

AC 2009-2091: CREATING EFFECTIVE AND EFFICIENT LEARNING EXPERIENCES WHILE ADDRESSING THE NEEDS OF THE POOR: AN OVERVIEW OF SERVICE-LEARNING IN ENGINEERING EDUCATION

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Creating Effective and Efficient Learning Experiences While Addressing The Needs Of The Poor: An Overview of Service-Learning in Engineering Education

Engineering educators across the globe face daunting challenges to adapt their curricula to prepare students to prosper in the global economy. Technology continues to advance, adding content that must be covered without compromising the fundamentals that are so important for engineers. We are asked to add professional skill development including communication, teamwork and leadership to the already packed curricula as well as develop societal and global awareness and create the next generation of entrepreneurs. Reports, such as those from the U.S. National Academy of Engineering^{1,2} advocate the integration of a very broad set of skills into the already packed curricula to prepare students for the 21st century's global economy.

It is a significant design challenge to create curricula that can accomplish these goals. Conservation principles tell us that if we continue with traditional approaches, we either have to take things out of the curriculum or add time toward graduation. An alternative is to find more efficient learning experiences for students that enhance learning the core content and facilitate expansion to the broader set of skills needed for engineers in this century. The good news is that there is significant research on pedagogies and practices that can do this. Service-learning is one of these potentially powerful tools that is backed by educational research³ and has the potential to provide this kind of efficiency⁴. In addition, service-learning has the potential to address broader needs of our local and global communities as a byproduct of the improved educational experience.

Service-learning is the intentional integration of service experiences into academic courses to enhance the learning of the core content and to give students broader learning opportunities about themselves and society at large. It is not an add-on volunteer activity but rather an integrated learning experience that creates curricular efficiency. Service-learning has the additional benefit of being a way to attack compelling needs of the poor and underserved in our societies.

In addition to curricular efficiency, service-learning leverages resources to address broader needs of the larger society. This is vitally important in these days of stretched governmental budgets and growing social and environmental challenges. Service-learning creates opportunity out of potential tension of whether to invest in the poor or the technological machinery of the nation. The service-learning experience provides rich learning opportunities for students as they address compelling needs of our communities. It is a tool to enhance engineering education while addressing the needs of the poor and those who might otherwise be left behind the move to industrialize the developing world.

Service-learning has enormous potential to enhance engineering education. While there are many successful examples of service-learning within engineering^{5,6}, our field has been slow to integrate service-learning into our curricula on a broad scale. This paper

outlines the components of service-learning, highlight research behind the pedagogy and briefly describe successful examples from different kinds of institutions.

Characteristics of Service-Learning

Service-learning can be defined as *a type of experiential education in which students participate in service in the community and reflect on their involvement in such a way as to gain further understanding of course content and of the discipline and its relationship to social needs and an enhanced sense of civic responsibility*⁷. The pedagogy of service-learning has four key characteristics. They are: service, the academic connection, reciprocal partnerships, and analysis or reflection⁸.

Service - A central component of the service-learning experience involves service opportunities that meet the needs of the underserved in a community and/or contribute to projects for the common good of the community. In engineering, service can take many forms, from direct contact with people through educational programs for children or the elderly to projects that are delivered to the underserved populations to address a need, such as a solar power system for a remote rural village. It can also take the form of research, data analysis and interpretation and presentation of results, such as addressing an important environmental issue. This service might address a short term need that is filled during a course or it could be part of a larger, on-going project or set of projects in an area.

Academic Connection - The service students perform must provide reinforcement of and connection with the subject material of an academic course. When looking to see if a course would benefit from service-learning, the question of how the academic learning would be improved by the service must be addressed. If there is not a clear connection, then service-learning is not a good fit for that course. In service-learning, the service is directly linked to what is being studied in the course to help students learn that material more effectively. If it is a design course, engineering design principles are being taught and the service provides an environment in which to apply what they have learned. In an engineering science course, the service is designed to reinforce concepts from the course. In any case, the service provides a context for the academic material. An example from a faculty colleague from India was from a Mechanical Engineering course on internal combustion engines. Integrating a service experience where students installed and monitored emissions control devices gave the students a real, hands-on application to the theory being presented in the class. Students are still evaluated based on their demonstration of their mastery of the academic content of the course, similar to a traditional course. They are not evaluated on the number of hours spent on the service. In the engines class, students earned high marks for what they learned from the experience that could be applied to the course topics.

Reciprocal Partnerships - Service-learning involves partnerships characterized by reciprocity between those in the community and those on campus. The concept of reciprocal partnership is very important. Students performing service-learning are not doing something *for* the community, but rather *with* the community. Each member of the

partnership contributes to the goals of the project and each benefit from it. Students and community members work together as partners in addressing a community need, and both groups benefit from the activity. The community get increases its capabilities, capacity or the resources. The students get to participate in a richer learning environment. The community members are also part of the teaching team, working with faculty to create a learning environment in which students can both increase their mastery of the academic components of a course and become familiar with the social issues they are addressing. The faculty members develop familiarity with local needs, new student learning opportunities, and in some cases public research opportunities. The community members learn about the role of engineering and technology and their implications for their community. Good partnerships (and good engineering) utilizes available resources and creates sustainable systems. Our work in service-learning needs to create systems that can be sustained after we leave and must include the community and its resources.

Reflection or Analysis– Reflection is a vital component of service-learning. As part of the service-learning experience, participants are intentionally guided through activities to reflect upon (or analyze) the work being performed, the processes by which the work is accomplished, and the implications of the work. Traditional service-learning language uses “reflection” but many engineers are more comfortable thinking of “analyzing”. It is the same basic process which is really guiding the students through metacognitive activities, which have been shown to improve learning⁹. Metacognition, analysis or reflection can help students understand: the academic material covered by the course; how the course material relates to the service; the implications of the social context and issues associated with the need being met; and the role of engineering in the context of large social issues. The reflection also helps students process unintended learnings from the experiences. Students who participate in service can come away from the experience with their stereotypes reinforced. For example, students who develop a design for another country and spend a week in that country may come away with their stereotypes of the people from that country they are “helping”. Reflection activities can identify these potential problems and provide a way to guide the students to a broader view and a better understanding of the issues they are addressing and the people they have worked with.

Activities promoting analysis or reflection can take several forms and can include open-ended questions, written or oral guided discussion topics, periodic written summaries of the work being undertaken and its implications, and assigned readings. Experience has shown that the benefits of reflection are not tied to the length of the reflections. This is good news to engineering educators that we don’t have to require lengthy essays. What is found to be most effective is frequent and targeted reflection activities.

Balance Between Service and Learning

Service-learning, when done properly, creates a balance between service-based and academic learning. Each complements the other. Sigmon¹⁰ illustrated variations within this balance with the following table. Service-learning integrates the academic and community needs to the benefit of both. Service is not just performed as an add-on side

project nor is the service the primary focus of the experience. Both are balanced and each enhances the other.

service-LEARNING	Learning goals are primary; service outcomes are secondary
SERVICE-learning	Service outcomes are primary; learning goals are secondary
service learning	Service and learning goals are separate
SERVICE-LEARNING	Service and learning goals have equal weight; each enhances the other for all participants

There are many efforts around the globe that have encouraged service and volunteering for students, including engineering students. Some, such as India’s National Service Scheme have encouraged students to be active in their communities while at the university but are not connected with any course. Others, such as Engineers Without Borders, have engaged students on global projects as part of clubs and student organizations and are sometimes associated with courses. Many of these efforts, while doing very worthwhile activities and meeting compelling needs, have not tackled the challenges of integrating the service into the curriculum with clear academic outcomes. As a profession, we can send a very clear message that engineering is about improving lives of the world’s citizens if we were to integrate these components into the curricula of our programs. Leaving these activities outside of the curriculum can send the opposite message. If we simply put service as a requirement of our courses, we have abandoned the responsibilities we have as faculty members to guard the academic integrity of our programs. Service-learning seeks to integrate the service with appropriate academic outcomes to enhance our students’ education and our local or global communities.

Sampling of Research in Service-Learning

There have been many successful models for implementing service-learning across many disciplines¹¹ and within engineering^{5,6,12}. The majority of research on service-learning has been done outside of engineering and much of it has been focused on the impact on students’ views of themselves and the larger society. In the social sciences, for example, the disciplinary learning is often more closely tied to the service students are providing.

The learning in engineering education can be broken into the professional skills (what some called “soft” skills) and the technical skills. More evaluation has been done on the connection of service-learning with the professional skills. Evaluations from the Purdue EPICS Program showed students reported learning teamwork and communication as part of their participation of engineering design teams²¹. A study of students participating on global design projects at WPI documented their development in the areas of life-long learning and showed gains based on their experiences³³. There has been a great deal of research around the impact on students’ perceptions of themselves and their communities

as a result of their service-learning as well as their engagement in and views of civic engagement^{7,10}.

Reflection, the metacognitive process that is such a critical component to service-learning, has been shown to enhance learning. Bransford et al. documented the benefits of guided metacognitive or reflection activities as benefits to learning⁹. While not a study on service-learning, their work did cite a benefit of the experiences when placed into the context of the local community,

Learners of all ages are more motivated when they can see the usefulness of what they are learning and when they can use that information to do something that has an impact on others – especially in their local community

The reflective component of service-learning is well-documented⁷ and it has been found that the length of reflections is not the critical components but rather the frequency and content of those reflections²⁹. This is significant for engineering as many of the examples that come out of the liberal arts have students writing long reflective essays that can be a barrier for engineering students and faculty. Eyler found that reflections being frequent and intentional yielded the most learning gains.

While the self-reflection and awareness of the community is important for student development, many engineering faculty want to know how a pedagogy relates to improving learning in the core concepts. There is much less documented in the area of service-learning and core engineering topics. One study where engineering students were included as part of a large study was by D. Giles and J. Eyler³ in *Where's the Learning in Service-Learning*. The authors found that a majority of service-learning students reported that they learn more and are motivated to work harder in service-learning classes than in traditional classes. They also found that a majority reported a deeper understanding of subject matter, understanding complexity of social issues and being able to apply material they learn in class to real problems are among the important benefits of service-learning. Students were able to see applications of what they were studying.

Giles and Eyler also found that students who participated in service-learning retained material at a higher rates across disciplines³

...(a) phenomenon occurs when students are able to marshal a body of knowledge to solve problems presented in class but fail even to see a problem, much less the relevance of what has been learned, in a different setting. The new situation does not provide the cues associated with what has been learned; the “key words” from the classroom are not present in the wider environment. A service-learning student will have more ways to access this understanding.

Astin et al. examined the impact of service-learning across a sample of more than 22,000 undergraduates within the United States.¹³ In this study, they controlled for the impact of

volunteering outside of class to assess the impact of curricular service-learning. What was found was

for all academic outcomes, as well as some affective ones, participating in service as part of a course has a positive effect over and above generic community service (outside of class).

Among the academic outcomes enhanced through the service-learning were college grade point average, critical thinking skills and writing skills. The impact of the course-based service-learning was significantly more than for students who participated in generic community service. Interestingly, they found that service-learning participants had slightly lower standardized test scores than non-participants when entering college.

In addition to learning gains, service-learning has been linked to increases in student retention. M. Lima reported that after taking a Biological Engineering Service-Learning class at Louisiana State University, 93% of Women and Minority students remained in their discipline compared to the national average of 70%⁵. A similar result was found for students in a multidisciplinary service-learning course.¹⁴ Picket-May and Avery also reported retention gains more than 6% for students who participated in service-learning in their first-year¹⁵.

A joint study conducted at the University of Massachusetts-Lowell and the Massachusetts Institute of Technology showed that students who participated in service-learning increased their connection between engineering and community needs¹⁴. They also interviewed faculty on their views of service-learning and their receptivity to participating. The surveys found that 80% were positive about integrating service-learning into their courses if sufficient resources were provided. One concern that was identified among faculty was the impact of the service-learning on academic rigor.

Selected Successful Models of Service-learning in Engineering

There are many models of successful engineering service-learning^{5,6,12} and models and resources for service-learning from a more general perspective^{11,17,18}. Examples of engineering service-learning programs are provided that represent the breadth of models that are in use today. This is not by any means an exhaustive list but hopefully provides some perspectives of what service-learning is evolving from and into within the U.S. and in other countries. Additional models and resources can be found at the Campus Compact website¹⁷ and at the Service-Learning Clearinghouse¹⁸.

University of Massachusetts-Lowell – SLICE Program

One of the most ambitious and broadest service-learning approaches is at the University of Massachusetts-Lowell in their Service-Learning Integrated throughout the College of Engineering (SLICE) initiative. This approach has its goal to provide a service-learning experience in every semester for every engineering undergraduate^{19, 30, 31}. Their goals are:

... to revitalize our college through the energizing pedagogy of service-learning. The thesis is that service-learning spread throughout the core curriculum is more effective than one intensive course, which is more effective than none at all, that a mixture of required and elective service-learning (s-l) is more effective than either one or the other, and that service-learning will result in less coursework time than traditional programs satisfying ABET 2000 criteria.

They define service-learning as a hands-on learning approach in which students achieve academic objectives in a credit-bearing course by meeting real community needs. They have integrated service-learning into many kinds of courses. They include design courses, such as the electrical engineering capstone course where all students participate in a service-learning assistive technology project. They have also integrated service-learning into engineering science courses with project work that varies in size and scope as a function of the curricular constraints for the respective courses. This approach, at a college level engages community partners with the support structure at the college level and reduces the overhead that many faculty encounter starting their own projects.

The SLICE project objectives are stated as:

- Integrate service-learning into the engineering curriculum at UML so that every student is exposed to service-learning in every semester of their experience in every department at UML.
- Create a formal program to connect faculty to community groups (local and international).
- Develop appropriate projects/experiments for integration of S-L into about forty core courses in the undergraduate engineering curriculum at UML.
- Become an engaged college--engaged with the students, each other as faculty across departments, and with the community¹⁹.

The SLICE partnerships include many nonprofit organizations in the local Lowell area and international projects including a partnership with villages in the remote Andes Mountains of Peru. Professor John Duffy has worked to establish on-going partnerships with villages in remote areas of Peru where students can apply engineering solutions³³. His work has included building partnerships with Peruvian universities to provide support for fielded projects and expansion of the impact of the projects done by students at UML.

WPI

One of the longest running service-learning programs is at WPI. For more than 30 years, students at WPI have been required to participate on projects that integrate society and technology. His project model pre-dates much of the current service-learning movement and is an integral part of their institutional culture. All WPI students complete two projects, one is an Interactive Qualifying Project, or IQP. This project must explicitly connect society and technology. The WPI describes their programs as³⁵

all WPI undergraduates, whether they are pursuing studies in science, engineering, management of technology, or the humanities, gain experience tackling problems that lie at the interface of science, technology, social issues, and human needs. This unique interdisciplinary requirement brings together students from across the campus to research and address challenges that affect people and communities at home and around the globe

Faculty mentor students on the projects and an extensive infrastructure supports global placements of students. The institutional support structures allows long-term partnerships with individual projects strung together for significant impact, locally and globally. While not all of the projects would match all of the criteria for service-learning, the vast majority do. The institutional support and commitment is a model. The infrastructure built by the institution also shows how complex and even distant partnerships can be maintained allowing faculty and students to contribute where appropriate.

EPICS Program, Purdue University

The EPICS Program was started at Purdue in 1995 by Professors Leah Jamieson and Edward Coyle²⁰ as a way to improve the design education of the engineering undergraduates while simultaneously addressing compelling needs in the local community. Since its founding, it has grown into its own academic program and while remaining engineering centered, grown to be very multidisciplinary. Under the program, undergraduates earn academic credit for their contributions to long-term, team-based design projects that deliver innovative, technology-based solutions to problems identified by not-for-profit organizations in the community. The curricular structure and support of the EPICS program enables designs of significant benefit to the community to be created. Key features of the EPICS model include²¹:

- *Community Partners:* Each EPICS team is partnered with a “Project Partner” who is a not-for-profit organization, educational institution or governmental agency in the local community.
- *Large, Vertically-Integrated Teams:* Each EPICS team consists of eight to twenty undergraduate students who are vertically-integrated; including first-year, sophomores, juniors and seniors.
- *Long-Term Student Participation:* A student can participate in an EPICS team for more than one semester and even their entire career.
- *Variable Credit Hours:* An EPICS student can earn one or two credits per semester.
- *Multidisciplinary Teams:* In the 2007-08 academic year, 30 different majors participated in EPICS.
- *Start-to-Finish Design Experience:* EPICS provides a start-to-finish design experience for students. Projects begin with problem identification done by the students and moves through delivery of the project. The long-term structure allows EPICS to provide support for fielded projects, an additional value to the community partners.

The success of the program has resulted in EPICS becoming its own multidisciplinary, academic program under the office of the Dean of Engineering. EPICS provides an infrastructure to support multidisciplinary and multi-semester projects and partnerships. The investment in the infrastructure that manages the community partnerships and curricular structure allows faculty to participate by focusing on leading the design projects and mentoring students.

Center for Engineering Service-Learning at the University of California, Merced

The University of California Merced, the newest of the University of California campuses in the United States, integrated service-learning throughout their curriculum from the beginning of their campus in 2004. They adapted the approach from Purdue University to create the Foster Family Center for Engineering Service-learning²². The center is described as:

The Foster Family Center for Engineering Service-learning is a key component of an engineering education at UC Merced and the cornerstone of the school's learn-by-doing philosophy. The program contributes to student success, retention and professional preparedness, while also supporting the San Joaquin Valley's leading non-profit organizations.

UC Merced has integrated service-learning across their faculty and encourage all faculty to participate. Service-learning is even discussed during the faculty search process. Their approach is to have faculty working with multidisciplinary teams on long-term projects within the local community. They describe the benefits of their program as²²:

As a result of this program, UC Merced engineering students gain long-term define-design-build-test-deploy-support experience, communication skills, experience on multidisciplinary teams, and leadership and project management skills. They gain an awareness of professional ethics, the role of the customer in engineering design, the role that engineering can play in the community, and the importance community service and volunteerism. Community organizations gain access to technology and expertise that would normally be prohibitively expensive, giving them the opportunity to improve their quality of service and provide new services.

University of Auckland, New Zealand

The University of Auckland is an example of an international adaptation of the EPICS model of service-learning. Professor Heather Silyn-Roberts directs the program that was initiated at the Dean's level. Their service-learning course is a design course that is used as an elective course credit. The course is a Mechanical Engineering Course number (MECHENG 401) which is open to students of all disciplines as a second-semester elective worth 15 points. However, the project run all year so the students do 7.5 points worth of work in each semester. Each project has faculty mentors that come from Mechanical, Civil, Materials, Environmental and Software Engineering. The projects are also open to volunteer students that contribute greatly to projects. The Auckland model

has blended curricular and co-curricular components to help provide the broad expertise and continuity that real service-learning projects require. One dimension that the volunteers bring is the ability to engage younger students in the projects to become acquainted with the projects before they register for the class and take on the leadership roles and responsibility for the projects. This dimension also facilitates projects that can last longer than a year.

Active projects include

- Laser digitization of artifacts in Auckland Museum
- Wheelchair platform development: Carlson School for Cerebral Palsy
- Milk bottle recycling for the Waiheke Waste Resource Trust
- Software for seismic assessment of buildings: ACC
- Operations research-based study of Reipae dining hall

Puerto Rico Mayaguez

The University of Puerto Rico Mayaguez has a service-learning model that is centralized for the entire campus. The service-learning activities are directed through a center for service-learning under the direction of Professor Luisa Seijo Maldonado. The University Institute for Community Development (Instituto Universitario para el Desarrollo de las Comunidades (IUDC)) approaches partnerships from a community perspective. While many of the partnerships in the U.S. are based on organizations or agencies, the Institute at Mayaguez develops partnerships with local villages in the region of Mayaguez. They work to identify needs in that community that can be met through service-learning. The institute acts as the liaison between the faculty/students and the communities from across the UPRM campus. They partner with engineering faculty to meet needs where technology can be applied and often pair them up with faculty from other parts of campus. The partnerships span Civil, Electrical, Mechanical, Computer, Chemical and Software Engineering as well as disciplines outside of engineering.

Ireland

In Ireland there is an exciting national movement to place service-learning activities into the mainstream of their higher education institutions. There is formal endorsement by the national government and a growing movement in service-learning. A national service-learning organization, Campus Engage³⁴ is similar to Campus Compact in the U.S. and provides support for faculty in service-learning. Engineering, like in the U.S. has been a little slower to integrate service-learning. There are high quality examples of service in Ireland's higher education systems but very few examples of service-learning within engineering courses. Examples of high quality extra-curricular include the Community Links Program²³ that is housed at the Dublin Institute of Technology. This program works with issues in the Dublin area, including the inner city, and manages projects in the developing world. It has connected individual faculty with courses.

The Higher Education Authority Strategic Initiatives has funded academies to encourage more integration of service-learning into formal courses. They see service-learning as a tool for encouraging students to learn through the integration of theory and practice

The National University of Ireland, Galway launched a major project in 2001, entitled the Community Knowledge Initiative (CKI), which set out to underpin and realize a civic mission as part of its core activities.²⁴ The CKI aims to promote greater civic engagement through core academic activities and has begun to engage engineering faculty through design courses.

http://www.nuigalwaycki.ie/News_Item.asp?News_ID=40

University of Trinidad and Tobago

The University of Trinidad and Tobago (UTT) started integrating service-learning on an institutional basis in 2006. The new university (UTT) has partnered with the National Institute of Higher Education, Research, Science and Technology (NIHERST) on a service-learning initiative. NIHERST has assisted the UTT in this endeavor by taking a leading role in conversations being held across the country to provide input into this initiative, from the community, industry and academia.

Engagement by the university in community issues was not common and needed conversations and establishments of relationships. The faculty of UTT had already adopted Problem-Based Learning (PBL) as a pedagogical framework across the institution. Service-learning and PBL have many attributes in common and can build upon each other so it seemed to be a leverage point to introduce service-learning on a larger scale. The main difference is that the problems in service-learning are real problems situated within the community and therefore can evolve during the solution of the problem and the course. Service-learning also has an explicit outcome to give the participants a broader view of civic engagement and their personal place in society. These additions have proven to be more of a challenge that the service-learning advocates anticipated and progress has been slow. Most of the PBL examples were drawn from industry and the leap to community-based projects has been more of a barrier than anticipated. Most of the service-learning is being done through design courses and the strategy is to use the theme of design to cut across disciplines of the institution. UTT and NIHERST see service-learning as an opportunity to both enhance education, address compelling needs in the islands' communities, enhance the sense of civic engagement among students and to fulfill UTT's mission to be engaged with the community. NIHERST is leading the work to establish partnerships with local organizations, museums and schools to promote partnerships to reduce the faculty overhead to engage in service-learning.

India

In July 2008, 13 institutions were represented at the Indo U.S. Collaboration for Engineering Education (IUCEE)²⁵ faculty development course on service-learning. The faculty from each of these institutions committed to starting service-learning courses or programs at their own institutions at the end of the course and reports have shown that this work has begun this fall semester.

While service-learning was not an integral part of the curriculum at these institutions, the ethic of service to the community was very much a part of the campus culture through extra-curricular programs. The National Service Scheme and National Cadet Corps provide networks for students to participate in service opportunities while attending the university. In some cases, credit is given or required for a certain amount of service hours for each student to receive their degree. Some of these service opportunities were related to technology while others were more generic service that could be carried out by any discipline. A few service projects were integrated into students' experiences through undergraduate projects but there was not an integration into the core curriculum.

One appeal of the Indian faculty for the service-learning model is that it offers an efficiency to link students' coursework with the service activities. Rather than adding to the demands of students to do service outside of class, they can be integrated into class. The models for the initial service-learning projects include design courses as well as service projects integrated into other engineering classes. An example of the latter was the internal combustion engines course that would integrate installation and testing of emissions equipment on local transportation vehicles. This provides a needed service to the community and gives the students a real and first-hand understanding of the material they are learning.

The opportunities for service-learning in India, as with other countries are immense with many opportunities to meet compelling needs very close to their own institutions. With students already engaged in service activities, service-learning can add more interest to the study of traditional engineering subjects.

The experiences in service-learning of meeting real needs of real people as the added benefit of requiring use and development of the professional skills, such as communication, teamwork, leadership, and project management. Development of these skills is a priority for the Indian institutions. Students can gain these skills needed to be ready for engineering practice while they are on their campus.

International Organizations

There are umbrella organizations that work with student groups to do service projects on a global scale. These include Engineers Without Borders²⁶ and Engineers for a Sustainable World²⁷ and Engineers for World Health who provide opportunities to connect the students and faculty with service projects in the developing world. The implementation of these projects is sometimes done in a service-learning model within a course but more frequently done in strictly service mode outside of the classroom. These organizations provide an infrastructure for students to become engaged in projects in areas of need throughout the world and have made great contributions to meeting needs in the developing world and providing students a global perspective and experience. Our focus has been on service-learning but it is important to recognize models that compliment and supplement what we can do within our courses. . Clearly, a university student's education is not confined to the classroom and these opportunities add to the

curricular experiences of students. They are also meeting important needs throughout the world.

The founder of Engineers Without Borders, Prof. Benard Amadei at the University of Colorado, created a curriculum program, Engineering for Developing Countries²⁸, that formerly integrates coursework around the issues facing the developing world and projects for communities in those countries. His approach has created service-learning courses and it also provides tracks of courses that can lead to certificates and areas of emphasis

The education component of the EDC program is designed to include courses at the University of Colorado at Boulder that emphasize issues critical to the understanding of the developing world and sustainable development. EDC serves as a convener for a number of courses in engineering, sustainability, appropriate technology, renewable energy, international education and development, business, and various fields of humanities²⁸.

Summary

Service-learning is a growing pedagogy that has many potential benefits. It has been shown to be an effective means of educating students in traditional subjects as well as providing the opportunity for broader professional preparation and personal growth that are vital to the engineers of tomorrow. Research shows that the fears of faculty members that they have to compromise rigor for service-learning are not valid. Done correctly, service-learning can enhance learning of traditional content.

Service-learning also has the potential to change the views of our students about engineering. An example comes from a seminar for undergraduates from the University of Trinidad and Tobago about service-learning. At the start of the seminar the students did not understand or see the connection between their engineering studies and the ability to help their fellow citizens on the islands. This reaction is not unique to Trinidad and is common in the U.S. and other countries as well. In the seminar, students were asked to get in small groups and make a list of the skills they were learning that could benefit their fellow citizens. Many groups struggled to make a very long list and some could not even start the list. Trinidad and Tobago is an island nation that benefits from revenue from the oil industry. Like many countries, distribution of those benefits is a challenge and not uniform. There remain communities that lack essentials such as running water and sewers. In the student seminar, this disparity was discussed and the students recognized it as a need for their country. A list was made of the skills and knowledge that would be needed to design a water system for such a community. When the topics of pipe flow, fluid flow, pipe losses and pumps were listed, the many of the engineering students perked up and recognized them as course material that they took or would take. This exercise is really an example of the kind of reflection that is so necessary in service-learning to get students to make the link between the service and the academic learning. Once they started to see the links, the flood gates opened and the ideas for potential projects and learning experiences began to flow in all of the student groups. There was a

genuine excitement in the students that not only were they learning a profession that would provide an exciting career; they were also learning skills that can be applied to address important needs in their local and/or global communities. At the end of the seminar, the most frequently asked question was “how can we join a service-learning class?”

This excitement of being engaged in something that benefits others is seen in country after country. There is a connectedness that young people today feel and enjoy. As educators we can tap into that to motivate the students in our courses. We can take strategic advantage of learning opportunities in service-learning experiences to expand and deepen their education and give them a broader view of themselves and their profession. These strategic opportunities create an extremely efficient for learning experience and can be a powerful tool in curriculum reform.

In addition to student learning, today’s world faces many significant challenges. It is incumbent on us to not waste resources that can be used to meet these challenges. The intellectual capacity and student energy on our campus is just such a resource. In sustainable design, we look for simple and clever ways to do more and reduce consumption and waste. One could think of service-learning as sustainable education. At the end of the course, we produced something that will last beyond the course while simply conducting our course in a different manner. Service-learning can be used as an efficient way to meet compelling needs in the local and global communities with little additional resources.

In today’s economy, this is especially important. As budgets are being cut and tough decisions are being made on where to allocate resources, there can be a tension between serving the underserved of our society and investing in higher education. Service-learning uses the former as a way to enhance the latter. In developing countries, this is especially true where potential conflicts between building the educational and industrial infrastructure or meeting the needs of the all the citizens. Service-learning turns this potential conflict completely around and leverage the needs of the underserved as an opportunity to enhance the educational infrastructure and create better graduates for industry. In the process, the graduates leave our campuses with a deeper understanding of today’s societal needs and the opportunities for them to make a difference addressing these needs.

Closing thoughts for those new to service-learning

This paper has tried to highlights models and approaches to service-learning in many different settings as well as providing some evidence that there are potential learning gains through the pedagogy. There are many examples of specific projects and curricular materials on the websites and papers cited. If you are reading this interested in trying service-learning, go for it! It may very well become the most rewarding thing you do and you may find students learning in depth and breadth you never expected.

When you start, start small and imperfect. Start small enough that you have a good chance of success and build on that. Start small enough that you can be comfortable. Many faculty start with a part of a class as an option. This gives a smaller group to learn with and it also gives a comparison group to assess for faculty colleagues and potential publication. Also start imperfectly. Don't be consumed by worrying if all of the right components are in place in the perfect way. If you don't do much reflection the first time, that is okay. Start with something and build. If the perfect community partner is not available, that is okay too. Get started and grow and improve each time you teach. Most of the successful service-learning efforts started small and grew and developed.

Finally, look for resources on your campus. If other faculty are not doing service-learning, look to see if your campus has a service-learning center or a campus volunteer office. They can be a great help and they will probably be excited to see an engineering professor.

You and your students will learn a great deal. Our fellow citizens will be better for your efforts too.

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