

Fulfilling Engineering Program Objectives through Service Learning Campaigns in Developing Countries

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ABSTRACT: The civil engineering profession, in an adaptive reaction to emerging roles for civil engineers, is recognizing the need for new engineers to possess a more robust skill set than just the typical design background. This paper describes the efforts of Clemson Engineers for Developing Countries (CEDC) to fulfill the more nontraditional and often unaddressed learning outcomes noted by ASCE's Civil Engineering Body of Knowledge for the 21st Century as important prerequisites for licensure. The learning outcomes are addressed through ongoing international service learning projects in the Central Plateau of Haiti. The paper focuses on the following four outcomes and their fulfillment methods: leadership, teamwork, communication, and globalization. CEDC's unique organizational structure is critical to the fulfillment of these outcomes and facilitates a student-led learning environment. The student-led organization has allowed students to set up their own fundraising mechanisms, recruit interdisciplinary members and industry mentors, and develop their own project objectives. This level of student autonomy is noted as key to ensuring that students achieve competency in these four program outcomes.

Engineering professional societies and their related accreditation organizations are currently placing a strong and continuous emphasis on broadening, and in some cases expanding, undergraduate and graduate engineering programs. Within the civil engineering profession, such program

guidelines were published by ASCE in 2008 as the second edition of the *Civil Engineering Body of Knowledge for the 21st Century*, known as BOK-2. Contained therein is a recommendation that future professional engineering registration require either a M.S. degree or a 30 semester hour credit equivalent beyond the traditional B.S. degree. Also contained

within BOK-2 are 24 specific recommended outcomes of engineering education and experience that should serve as a prerequisite for licensure.

This paper suggests an effective means of exposing engineering students at both the undergraduate and graduate levels to four of the more nontraditional program outcomes listed and described in BOK-2: leadership, teamwork, communication, and globalization. Recent experiences of the authors in establishing the Clemson University student organization Clemson Engineers for Developing Countries (CEDC) are reviewed, and lessons learned from eight student site visits to the Central Plateau of Haiti are used to support recommendations for promoting these four program outcomes.

SERVICE LEARNING IN ENGINEERING

Service learning is an education-enhancing process intended to aid in student development and learning by engaging students in activities to address human and community needs (Mandar et al. 2009). Service learning has been used for decades as a pedagogical tool, but until recently, engineering programs were slow to incorporate service learning into their curricula. Service learning is recognized as a valuable pedagogical tool that has a powerful impact on young people and their development (Swan et al. 2007; Eyster 2002). Service learning gives young engineers an opportunity to see how their work directly affects the lives of others.

Traditional engineering curricula focus on design, analysis, and implementation skills related to the specific engineering field of study. However, many professional and accreditation organizations, including ASCE and the Accreditation Board for Engineering and Technology, have acknowledged a shift in the business environment that demands engineering graduates who are better trained in interpersonal skills such as leadership, teamwork, communication, and globalization.

Research has shown that service learning facilitates development of leadership skills, self-esteem, teamwork, communication skills, and acceptance of cultural diversity (Brandell and Hinck 1997; Shumer and Belbas 1996; Wade 1997; Mehta and Sukumaran 2007). The reciprocal relationship that forms between the students and community nurtures personal growth and a deeper sense of social responsibility among students while empowering communities as they become more self-sufficient (McCormick et al. 2008).

Service learning participation encourages students to use theoretical concepts from the classroom in a prac-

tical, real-world application. This experiential learning helps students develop skills that may not be addressed in other undergraduate courses. Experiential learning reinforces students' education and creates enthusiasm for learning (Mehta and Sukumaran 2007; Cline and Kroth 2008). Further, when incorporating a component outside the bounds of the typical university setting, experiential learning helps connect students with practicing engineers and professionals. These connections facilitate business opportunities and mentoring for students and promote sharing of knowledge between industry and academia (Finger et al. 2007).

Service learning projects outside of the United States encourage a more global perspective in engineering students, and recent trends, including the rapid growth of Engineers Without Borders (EWB), show that many engineering service learning groups choose to work with international projects (Riley and Bloomgarden 2006; Amadei 2003). By witnessing these problems firsthand and interacting with the community, students gain a deeper awareness of global issues such as water availability, poverty, and mass unemployment. Furthermore, students better understand the importance of their contribution to the community stakeholders. Although visiting the site of an international-based service project immerses students in another culture, students who do not travel still benefit from interaction with a foreign community. Service learning courses help students become culturally aware through reading assignments, direct communication with international stakeholders, and shared experiences with students who visited the community.

CLEMSON ENGINEERS FOR DEVELOPING COUNTRIES

The Clemson University student organization Clemson Engineers for Developing Countries recently completed efforts related to the design and construction of a water treatment and distribution system for Cange, a rural village located in the Central Plateau of Haiti. Six CEDC students traveled to Cange for one week in June 2009 to obtain the field data required to execute their designs. These design efforts, and those related to similar infrastructure improvements in Cange, including prefabricated housing alternatives, were addressed in a 1 credit hour class. Twenty students were enrolled in the combined undergraduate/graduate course during the spring semester of 2010. To encourage cross-disciplinary collaboration, course enrollment was open to any undergraduate or graduate student at

Clemson University, regardless of major. The work in Cange was executed in coordination with the Episcopal Diocese of Upper South Carolina, Partners in Health (PIH), and other groups who have maintained a longtime presence in Cange.

The devastating earthquake in Haiti on January 12, 2010, placed an added urgent emphasis on the student design projects. The PIH complex in Cange, one of the leading medical facilities in the country, experienced an overwhelming influx of refugees. Missionary, medical, and other personnel located in Cange urged CEDC student project teams to expedite their water system designs and oversee system installation in Cange as soon as safe travel was practical. Thus, a second site visit for the purpose of distributing design documents and interacting with international stakeholders was executed in March 2010.

Since its inception in 2009, CEDC has sent 25 different students on eight trips to Haiti's Central Plateau to collect data for future design work and assess the current status of ongoing projects. With the water project in Cange nearing completion, CEDC is now expanding its outreach to other villages located on the outskirts of Cange. In October 2011, student teams executed site assessments in five villages within a 5-mile radius of Cange. At these villages, students investigated the current water condition by performing fecal coliform tests at the water source and outlet points, explored the terrain to identify logistical barriers, and surveyed local villagers to understand potential risks, threats, and opportunities. The initial funding and support for these new projects was obtained through a partnership with the Adopt-A-Village program sponsored by the Episcopal Diocese of Upper South Carolina.

As CEDC strives to undertake eight new projects in Haiti, the organization as a whole is increasing in size and strength. CEDC is currently at its largest, with 37 students enrolled during the fall 2011 semester. The need for additional skill sets beyond the realm of civil engineering has encouraged CEDC to recruit members from various departments. Students from the English department are heading efforts to document the background of CEDC and the Central Plateau of Haiti and publicize the story throughout the university and in the local media. Also, these students are drafting grant applications and proposals to acquire sustained funding for CEDC. Likewise, financial management students are responsible for managing and balancing CEDC's budget. CEDC has become a truly interdisciplinary organization by allowing students from any major or discipline to take part in its international efforts.

In May 2010, David Vaughn, director of business continuity and disaster management at Fluor Corporation, joined CEDC to help manage and overcome the growing pains of a young organization. Vaughn now volunteers as the organization's industry advisor and provides expertise in contingency operations, management, and global engineering. He interacts with students on a daily basis and is involved during all phases of the project. Students depend on Vaughn for professional advice, design input, and organizational guidance. Specifically, Vaughn plays a significant role in educating students about the mission planning exercises, in which students determine a course of action to accomplish essential tasks. Vaughn fulfills his responsibilities as industry advisor by guiding students in the right direction while allowing them to formulate their own solutions.

The introduction of field interns in May 2011 was another addition that improved the CEDC organizational structure and promoted a stronger association between Clemson and Cange. Two civil engineering undergraduate students are currently serving as CEDC's field interns for approximately 9-month terms. The interns are responsible for overseeing construction activity, reporting progress, relaying communications to responsible parties, and mitigating any pressing issues. Essentially, these students serve as field operatives on the ground in Haiti, as the organization functions from Clemson.

ASCE BOK-2 RECOMMENDED PROGRAM OUTCOMES

The ASCE (2008) *Civil Engineering Body of Knowledge for the 21st Century* calls on civil engineering students to increase their knowledge, comprehension, and application of 24 outcome areas in a B.S. curriculum. BOK-2 acknowledges that for many of the outcomes, participation in activities outside the classroom is an effective means of fulfilling, or partially fulfilling, the outcome requirements.

For a number of outcomes, however, BOK-2 makes a strong statement that more needs to be accomplished in teaching the outcomes in the classroom. With respect to the leadership outcome, for example, BOK-2 states, "Leadership can be taught and learned. ... The formal education process has the potential to make a significant impact on teaching leadership principles and developing leadership attributes." The key to BOK-2 implementation, therefore, appears to be structuring a careful balance between what is taught

within the classroom and what is applied through student activities outside the classroom.

The four recommended BOK-2 program outcomes addressed in this paper are as follows:

1. *Leadership*. BOK-2 defines leadership as “developing and engaging others in a common vision, clearly planning and organizing resources, developing and maintaining trust, sharing perspectives, inspiring creativity, heightening motivation, and being sensitive to competing needs.” ASCE encourages the application of leadership principles within small homogeneous groups and university-sponsored organizations.
2. *Teamwork*. BOK-2 cites the importance of teamwork and specifically states the need for “understanding team formation and evolution, personality profiles, team dynamics, collaboration among diverse disciplines, problem solving, and time management and being able to foster and integrate diversity of perspectives, knowledge, and experiences.” Students are encouraged to participate in activities such as student government and civic and service organizations.
3. *Communication*. BOK-2 particularly stresses the need for young engineers to acquire the skills necessary to communicate with both technical and nontechnical audiences. Students are encouraged to “seek out tasks and functions that involve ever more challenging communications.”
4. *Globalization*. Global issues cited in BOK-2 that serve as a learning framework include “the international scale of such extreme and long-term environmental events as natural disasters, global climate change, and their impacts on the natural, built, and social environments.” Global professionalism is also cited, highlighting the challenge of practicing ethically in a global environment. Industry interaction is mentioned as one of many ways to generate global awareness within an academic program.

ADDRESSING BOK-2 PROGRAM OUTCOMES THROUGH CEDC INITIATIVES

Leadership

CEDC is structured similar to a business unit, such that a project manager role is awarded to talented students during their second semester of involvement with the organization. During subsequent semesters,

project managers who demonstrate outstanding abilities are promoted to a director's role. The initial semester allows team members (project engineers) to become oriented to a project.

At the beginning of the semester, the directors outline the semester goals for their respective divisions. Once the goals are set, the director is responsible for defining a milestone schedule to achieve these goals and holding the project managers accountable for meeting each milestone deadline. Project managers have a firm grasp of the design opportunities within their specialization and organize and lead four to five project engineers to a common goal. Project managers facilitate brainstorming sessions to determine multiple solutions to a given problem. Project teams perform a feasibility study for each solution, and based on the results, the project manager chooses a direction for the team to pursue.

Teamwork

As a part of CEDC membership status, students are expected to work in teams to accomplish complex design tasks. Each student project team is assigned to focus on the tasks needed to improve the public health of one specific village. When a task requires technical expertise beyond the capacity of the project team, a subject matter expert (SME) is brought in for advice. A CEDC SME is a skilled graduate student, professor, or industry professional who specializes in the field of inquiry. These project teams must work together as an intradisciplinary civil engineering group, and additionally, these teams work with SMEs as a larger interdisciplinary team to accomplish goals outside of their engineering specialties.

Communication

Communicating effectively includes both understanding what others are attempting to communicate and expressing ideas to others in a concise manner. CEDC communication activities include presentations to professional and student organizations, local businesses, large corporations, and undergraduate classes. Additionally, students are selected to give interviews for media outlets. Students must adapt their presentation styles to appropriately address each of these unique audiences.

CEDC teams also interact with local professional engineers, who review completed design documents. The design teams must prepare the design documents with sufficient clarity to convey design intent to construction crews, who often receive their instructions through a third-party translator. To help address this

issue of clarity, once design drawings are completed and reviewed, the design team typically prepares supplementary manuals and other technical documentation to accompany progress reports for client representatives in Haiti. This documentation often takes the form of step-by-step instructions with photo insertions. Because of field miscommunications, continuous construction oversight is required. CEDC provides interns who serve as construction managers to mitigate these concerns.

In the classroom, poststrip reports and postsemester reports are used to maintain continuity between the semesters of the class. These reports document as many details as possible. Students describe design documents and their methods of development in depth, similar to what is executed in a typical civil engineering capstone design class.

Globalization

As a result of the earthquake, the CEDC student teams in Haiti faced numerous challenges that are unique to working in an international environment. Coordination with international organizations was required to ensure the safety of the team traveling to Cange. Building materials and supplies required for even the most basic reconstruction efforts were not readily available. CEDC tries to maximize the use of local labor and materials to support the community's economic activity. However, the local labor force often is not sufficiently trained to interpret design documents or execute complex construction operations. The economic and social benefits of using labor-intensive materials versus materials with low labor costs but a higher material cost is a constant consideration. Facility design documents must be crafted to ensure that all construction can be accomplished with hand tools because heavy construction equipment is not available.

Students also face challenges unique to working in another country and culture. For instance, no formal building codes exist on a large scale within Haiti. Students had to consider the ethics of this situation, and their solution was to execute CEDC designs in compliance with U.S. code requirements for both seismic and wind events. Another cultural challenge was the reluctance of Cange residents to provide design feedback related to the community water stations. Students determined that the community members were hesitant because they thought that expressing a dislike for the ergonomics of the designs would be an insult to CEDC. To avoid requiring the community members to express negative thoughts, the CEDC

team drafted three designs and modified the questioning by asking which aspects the community favored most. As CEDC continues working with the community of Cange, the group has become increasingly aware of cultural differences and continues to work to address these differences.

RECOMMENDATIONS

We recommend the following efforts as effective ways to promote the four BOK-2 program outcomes highlighted in this paper: create a university-sponsored student organization, fund the student organization activities, incorporate media relations, interact with the engineering profession, and take on the unique challenges and benefits of working in a developing country.

Creating a University-Sponsored Student Organization

In early 2009, the authors initiated contact with a group of Clemson University students to brainstorm ways in which the students could best participate in activities outside the classroom that would satisfy the students' desire to help in the developing world and serve as differentiators on an employment resume. The discussions soon focused on international service work in general and in particular on creating an autonomous organization serving developing countries. Although the university has a successful chapter of EWB, the students were of the strong opinion that creating their own organization would better enhance student interest and participation. Clemson University recognized Clemson Engineers for Developing Countries as a university student organization in January 2010. Civil engineering faculty and university administrators have observed that, indeed, permitting the students themselves to develop their own objectives, select their own peer reviewers, and make their own fundraising decisions has greatly enhanced their leadership, teamwork, and communication skills. The CEDC faculty advisor strongly believes that student groups such as CEDC should be given the maximum amount of autonomy possible under whatever constraining policies may exist within the academic institution.

Funding the Student Organization Activities

Requiring the students to acquire the funds necessary to finance CEDC's efforts creates numerous opportunities for students to participate in fundraising presentations to nontechnical audiences, thus greatly

enhancing their teamwork and communication skills. The attention following the earthquake in Haiti and the fact that students were working in Cange before the earthquake most likely increased their ability to raise funds from church groups, civic organizations, and industry sponsors. Students are currently contacting major corporate entities to solicit long-term financial support for CEDC.

Incorporating Media Relations

The student group has been interviewed and filmed on numerous occasions by university and statewide press media. Selecting engineering projects with a high degree of public interest has proven to be an excellent means for the students to practice and perfect their communication skills.

Interacting with the Engineering Profession

EWB and other well-established student organizations have formal built-in mechanisms for industry interaction and peer design review. CEDC students, however, were forced to seek out their own industry partners. The project in Cange, Haiti, was identified initially through contact with the Episcopal Diocese of Upper South Carolina. Local professional engineers associated with the Episcopal Diocese gave CEDC students the opportunity to assist with the design and construction work in Cange. CEDC students expanded these contacts by establishing their own group of industry advisors. Interacting closely with students, David Vaughn volunteers as an ongoing industry advisor who provides expertise in contingency operations, management, and engineering in an international environment. Students also benefit from establishing closer outside-the-classroom interactions with faculty members from multiple departments. This interaction is mutually beneficial; the faculty members gain a better understanding of student perspectives and growth.

Taking on the Unique Challenges and Benefits of Working in a Developing Country

It is an understatement to say that executing engineering design work in a developing country such as Haiti requires comprehension of the local demographics, government, religion, history, and culture in general. CEDC students had unique opportunities to participate in religious services and festival celebrations during their visits. Their design alternatives for community fountains required carefully prepared interactions with the local population as well as with others who have spent considerable time working in the country.

CONCLUSION

ASCE issued a strong challenge to the profession to broaden academic curricula and place more emphasis on such topics as leadership, teamwork, communication, and globalization. To address this challenge at Clemson University, the student organization Clemson Engineers for Developing Countries was formed, and a number of international design and field exercises are ongoing. CEDC activities have been well received and supported by the Clemson University administration, local practicing professionals, and the Clemson community at large. Recently, CEDC earned the 2010–2011 Commendation of Excellence for Service Learning from the South Carolina Commission on Higher Education.

CEDC's efforts are accomplishing the goals not only of ASCE, but also of service learning programs in general. The fact that CEDC focuses its efforts in a developing country and that students are given total autonomy in managing the organization has perhaps enhanced the goals established for the organization.

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