9	Week 5	Lecture, Project	1,2,4
Project Management		Week 3	Week 3	Week 2,3	Week 2,3	Week 2, 3	Week 2	Lecture	1,2,4
Wastewater Lagoons		Week 11	Week 11	Week 5	Week 5	Week 5	Week 8	Lecture, Project	1,2,4
Water Lifting Devices			Week 8	Week 10	Week 12			Lecture	1,2,4
Septic Tank Design and Maintenance				Week 4	Week 4	Week 5	Week 8	Lecture	1,2,4
Self Supply						Week 8	Week 4	Lecture	1,2,4
Energy Recovery: Biogas Digester/AD						Week 13	Week 11	Lecture	1,2,4
Multi-Media Crash Course							Week 6	Lecture, Project	
Wastewater Reuse							Week 9	Lecture	1,2,4
Microbial Risk Assessment							Week 9	Lecture, Project	1,2,4
Behavior Change							Week 10	Lecture	2,4
Composting							Week 13	Lecture	1,2,4

Objective 1-Apply engineering fundamentals and appropriate technology in design,construction, operation, and maintenance of engineering projects that serve people living in the developing world and smaller communities in the U.S.
Objective 2-Learn how community-based engineering projects fit into larger, global issue of sustainable development
Objective 3-Develop an understanding of the important interrelationship of public health and engineering
Objective 4-Incorporate environmental, societal, and economic considerations of the developing world into engineering practice