



## Community Outreach and Engagement through Sustainability

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## **Abstract:**

Many communities and many engineering programs embrace the need to study and practice sustainability. Human activities must be designed to allow this generation to meet its needs without compromising the ability of future generations to meet their needs. Sustainability is often described as requiring attention to the triple bottom line: people, planet and prosperity.

This paper presents background concerning the incorporation of sustainability into engineering, for example, in the student outcomes of ABET criteria and in the codes of ethics of some engineering disciplines. We focus on describing and analyzing the efforts toward sustainability being taken in our community and the efforts of our engineering department to incorporate sustainability throughout our curriculum. We describe the methods we are using, starting with an intensive 4-day summer workshop (including a community college faculty member), which resulted in action items including plans to alter specific courses. We also describe the Department of Education funded grant that is supporting this work to incorporate sustainability, service learning, and advances in educational technology in all STEM programs at our university.

Unique features of these community and university efforts include the involvement of all faculty members in our department in the project and as authors on this paper and the increasing involvement of engineering faculty and students in our community's sustainability efforts.

## **Introduction**

In the Department of Engineering at Colorado State University-Pueblo, we are increasing our engagement with our local community by focusing on sustainability. We believe that this combination (local community engagement of engineering programs on topics related to sustainability) is unique. In this paper we briefly review engagement and activities in sustainability by other engineering programs. We then describe our university, department, and community, including features that make this approach attractive, describe our activities in sustainability, and discuss the strengths and weaknesses of this approach.

## **Background and literature review**

Sustainability is an increasing focus in engineering. The Professional Obligations in the NSPE Code of Ethics includes the statement: "Engineers are encouraged to adhere to the principles of sustainable development in order to protect the environment for future generations." NSPE gives the following definition: "'Sustainable development' is the challenge of meeting human needs for natural resources, industrial products, energy, food, transportation, shelter, and effective waste management while conserving and protecting environmental quality and the natural resource base essential for future development."<sup>17</sup> The ABET criteria now include the requirement that programs demonstrate that graduates are able "to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability."<sup>1</sup>

Because of these professional and educational obligations, engineering programs are incorporating instruction in sustainability. A survey by Murphy *et al.*<sup>16</sup> of how engineering programs are incorporating sustainability into curricula found that the two more common approaches are to design courses on topics in sustainability and to incorporate sustainability topics into other classes. Two less common approaches are to focus on technologies (e.g. carbon capture or solar power) and to offer courses cross listed with a non-engineering department or listed as an interdisciplinary course. The survey did not ask about community engagement and the paper mentions no examples.

Papers by Aurandt and Butler<sup>2</sup> and by Burian<sup>3</sup> are typical of such activities. Aurandt and Butler describe case studies of three courses: Green Industrial Organic Chemistry, Environmentally Conscious Design and Manufacturing (Kettering University), and Sustainable Engineering (University of Oklahoma). The courses involved little engagement with any outside community. However, at Kettering, which has a required co-op program, “students [who took the green chemistry course] reported that they applied or observed some aspects of the green chemistry where they worked.” Guest speakers from Herman Miller and Steelcase discussed examples of green chemistry in industry. Students in the other Kettering course “choose a product to optimize for environmental sustainability at the beginning of the course ...; this pedagogy ... mimics real-world scenarios.” Other case studies are also used. Burian describes the integration of sustainability into the curriculum at the University of Utah using “brief references to sustainability at the lower levels, targeted modules in junior and senior level courses, and dedicated project-based electives at the senior and introductory graduate level.” Burian mentions the Engineering-LEAP (E-LEAP) Program, “a year-long seminar focusing on the theme of community building in American and in global settings, and the ethical standards of engineering.” He notes that “A paper on sustainability is required, but limited class time is dedicated to specific discussion of sustainability.” Recent information on the E-LEAP program shows that the program does incorporate community engagement, but in the form of mentoring of K-12 students, not on the topic of sustainability.<sup>29</sup>

Universities with chapters of Engineers without Borders often have their students involved in projects that help disadvantaged communities, but most of such projects involve working trips overseas with only some education in sustainability. By design or not, such projects do teach students about sustainability. Miles Graugnard, a senior mechanical engineer at Santa Clara University, commented on his group’s water project in Honduras:

While many engineering projects seek to provide new technologies that combat problems in the developing world, what makes EWB’s project unique is its emphasis on education and empowerment. “The problem with a lot of engineering projects is that they just give technology to a community without training or educating the population,” says Graugnard. “Our overall goal for the project is to empower the community; we are more of an engineering resource, and we are working directly with the community to ensure they can be self-sufficient and that our project is sustainable in this way.”<sup>23</sup>

Some EWB projects have recognized that activity must be supported by instruction. For example, Princeton developed the Sustainable Engineering and Development Scholars (SEADS) program, which “aims to promote a multidisciplinary approach to sustainable development

through critical discussion, leadership development, and community engagement.” However, only 12-15 freshmen and sophomores are involved in the program.

While engagement encompasses research, teaching, and service activities, engagement in engineering programs has often focused on service learning. The roots of an experiential approach to teaching and learning are deep, with John Dewey having written in 1938:

A primary responsibility of educators is that they not only be aware of the general principle of the shaping of actual experience by environing conditions, but that they also recognize in the concrete what surroundings are conducive to having experiences that lead to growth. Above all, they should know how to utilize the surroundings, physical and social, that exist so as to extract from them all that they have to contribute to building up experiences that are worth while.<sup>10</sup>

Mariappan *et al.* note:

The concept of Service Learning is not new, and it has been in use in various forms especially in liberal arts and education. Traditionally, engineering has been engaged with the community beyond the campus boundaries through technical assistance programs, university extension, and work of individual faculty serving as consultants to local community organizations. However, the community engagement is usually not systematically integrated within the engineering curriculum. Most programs tend to be focusing more on a student’s professional development, rather than on their becoming socially responsible engineers who are prepared to address the needs of increasingly complex societies and communities using contemporary technologies in a cost-effective way.<sup>15</sup>

Some engineering programs have sought to systematize their service learning. Purdue University’s EPICS (Engineering Projects In Community Service) program was founded in 1995.

Under this 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. (Coyle *et al.*)<sup>8</sup>

The projects serve a community service or education organization, but do not all relate to any theme, such as sustainability.

Ample literature exists on the improvements in recruitment, retention, and learning from service learning. Of special interest to us are the implications for Hispanic students. In a study of McNair Program students, who are low-income students receiving federal funds to pursue STEM degrees, Conrad *et al.*<sup>7</sup> found that the minority students in the group cited as main reasons for pursuing STEM degrees the opportunity to “contribute to the well-being of their communities and of society as a whole” and “the possibility to use their science and engineering education for social purposes.” White *et al.*<sup>30</sup> cite Gregory and Hill’s findings that: “Many minority students come from cultures that value interdependence and collective contribution and do not attend college just for themselves, but rather to benefit family and community”.<sup>12</sup> They added: “This obligation is viewed as an essential component of the student role that cannot be deferred until graduation, which in turn leads to a conflict between the rigorous demands of STEM programs and the need to give back to the community while in school.”<sup>30</sup>

*This literature review demonstrates that the components of our activities (engineering, engagement, and sustainability) are not new, but we believe that the combination is unique.*

### **Features of our university, department, and community**

Colorado State University-Pueblo is a regional, comprehensive university with an enrollment of about 5250 students. The Department of Engineering offers ABET accredited BS degrees in Industrial Engineering and Engineering, as well as MS degrees in Industrial and Systems Engineering and Engineering. The BSE degree has a specialization in mechatronics and the MSE degree has emphasis areas in mechatronics and railroad engineering. The Department enrolls about 250 students and is growing, having doubled in size in the last four years. The seven faculty members have degrees (at BS, MS, or PhD levels) in electrical engineering, engineering management and systems engineering, industrial automation, industrial engineering, mathematics, mechanical engineering, and mechatronics.

The University has no PhD programs, and limited MS programs. Thus, the focus of the University and the faculty is on teaching. The Department of Engineering is one of the most research oriented departments on campus, with ongoing projects, as examples, on the Sabatier reaction (to support space travel), nanotechnology and manufacturing, control systems, facility location, and renewable energy.

The University and the Department have a strong tradition of engagement. Across campus, departments host events such as History Day, Math Day, and STEM Day (for the local Boys and Girls Clubs). Research includes work by a history professor on labor relations in the steel industry in Pueblo, a sociology professor on organized crime in the Rockies, several biology professors on water quality in a nearby creek, and a business professor on the economic impact of the University on its region. The University is officially designated as a Hispanic Serving Institution. Enrollment is 26% Hispanic and 9% African American; 87% of students come from Colorado, and 43% from the county in which the university is located.

In the last three years, the University has received two Department of Education grants that relate to the topic of this paper. The Regional Access to Graduate Education (RAGE) grant includes a component to expand community-based research in graduate education. The Providing Opportunities to Excel (PROPEL) grant includes components to integrate sustainability and service learning into all the STEM disciplines. Both grants have supported the Department in the activities described below.

The Department has strong local connections with industry, including student internships, class projects, and research. Representatives from local manufacturing companies and other engineering based companies, as well as other organizations such as hospitals, serve on the Department's advisory boards for the two BS programs. The Department uses adjunct faculty members from local industry to bring specific expertise to certain courses, such as safety and material science. The faculty in the Department has a strong tradition of working as a team; we work on and solve problems together. We often work together on projects and publish together, as with this paper. We value strongly the integration of research, teaching, and service. We are

very active in the American Society of Engineering Education, with two of us having served on the national Board.

The faculty emphasizes the societal and ethical obligations of engineers, starting in the first year, though the senior project. Seniors are invited to join the Order of the Engineer. The Obligation recited by new members includes this statement:

As an Engineer, I pledge to practice integrity and fair dealing, tolerance and respect, and to uphold devotion to the standards and the dignity of my profession, conscious always that my skill carries with it the obligation to serve humanity by making the best use of Earth's precious wealth.<sup>18</sup>

We interpret this statement as supporting sustainability.

Any discussion of community engagement must define "community." The University primarily serves southern Colorado:

As a regional university, CSU-Pueblo serves Pueblo and the surrounding areas of southern Colorado. Besides the main populations in Pueblo and Pueblo West, the region served includes Cañon City and Westcliffe to the west, Walsenberg and Trinidad to the south, and various small towns along the Arkansas River valley to the east. The majority of students have traditionally come from these areas. With the recent growth of Fort Carson and Colorado Springs and its suburbs to the north, a growing proportion of the students now commute from this area. As a result, CSU-Pueblo recognizes that the region it serves is growing. In response, the university now offers courses and certain degree programs in Colorado Springs.<sup>4</sup>

This description highlights some features of the area, including the university's location near the Arkansas River and near a military center.

The place names in the above description also indicate the Hispanic nature of the area. Our service area encompasses one of the most ethnically and economically diverse areas of Colorado. Colorado's Hispanic population is ranked seventh highest nationally at 20.3%, with an area Hispanic population nearly double that at 39.5%. Eleven feeder school districts have a 59.5% Hispanic population, a predictor of increasing Hispanic enrollments at the University. Since 2005, the University has seen a 53% increase in freshmen, with 79% more Hispanic new freshmen and 90% more Hispanic freshmen entering STEM programs. The University's service area "also encompasses Colorado's most economically-depressed areas. Pueblo residents have a median income of \$39,016, compared to \$55,735 throughout Colorado (USDA, 2009). Further, 22.8% of Pueblo residents (26.7% Hispanic) live in poverty, compared to 9.3% in Colorado and 14.3% across the nation."<sup>6</sup>

Pueblo and its region have always supported economic development. The Pueblo Economic Development Corporation is supported by membership dues and seeks to attract primary jobs.

In 1984, the citizens of Pueblo, Colorado gave their approval for adding a half cent sales tax on themselves to create funding for economic development and to bring primary jobs to the area. Since 1984, the extension of the half cent sales tax has continually received their approval.<sup>21</sup>

Recently Pueblo and other communities in the area have demonstrated understanding of the need for sustainable development. In 2011, Pueblo added Sustainability Principles to its Regional

Development Plan. In 2012, with state funding, the community completed a sustainability plan; regular meetings are supporting the implementation of the plan. The town of Fowler, 38 miles east of Pueblo, has received awards for its activities in sustainability.

Thus, features of our university, Department, and community support our activities in community engagement around sustainability.

### **Our activities**

While the Department was already strongly engaged with the local community, the PROPEL grant was the impetus for us to expand that engagement and to focus on sustainability. The PROPEL grant focuses on improving STEM education through sustainability, service learning, and technology for teaching.

In the summer of 2012, all seven faculty members (and a faculty member from a local community college) participated in a four-day intensive workshop, with one day devoted to each topic of the PROPEL grant (sustainability, service learning, and technology for teaching) and one day in which we integrated those topics and planned our future activities. The workshop was designed to support the PROPEL goals:

- Integrate sustainability across the curriculum to engage and motivate students and faculty and thus to improve learning
- Increase service learning to engage and motivate students and faculty and thus to improve learning
- Use instructional technology to improve learning
- Improve articulation with community colleges.

The goal of the workshop was to increase faculty knowledge in sustainability, service learning, and instructional technology, to reach a shared understanding about those topics, and to decide on specific action items to be developed more in the rest of the summer and implemented in the 2012-2013 academic year.

For each of the first three days, each faculty member was assigned papers to read and to report on during the workshop; discussion in each morning involved definition of terms, broad discussion, and brainstorming, while the afternoon session was focused on applying the ideas to our courses and curriculum. Papers were assigned that related to the courses each teaches. For example, the professor who teaches our introduction to engineering read the paper by Kemppainen *et al.*<sup>14</sup> on sustainability in a first year program. The professor who teaches our robotics course read Hobson's paper<sup>13</sup> on service learning in a robotics course.

Each of the first three days of the four-day workshop was structured around learning and open discussion in the morning, lunch as a group, and an afternoon devoted to summaries of the papers we read, and a focus on action items. The morning sessions were meant for us to think broadly, to brainstorm, and to cast a wide net. The afternoon sessions were meant for us to apply our ideas to our courses and to our curricula.

The first day was devoted to sustainability. In the morning we discussed:

- What is sustainability?

- Why and how can we incorporate sustainability into engineering?
- What are we doing already?
- What more should we be doing?

In the afternoon session we each reported on the papers we read, responding to the question “How does what you read apply to what we do?” We reviewed our curriculum and chose two courses to which we will add sustainability in 2012-2013. In the final hour, we debriefed, finalized a list of action items and also decided on further learning we need in sustainability.

The second day was devoted to service learning. In the morning we discussed:

- What is service learning?
- What is our community?
- Why and how can we incorporate service learning into engineering?
- What do we do already in service learning?
- What more should we do?

Our discussion was informed by two quotes from the PROPEL application:

Because Hispanic university students are often reluctant to dedicate themselves to the STEM fields, believing the profession will not integrate well with their community-minded career aspirations or that the time commitment to STEM majors will prevent them from actively engaging with their community, we created new STEM service learning opportunities. These will focus on innovation in addressing sustainability issues in the community, state and country.

Service learning is a critical component in attracting Hispanic and low-income students to STEM degrees. Hispanic STEM students in particular express a desire to pursue a chosen profession that will benefit their community (Conrad, 2009). Emphasis in sustainability, infused across the STEM curriculum through unique opportunities for service learning, will attract and retain STEM students (Krabacher, 2008). In fact, student engagement can be greatly increased by emphasizing the relevancy of sustainability across all STEM courses (Schild and Clark, 2010).

In the afternoon session we each reported on the papers we read, responding to the question “How does what you read apply to what we do?” In the final hour, we debriefed, finalized a list of action items and also decided on further learning we need in service learning.

On the third day, we had several demonstrations of technology, by computer staff and by our own faculty, including the use of Apple technology and the LiveScribe pen for creating online material for students. The grant had purchased pens for each of the 7 faculty and by the end of the day each had created a PenCast and shared it with the other faculty. We also shared our methods for using Blackboard and we discussed methods for online courses.

The workshop was designed to have enough but not too much structure. Each day had a focus, and each session had a purpose, but discussion was not tightly controlled. The overall goal each day was to have a long list of possible action items by the end of each day.

Our discussions resulted in a *very* large list of possible activities related to faculty development (for example, have one professor teach us all systems dynamics as important modeling tool for



sustainability), program changes (add biology as a required course in our engineering programs), specific topics on sustainability (teach about ISO 14000), student activities (have our students teach K-12 students about sustainability), the senior projects (require each team to assess impacts on sustainability), and outreach and engagement (work with the city of Pueblo to help them design and locate a new recycling facility).

On the fourth day, we returned to reality and created a list of activities that build upon and extend what we already do. We reviewed our notes from the first three days, and enunciated some of our shared conclusions, for example

- Service learning must be of mutual benefit and mutually meaningful to all three: community, students, and professor.
- Good teaching uses a variety of technology, as appropriate: PowerPoint, whiteboard, class exercises, engineering labs, etc.

We then created a list of specific actions items, with responsible person(s), time frame, and resources required. We began to work on the details of each task.

In the remainder of the summer and in fall semester of 2012, faculty members have worked on the tasks we set ourselves. Since the PROPEL grant is now in its second of five years, we will have the opportunity to do more of the activities from our ambitious list.

We now describe activities of the Department in engaging with the local community on topics in sustainability. The activities are grouped into: activities completed before summer 2012, activities ongoing before and after summer 2012, activities initiated because of our plans from the workshop, and activities we plan to initiate in the future.

Before our summer 2012 workshop, the Department had already completed many activities related to sustainability. Several projects have been sponsored by iCAST (International Center for Appropriate & Sustainable Technology; see <http://www.icastusa.org/>), including an MS thesis<sup>9</sup> and further work on making briquettes from waste from electric generating plants,<sup>24,25</sup> graduate student projects evaluating the claims of GreenGold Lubricants (see <http://www.greengoldlubricants.com/>), and MS theses on topics related to sustainability: solar power in the local area,<sup>26</sup> wind power and solar power potential at the University,<sup>27,28</sup> sustainability in hospitals,<sup>19</sup> and sustainability in energy use.<sup>20</sup> The MS committee for the last thesis including a person from one of the local electrical generating companies and the student was invited to present the thesis to their staff.

Other projects related to sustainability are ongoing. Through the University's involvement in the NASA-funded Space Grant, many students and faculty are working on a project to use solar power to manufacture fuel on Mars.<sup>11</sup> Students in the introduction to industrial engineering course are challenged each fall to create objects from trash that someone might buy; they have built solar cookers, cardboard homes, a backpack from crushed soda cans, a table from recycled cans, a child's chair from cardboard, a grill from a recycled metal drum, and a greenhouse from water bottles. One of us was on the core committee for the creation of a sustainability plan for our local county and this involvement led to some of students being involved in working on the location and layout of a potential Material Recycling Facility; we will be continuing to support the implementation of the plan. Students in the American Society of Mechanical Engineers

student section are building a solar tricycle. Two faculty members have served on the board of the local chapter of the Colorado Renewable Energy Society. Some courses already included some topics on sustainability, for example, the introductory graphics course uses the SolidWorks sustainability module to perform a life cycle analysis of a cup holder.

As a result of the summer 2012 workshop, we have made changes to several classes in fall 2012 and will be making more changes in spring 2013. Our goal is to add sustainability topics in every course. Some changes are small (for example, turning “tower” into “wind tower” in a statics problem) and some are bigger (for example, in a probability and statistics class, describing the use of the Weibull probability distribution in modeling wind speed and designing wind turbines). We wrote learning objectives about sustainability for the introduction to engineering and are working on writing learning objectives for higher level courses. An experiment was designed and implemented involving adding material on sustainability to one section of the introduction to engineering course. One engineering professor has received a two year grant from the Colorado Department of Transportation (CDOT) to study the Solar Highway Impact in Colorado. The PROPEL grant will support the purchase of two wind turbines; equipment and site selection are underway.

We plan other changes. Recently, the Department began to work with the local Wastewater Reclamation Facility on possible projects including instrumentation and control, 3-D modeling, data analysis, and automation. Both undergraduate- and graduate-level engineering students will be involved in these projects. The senior project class in Spring 2013 will include a new requirement for the final report to include a section on sustainability aspects of the project. Topics may include optimization of resources, product life cycle, benefits to the current and future generations, etc. A rubric for evaluating this section has been developed.

### **Strengths and weaknesses**

We have made progress on engagement of our local community on topics related to sustainability, but we still have much work to do. The Engineering faculty members share a strong commitment to using engineering to benefit people. Sustainability is an important topic that excites and motivates our students, and the topic also excites and motivates the faculty. Similarly, service learning has benefits for students, and we, too, enjoy the practice of engineering through our engagement with the community and we enjoy contributing to the well being of our community.

Sustainability, with its inclusion of people, plant, and profits, is a broad topic. Whether a strength or a weakness, this breadth allows us to include many of our activities under this umbrella. The faculty members increasingly view sustainability as an integrating theme of the Department, although we also agree that all of our activities should not fall under that theme.

While we have already built strong relationships with many local companies, we are still working to create more and stronger relationships with local governmental agencies and nonprofit organizations. Our experience in partnerships helps us create these new relationships.

We have identified two issues that need improvement in using our community engagement to educate students. First is the need, as with some Engineers without Borders projects, for explicit classroom activities to reinforce the learning that we intend our students to achieve through these activities. Second is that while our local focus is a strength, we also want to have our students apply the concepts of sustainability in the world arena. Regarding the first issue, we are discussing adding explicit instruction on sustainability in our senior seminar, the first semester of our two-semester senior project course sequence. Regarding the second issue, we need to use our international students to broaden the view of our local students.

The Community Engagement in Engineering Education Division of the ASEE states: “Ideally, student teams and citizens work together on the shared purpose of completing community-identified projects aimed at increasing community assets.” We believe that we have made great progress toward that vision but still have far to go.

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