

Implementing Sustainable Development through Problem-Based Learning: Pedagogy and Practice

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Abstract: This paper presents an approach for implementing sustainability within a university environment, and for helping students become more effective problem solvers and professionals. In a “Sustainable Urban Development” course, taught by the writer, students develop projects to make their campus and community more sustainable. In the process, students learn how to analyze sustainability, work with decision makers, and put classroom knowledge into practice. Further, through this course’s emphasis on problem-based learning, students acquire critical cognitive skills and professional skills as they tackle complex, interdisciplinary, and real-world problems. Systematic evaluations of the course offer useful lessons. One is how to create synergies. For instance, while students benefited from hands-on experience with sustainability, the university benefited from students’ work. Another is how to demonstrate and quantify benefits from sustainability, which is vital to gaining support. Yet another is how to enable students to learn from both successful and unsuccessful attempts to implement ideas. Courses such as this can create important bridges between theory and application, and between education and professional practice.

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Introduction

The call for sustainable development echoes around the world, and universities are ideally positioned to answer. More than a decade ago, a group of 22 international university presidents and officials convened in Talloires, France, declaring the importance of universities in the “education, research, policy formation, and information exchange necessary” for sustainable development (“The Talloires” 1990; “Talloires” 2002). The Talloires Declaration has become steadily louder, with the Halifax Declaration (“Creating” 1991), the Earth Summit Agreements (“Report” 1992), the Swansea Declaration (“The Swansea” 1993), the CRE–Copernicus Charter (“Co-operation” 1994), and the Lüneburg Declaration (“Higher” 2001)—each of which emphasizes the roles and responsibilities of universities to promote sustainable development.

Universities are also positioned to answer the call of the profession—to help students develop the knowledge and problem-solving skills to become effective practitioners. Students typically graduate with much textbook knowledge, but with little experience in real-world problem solving. Traditional methods of academic instruction, such as lectures, may inadequately prepare students to make the transition from the classroom to the profession. Moreover, problem solving often requires more than an analytic exercise on paper; it requires working with people and orga-

nizations. As Grigg (1995) notes, engineers are increasingly placed in positions where they need an understanding of not only scientific concepts, but also the societal context of decision making.

In addition, many professional organizations have established sustainable development as a guiding principle. Notably, in 1996, ASCE became among the first to explicitly address sustainable development in its Code of Ethics. The first fundamental canon in the ASCE Code states, “Engineers shall hold paramount the safety, health and welfare of the public and shall strive to comply with the principles of sustainable development in the performance of their professional duties” (ASCE 1996). Arguably, the implications of this canon extend not only to professional practice, but also to professional education.

In the past decade, courses on sustainable development have grown within curricula of civil and environmental engineering, and other disciplines. The emphases of these courses vary from general principles to specific subjects, such as green buildings, alternative-fueled transportation, and pollution prevention. These courses generally recognize that sustainable development is more than a lofty theory; sustainable development requires action “on the ground.” Yet students often lack opportunities to put sustainability principles into practice. This relates to a more general educational concern that the classroom often focuses on what information students should be told, rather than on how students can effectively learn and apply information (Shepherd and Cosgriff 1998).

This paper seeks to address these needs, providing contributions in two main areas. The first is the pedagogy and practice of sustainability. A course called “Sustainable Urban Development,” taught by the writer, provides students with both fundamental knowledge about sustainability, and experience with implementing sustainability through student-designed projects. It also demonstrates how to promote sustainability by promoting synergies within a university, and vice versa. For example, the students’ projects can unite and build upon research, education, administra-

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tive, professional, and outreach efforts at a university. In turn, these university efforts can be bolstered through students' projects. This course was systematically evaluated, over four years, offering lessons and guidance that are summarized herein.

The second is the development of innovative teaching strategies to link pedagogy and practice. This course uses a problem-based learning (PBL) approach that emphasizes learning by doing: Students identify a sustainability problem on campus, and then develop a sustainability project to address that problem. The PBL approach enables students to build cognitive and meta-cognitive skills for acquiring, analyzing, and applying knowledge. Further, as students develop their projects, they learn important professional skills—for instance, how to work with decision makers and the public, how to manage interdisciplinary problems, how to deal with uncertain and incomplete information, and how to communicate effectively through oral and written presentations. Using PBL as a framework, this paper analyzes the benefits and challenges of learning from experience, and the design of classroom projects that promote practice-based learning.

This paper proceeds as follows. After this first and introductory section, the second section examines university initiatives to promote research, education, and application of sustainable development. The third section examines PBL as a practice-based pedagogy, and as an approach for learning how to implement sustainability. These are brought together in the fourth section, which presents the course on “Sustainable Urban Development,” based on PBL. The fifth section summarizes experiences and lessons from the course, while the sixth section offers recommendations.

Sustainable Development at Universities

What is sustainable development, and how do we implement it? The widely accepted definition—“development that meets the needs of the present without compromising the ability of future generations to meet their own needs” (World 1987)—provides scant guidance for implementation. A university campus, however, can serve as a useful laboratory to test ideas and methods of implementation. Currently, nearly 300 universities in the United States have enrolled as members in the Campus Ecology program, designed to promote initiatives in campus sustainability (“Campus” 2002). Through such initiatives, universities have capitalized on their courses and research, their partnerships with the profession, and the activities of their faculty, staff, and students. This section will look to examine five main ways that universities promote sustainability—policy, research, education, infrastructure, and outreach activities. [Data for this section were obtained from the National Wildlife Federation’s program on Campus Ecology (“Campus” 2002), Second Nature (“Second” 2002), press releases, university Web sites, and interviews with university officials conducted between 1998 and 2002.]

Policy

Universities have signed onto sustainability as a guiding policy, and have created groups for campus sustainability. For example, the California Institute of Technology Environmental Task Force encourages students, faculty, and staff to work on campus environmental initiatives such as recycling, bicycling, and energy conservation. The Connecticut College C-Green campaign promotes environmental stewardship in the classroom and in campus operations. Ball State University convened the Green Committee 2 to

implement the nine tenets of the Talloires Declaration—the publics, the universities, the students, the faculties, the exemplars, the funders, the practitioners, the schools, and the organizations.

Research

Universities have engaged faculty, staff, and students in research to develop more sustainable technologies. For example, through the Global System for Sustainable Development, Massachusetts Institute of Technology provides institutional, financial, and regulatory incentives for sustainability and technology development. Cornell University’s Work and Environment Initiative promotes research on eco-industrial development, labor, and the environment. The University of California at Davis pursues research on strategies and technologies for sustainable management of urban forests. Georgia Institute of Technology’s Institute for Sustainable Technology and Development promotes research and coordinates campus activities in sustainability.

Education

Universities have designed new courses and redesigned existing courses to educate students about sustainability. Harvard University recently established a Center for the Environment, emphasizing courses and programs on sustainability. The Heller Graduate School at Brandeis University created a master’s degree program in Sustainable International Development. Brown University implemented a campuswide Brown is Green initiative to promote environmental education and stewardship, with student projects on campus sustainability.

Infrastructure

Universities have implemented more sustainable infrastructure and practices on campus. The green building for the University of California at Santa Barbara’s Don Bren School of Environmental Science and Management was awarded the Leadership in Energy and Environmental Design (LEED) Platinum rating by the U.S. Green Building Council. The University of Texas at Houston used The Natural Step to make its Health Science Center a green building, with significant reductions in resource use, toxic substances, waste generation, and costs. Dartmouth College has implemented a campuswide composting program and an organic farm.

Outreach

Universities have used sustainability as a way to bring together academia, industries, and communities. The Bates College dining facility established responsible purchasing, composting, and recycling initiatives, which involve local organic farmers, homeless shelters, and soup kitchens. Rutgers University developed policies for environmentally sensitive contracts, favoring the purchase of products from green businesses. At the University of South Carolina, student volunteers and campus recycling staff worked with charitable organizations to donate food, clothing, building materials, and furniture, which in turn saved the university approximately \$30,000 in disposal costs.

From an administrative perspective, a force behind campus sustainability is economics. Universities can profit from sustainability, through direct and indirect reductions in costs (e.g., expenditures, resource use, waste generation, health risks, absenteeism, and liability) and increases in benefits (e.g., revenues, efficiency, productivity, public relations, and improved quality of

campus life). An important selling point for campus sustainability is that it can improve not only the university's environment, but also the university's bottom line.

From an educational and research perspective, opportunities to learn about sustainability are all around the campus. But learning about sustainability requires more than classroom discussion; it requires practice in real-life settings. As Chameau (1999, pp. 1–2) aptly notes, the challenge is to “change our mind-sets, not just our problem-sets....We need strategies that reinforce learning in the classroom with discovery in the research laboratory and practice in the management of the campus.” This need sets the stage for problem-based learning and the course on sustainable development.

Problem-Based Learning for Practice-Based Pedagogy

Problem-based learning emphasizes learning by doing. It also provides a motivating context for learning. Students are given a real-world problem similar to those they would face as professionals. They take ownership of the problem, and the problem-solving process. Instructors, in turn, take the role of a cognitive coach. A pedagogical goal of PBL is to help students develop their own problem-solving skills, rather than tell them how to solve the problem.

Problem-based learning emerged more than 25 years ago to improve methods of professional instruction (Barrows and Tamblyn 1976). A problem with traditional methods, such as lectures, is that they focus on what students should be told, rather than how students can learn to acquire and apply knowledge to solve practical problems (Shepherd and Cosgriff 1998). The literature on cognition and meta-cognition argues that problem-solving skills should be developed with course content (Collins et al. 1989; Barrows 1991). Problem-based learning does just that: Students are presented with a real-world problem, and then engage in a self-directed learning process as a form of cognitive apprenticeship. On a meta-cognitive level, this enables students to evaluate and refine their own problem-solving strategies (Bransford et al. 1986).

The literature on problem-based learning in engineering education suggests many educational and professional benefits of this approach (Hendley 1996; Dutson et al. 1997; Johnson 1999), which support the findings of other professional literature (Albanese and Mitchell 1993; Chen et al. 1994). The benefits of PBL are examined here, focusing on five main themes—applicability, problem solving, active learning, motivation, and professional skills.

Applicability

PBL can make knowledge more accessible and applicable because it is used to solve real problems. When problems are relevant and genuine, higher levels of comprehension and skill development can occur than in traditional instruction (Albanese and Mitchell 1993). Some argue that traditional educational methods may actually impair natural problem-solving skills (Barrows and Bennett 1982) because students are given information rather than problem-solving opportunities (Johnson 1999). The deliberate link between course content and problem solving can enable students to make stronger associations between existing and newly acquired information and skills, and to make that knowledge more memorable in the future (Eisenstaedt 1990; Barrows 1991).

Problem Solving

PBL helps students develop skills for solving practical and real-world problems. Typically, students become proficient in solving narrowly defined textbook problems, but have relatively little experience in solving ill-structured, open-ended problems—the type often faced in practice. This is especially true with sustainability problems, which require flexible, integrative, multidisciplinary problem-solving approaches, rather than singular solutions. In addition, students learn that problem solving is often more than the product of an intellectual exercise. Problem solving requires implementation, and good solutions may nonetheless face barriers to implementation. Through PBL, students can acquire additional skills, often social and political skills, necessary to implement solutions.

Active Learning

In PBL, the students, not instructors, are responsible for determining what information and analyses are needed to resolve the problem. Students learn to seek out and evaluate information from various sources, such as journal articles, documents, organizations, experts, and community members. Thus, a textbook is viewed as one source of information, rather than the source of the solution. Active learning can help students beyond graduation, as knowledge becomes outdated and students need to acquire new knowledge on their own. In this sense, PBL helps students to learn how to learn.

Motivation

PBL provides motivation for learning and for solving a problem. Students tend to become more interested in a subject when it has personal or societal relevance. Because PBL is based on a real-world and real-time problem, it can make abstract concepts more meaningful because students use them to solve or improve a current problem. Furthermore, PBL can provide a way for students to move beyond the classroom and serve as resources to their communities. The problem that students address, and the solutions they develop, can help to meet a community or societal need.

Professional Skills

PBL helps students develop professional skills, such as cooperative and interdisciplinary problem solving. Students learn to work both independently and collaboratively, as would many professionals. Even though students engage in self-directed inquiry through PBL, they regularly convene to share, evaluate, and critique each other's work. In addition, students perform activities that are regarded as components of professional practice. They deal with multiple and often conflicting goals and values, work with constraints, and determine the most appropriate action to take, often in the absence of complete information or certainty. Students learn to employ initiative, resourcefulness, and personal accountability as they develop solutions to the problem.

Problem-based learning exercises typically proceed through four phases—problem presentation, problem investigation, problem solution, and process evaluation (Shepherd and Cosgriff 1998). The kernel of PBL is the problem itself: The problem should be a real-world situation, complex and open ended, that will challenge higher-order thinking, creativity, and synthesis of knowledge. In addition, PBL problems should enable students to confront issues of implementation, and to work directly with decision makers, advisors, stakeholders, and the public.

Implementing Sustainability through Problem-Based Learning

Course Overview

The writer designed and taught a graduate course at the Georgia Institute of Technology called “Sustainable Urban Development” over four years. In this course, students developed projects to make aspects of the campus more sustainable. The projects became the basis of the problem-based learning process: Students were required to identify a *problem* (something that could be made more sustainable) and create a sustainability *plan* (how to make it more sustainable).

This course attracted students from several disciplines, including civil engineering, environmental engineering, industrial systems engineering, architecture, building construction, public policy, management, and city and regional planning. The diversity of students, and their areas of expertise, fit well with a course on sustainability, which seeks to be multidisciplinary and integrative. The course met three hours at a time, one day a week throughout the term. The long time block was useful to discuss projects, make presentations, and share experiences. At the end of the course, students submitted two reports—one on their final project, and one on lessons for implementing sustainability.

Sustainability, in this course, referred to activities that would promote the “three E’s”: economy, environment, and equity. In addition, students were given the task of developing their own list of “principles of sustainability.” This included more specific criteria such as “reduce resource consumption” and “reduce or eliminate use of toxins.”

Through project proposals and reports, students explicitly discussed how their projects would address both broad (the three E’s) and specific sustainability principles.

An emphasis of the course was learning about implementation—specifically, interactive implementation. Students were urged to communicate and work with stakeholders (such as university staff, students, companies, and community members), through all phases of their project, in order to

- Learn how the project could help meet a need and could fit into existing operations,
- Obtain feedback to assess the feasibility of the project, to identify opportunities and possible barriers, and to learn about prior efforts or related work,
- Offer ideas and alternatives that may not have been considered, and bring in successful examples from other universities or campuses,
- Find ways to reduce barriers, before they become too large; yet if barriers appear insurmountable, then redefine the project,
- Demonstrate ways that the project would provide benefits and cost savings, backed up with evidence,
- Generate support and ownership for the project, which can impart a sense of responsibility, commitment, and advocacy,
- Develop a foundation for future use or continued work, so the project is not abandoned after the course has ended, and
- Overall, create a useful and beneficial project that will be accepted.

Another feature of the course was the opportunity to develop, practice, and improve professional communication skills. Throughout the course, about every two weeks, students made oral presentations of their work. The instructor would provide feedback on students’ individual presentations, both in terms of content (i.e., project scope, direction, activities) and in terms of

form (e.g., delivery, style, visual aids). In addition, students provided written updates, each week, on their projects and their learning process. These activities helped to ensure progress on the projects, and to document the learning experiences as they were happening. Moreover, these activities helped students to improve significantly their speaking and writing skills.

The course also had an important capstone. Students gave oral and written presentations of their work to top-level campus administrators and other decision makers with authority to implement the projects. Because students knew that key campus officials would be hearing and receiving their projects, they also knew that their work was not just a classroom exercise; they could influence campus policies and practices. Of course, this would not guarantee that their projects would be implemented, but it did offer a forum for students to present their work, and for administrators to provide suggestions.

Course Syllabus (Excerpts)

An objective of this course is to explore the principles and practice of sustainable development. This is an exciting and unique opportunity to make an urban community more sustainable. In this case, your community is Georgia Tech and its surrounding neighborhoods. You will design and implement sustainability projects, and present your work to top-level administrators and the Campus Master Planning Committee. Notably, as a result of previous years’ projects, the central principle of the campus master plan has become “sustainability.”

This course will be run in a problem-based learning environment. You will identify a problem, investigate alternatives, perform analyses, work with stakeholders, and develop an implementation plan. You will take ownership of your project and the problem-solving process, as would a professional. Remember that it is not enough to come up with a good plan; you will need to “sell” your plan to decision makers, the administration, and the public. To do this, focus on incentives, especially cost savings and other measurable benefits for Georgia Tech. Be sure to substantiate your recommendations with data and analyses.

Your sustainability project is the major product of this course. An additional product will be your “lessons learned” on how to implement sustainability. Throughout the course, you will write up and discuss what you have learned. Also, seek out and bring in resources that you find helpful. Class discussion periods will be an opportunity to learn from each other, discuss challenges and successes, and improve the implementation process.

An important part of this process is learning how to translate ideas and plans into actions and results. Yes, you will encounter barriers. A pedagogical goal of this course is to learn how to identify and overcome barriers, to create necessary incentives and support, and to adapt your implementation strategy to be effective.

The timing for your course project is ideal. Georgia Tech is developing a new campus master plan, and the Campus Master Planning Committee has generously allowed us to participate in their process. You will be working with decision makers, administrators, consultants, students, faculty, and staff to design and implement your project. Finally, when working with these stakeholders, please be considerate of their time, be receptive to their viewpoints and needs, be well prepared, and be sure to follow up with a note of thanks.

Sustainability Projects: Report Format

Please prepare your report to cover each of these six main sections. Consider the subtopics within each section, and feel free to discuss additional topics.

1. Executive summary
 - Highlight main findings, benefits, results, and recommendations (one to two pages).
2. Project definition and motivation
 - What is not sustainable at Georgia Tech? Why is this a problem?
 - Why would Georgia Tech benefit from being more sustainable in this area?
 - Perform initial sustainability assessment.
 - Discuss potential benefits and cost savings of the project.
 - Identify successful precedents at other campuses, and what we can learn from them.
 - Determine the purpose and scope of the project, and its relationship with other activities at Georgia Tech.
3. Sustainability project development
 - Develop a project for making Georgia Tech more sustainable in this area.
 - Generate visions, ideas, and alternatives.
 - Investigate results from other campuses (if relevant).
 - Obtain baseline information, and evaluate data sources.
 - Develop, analyze, and prioritize alternatives.
 - Discuss feasibility, advantages and disadvantages, and benefits and costs.
 - Narrow down the alternatives to the most promising.
 - Emphasize benefits and cost savings to Georgia Tech.
4. Sustainability project implementation
 - Develop a plan for implementation.
 - Assess what needs to be done, and who would do it.
 - Investigate incentives and barriers, and what would affect the feasibility of implementation.
 - Establish goals of the project, and how progress can be monitored.
 - Identify the resources needed (e.g., funding, people, resources, expertise, partnerships, additional research) in order to implement the plan.
5. Results and future recommendations
 - Be specific. Be able to support your recommendations with solid evidence.
 - Focus on your specific analyses for Georgia Tech.
 - Elaborate upon the main points in your executive summary.
 - Discuss benefits and possible barriers.
 - Provide recommendations for where Georgia Tech can go from here.
6. Appendices
 - Provide data, maps, references, resources, etc.

Lessons Learned for Implementing Sustainability

Please prepare your report to cover each of these seven main sections. Consider the issues and questions within each section, and feel free to discuss additional topics.

1. Executive summary
 - Highlight main lessons learned (in one to two pages), in bullet-point format.
2. Learning
 - What were the most valuable things that I learned?
 - Were there any surprises? What were they, and what did I learn from them?

- How would I have done things differently?
3. Successes and shortcomings
 - What were the successes? Why were they successful?
 - What were the not-so-successful approaches, and why?
 - What did I learn from both?
 4. Barriers
 - What barriers and challenges did I encounter? How did I overcome them?
 5. Resources
 - Which resources (including people) were most helpful or not as helpful?
 6. Recommendations
 - Elaborate on the points in the executive summary.
 - Provide recommendations for students trying to implement sustainability on campus.
 - Provide recommendations for universities trying to implement sustainability.
 7. Appendices
 - Include information on resources, contacts, information from other universities or organizations, references, Web sites, transcripts of interviews, questionnaires, data sources, etc.

Topics for Sustainability Projects

Students' campus sustainability projects covered a range of topics. In four years of teaching the course, more than 40 projects were developed, and about half of those followed up on student projects from previous years. Student projects included the following:

- Framework for sustainability. Develop sustainability indicators, perform sustainability audits and monitoring programs, and compare sustainability programs among universities.
- Sustainable buildings. Provide guidelines for creating green buildings, develop plans for deconstruction, and improve indoor air quality by using less-toxic supplies and materials.
- Energy efficiency. Perform energy audits, renovate systems, increase the use of photovoltaics, and develop programs for reducing energy consumption.
- Water conservation. Implement xeriscaping, retrofit existing buildings with low-flow devices, and develop an education program for K–12 schools on water conservation.
- Storm water management. Collect and reuse storm water, develop green roofs, and increase the amount and connectivity of pervious surfaces.
- Sustainable landscaping. Reduce or eliminate the use of pesticides and fertilizers, implement an integrated pest management program, and use native vegetation.
- Recycling and composting. Reduce waste from on-campus facilities such as dining services, recycle cardboard and computers, and develop a composting program.
- Transportation. Switch from diesel fueled to alternative fueled buses on campus, improve the transit connections to campus, and reduce the parking demand on campus.
- Hazards reduction and pollution prevention. Offer organic food in the cafeterias, reduce non-point-source pollution, and implement integrated pest management.
- Education and outreach. Develop a sustainability Web site and coordinate sustainability activities on campus.

Course Experiences and Evaluations

The instructor regularly and systematically conducted evaluations of the course in four main ways. These evaluations were impor-

tant not only for the instructor to obtain feedback, assess student progress, and refine the course as it was being taught, but also for students to reflect upon and share their own progress and their learning experiences.

1. Several times during the course, the instructor asked students to provide written (and anonymous) responses to the following questions: (1) What are the most useful parts of the course? (2) What parts could be improved? (3) What specific suggestions can you offer for changes?
2. Each week, students submitted weekly written evaluations on their project activities, their learning experiences, and their successes and barriers.
3. Also each week, students reviewed, assessed, and synthesized their activities and experiences during open group discussions, and the instructor recorded these results.
4. At the end of the course, students provided a formal written report on lessons learned, in addition to their project reports.

The following section synthesizes the main findings from these evaluations, providing direct quotations from students. These illustrate the effectiveness of PBL to understand and implement sustainability, and the effectiveness of PBL for student learning.

Effectiveness of Problem-Based Learning to Understand and Implement Sustainability

Students regarded PBL as an effective way to learn about sustainability. The course also inspired broader thinking about sustainability.

- “I didn’t really stop to think about how literally everything we do can be done better or more efficiently, and all the small changes we make can really add up to make bigger differences.”
- “This class has allowed me to see that opportunities for sustainability are everywhere, and it has given me a sense of urgency to do what I can to create a sustainable environment.”
- “Sustainability courses should pursue the dissemination of ‘gained knowledge.’ There is nothing more frustrating than doing a good project that we know will end up in a drawer (or in the trash) and that will not benefit anybody.”
- “We learned more about sustainability by designing a plan for our campus, than if we were designing for a hypothetical case, full of unrealistic assumptions.”
- “As a sustainability curriculum is established, faculty should encourage creative thought and the analysis of local conditions.”
- “The most important element of sustainability is to realize that everything is interrelated.”
- “I also learned that the first step toward a successful sustainability plan is education.”
- “I found that sustainability seems easy when discussing principles, but it becomes much more complex when applying it to the real world.”
- “A lot of what I’ve learned I’ve extended to my personal life. The class instilled a sense of urgency to get things done and be a part of the solution.”

Students recommended careful project definition and feasibility assessments, and communicating with stakeholders in this process.

- “Projects should be chosen carefully. The following issues should be considered when selecting a project: What are the data requirements? Are the data available? What is the benefit of implementing this project? What are likely to be the barriers

in pursuing this project? Who has the capacity to make decisions in this area? How interested am I in this subject?”

- “Before you go out and implement a sustainable project, you should perform an audit of your campus, and see what sustainable measures are currently going on.”
- “You have to tell people why to do something (i.e., educate) because you cannot assume that they will go along with your idea, even if the benefits seem obvious.”
- “Smaller changes are more easily accepted than larger ones.”
- “Develop an ‘elevator pitch’—a short statement to succinctly describe the topic. Not only does this help you to focus the topic, but it also gives you a prepackaged introduction when first meeting administration and staff members.”
- “Our largest successes came about by spending adequate time preparing for meetings and interviews. Administrators were far more forthcoming with information when questions were thought out in advance, and when we prepared materials for review. I believe they were also more motivated to work with us when we appeared to value their time and input by making the advance effort.”

Students quickly learned that they needed to “sell” sustainability to get decision makers to listen.

- “The biggest barrier was that those in charge of implementing sustainability did not see the importance of sustainability by itself. It was only when we emphasized the concomitant benefits—such as cost reduction—that we found much motivation for action.”
- “A project or policy must be marketed to the decision makers.”
- “When presenting an idea, especially one that is not widely known, it is important to show the benefits of the bottom line—cost.”
- “Costs are an important, and inevitable consideration of any sustainable project.”
- “Decision makers really respond to cost savings, probably more than anything else.”
- “It is very difficult to create a qualitative measure for some benefits and costs.”
- “Part of implementing sustainability is getting people to see that markets do not function perfectly and that outcomes would be different if costs were not externalized.”
- “The real trick is not thinking of the ideas but in overcoming the barriers.”
- “It is very important to present win/win scenarios to the persons involved to gain support for the project and provide assistance in executing the plan.”
- “Another way to gain approval of plans is to use an ‘expert’ opinion in the analysis of alternatives.”
- “No one will implement this plan, even though we tell them exactly what to do, unless they understand why to do it.”
- “Show the successes of your ideas at other campuses and places.”
- “The manager believed that there was no way this project could work. It was only after stories of successful examples at other universities and other major cities that he came around to thinking that this might be possible.”

Students also recognized the importance of collaboration and support, finding a champion, and working closely with stakeholders throughout implementation.

- “When building relationships with the decision makers and potential implementers of your project, try to get them excited about the project and have them be the primary developers of the project.”

- “Implementation will likely require someone on the administration emerging as a ‘champion’ of this project.”
- “I learned that having all the ingredients for positive and feasible problem solving does not guarantee action. Action must be motivated, coordinated, and supported through top-down, bottom-up tactics to convince and inspire.”
- “To gain support from the administration, the concept must emphasize the benefits that are associated with implementing policies supporting the principles.”
- “Project initiators must also be flexible and ready to change directions or your way of thinking.”
- “The most important thing to remember when attempting to implement a sustainability project on a university campus is that there are a lot of people who do not really buy into it.”
- “Related to this issue is the need to examine work from others’ perspectives.”
- “Put yourself in their shoes and think how they would feel about what you’re proposing. When doing this, try to make a map of who and what your idea will affect. Make sure your benefits involve money in some way because the bottom line is cost.”
- “When meeting with administrators and staff, do not assume that they share your viewpoint, or are as well-prepared.”
- “Do not add work to anyone else’s pile. People are resistant to change if they think it will have an adverse effect on them or their job.”
- “Hold at least one topic meeting with multiple persons and functions in attendance—especially when discussing future changes. This allows a group to take ownership of the work. And it makes the end result much more likely to be implemented.”
- “It was nice to be able to investigate something you are interested in rather than what the professor is interested in or what the program requires.”
- “I think that the whole project was a big success. For me, it was an excellent experience. It is the first time that I participated in the complete cycle of a project.”
- “The most important thing that faculty and staff could do in working on a campus sustainability initiative is to harness the students’ energy and enthusiasm by finding projects that are meaningful. Practical exercises that actually make a difference in the end will get much more interest than academic and theoretical assignments.”
- “At times, I just wanted someone to tell me what to do. But in retrospect, I see how valuable this whole course experience was. I learned how to think on my own and be resourceful.”

Students gained general knowledge and skills from work on their specific projects that would be transferable to other areas, and emphasized the value of learning from people.

- “The best part is that I can apply what I have learned to a range of areas, not just campuses.”
- “The most valuable things I learned were how to go after the information I wanted and how to convince others of my ideas.”
- “I learned how to develop potential means of meeting multiple objectives which may appear to be mutually conflicting.”
- “I learned a lot about all of the politics and the reality of actually trying to get this plan implemented.”
- “We learned that, more often than not, team members may think they are all working on the same topic, when in fact they each have a different concept. Create a working project title and abstract or outline that everyone can review and critique.”
- “People are your greatest sources of information in that they provide insight to barriers and insight about how to overcome these barriers.”
- “Establish good relationships with people. That’s a critical ingredient for success.”
- “The more valuable lessons for me came from having to interact with people in the business world to get the information I needed to complete this project.”
- “Talking to an informed individual for just a hour can often yield more information than culling through reports.”

Effectiveness of Problem-Based Learning for Student Learning

Students appreciated the opportunity to work on real-world projects and “make a difference.”

- “I think the most successful curriculums are the ones that give the opportunity to put in practice the concepts learned in the classroom.”
- “The class has been enjoyable and the opportunity to produce a product which will actually be used is refreshing from the usual class where your final product either gets filed or thrown away.”
- “The most valuable learning tool in this process for me was that I could apply techniques learned in school to a concrete project.”
- “I feel that a major success of my project was the feeling that I will be making a difference.”
- “I learned that my best ideas may not always work and it takes a lot of work to get them into place. I also realized that my purpose may just be to deliver the message of my idea to those in charge so they might take it into consideration in the future.”
- “Even though at times I felt as if I was making no progress, I learned a great deal. The frustration, the time constraints, and the lack of internal organization on campus provided glimpses of what one may encounter when working on similar projects in the real world.”

Students felt it was valuable to take “ownership” of the project and learning process, even though at times they faced challenges.

Lessons and Challenges for Problem-Based Learning Instruction

Problem-based learning can help students gain practical problem-solving experience, and can help students to implement projects that have benefit to the greater community. This paper has examined the potential contributions and strengths of PBL, but what about its challenges?

A first is finding the appropriate balance in instruction—between giving students freedom in project design and implementation, yet giving them enough feedback so they do not become too lost or too frustrated. Overall, students appear to appreciate their freedom in PBL (in the course evaluations conducted by the writer, fewer than 5% of the students wished they had more instructor guidance). Students may expect the instructor to provide direction, but the instructor should generally refrain from telling the students what to do. By allowing students the freedom and flexibility to pursue ideas, not all of which will be successful, students can develop independent problem-solving strategies, and learn how to identify and overcome barriers.

A second is helping students deal with those barriers. Students often need to go down dead ends to learn how to assess project

feasibility, and to determine whether a barrier is surmountable. Students are often surprised that good ideas face resistance or even rejection. But through this process, students can learn how to shape ideas and work with stakeholders to improve project acceptance. When students continue to run into barriers, and have not made progress on their projects, instructor intervention and assistance would be appropriate. Also helpful are group sessions during the class, where students share experiences and strategies for working within the university system.

A third is the design of suitable and feasible projects. In this course, students, rather than the instructor, designed their specific sustainability projects—even though the instructor provided general guidance, resources, and ideas. The instructor also invited campus officials to come to class, early in the term, to discuss campus operations and to offer suggestions for projects. Students were encouraged to come up with innovative ideas, but those ideas needed to mesh with needs, goals, and operations on campus. By working directly with campus staff, students could generate more suitable projects and gain institutional support. Students were also encouraged to investigate and document precedents at other universities, which can both demonstrate potential benefits and save time in project design.

A fourth is time. Implementation takes time, and although some of the projects were implemented during the course, some had just begun by the time the course had ended. Several students stayed with their projects, even after the course had ended, to make sure implementation moved forward. Students in later years of the course also picked up projects that were started in previous years, continuing the implementation process. The student was often the champion for the project, so once the champion was gone, the project could languish. Yet other projects flourished, which typically occurred when campus officials and staff took responsibility for the project. Also, at the end of each course, decision makers received copies of the students' project reports. Years later, even after students had graduated, decision makers were using the data, analyses, and recommendations from their reports. Students should be encouraged and reminded of this—that even if their projects do not take hold during that term, their projects still may be implemented.

A fifth is maintaining enthusiasm. The instructor needs to encourage students to not get discouraged. Students may spend quite a bit of time and effort at the beginning, trying to develop a project and gain support, while seeing few results. Changes come slowly, but they do come. In turn, students need to maintain enthusiasm and involvement with stakeholders, because those individuals can determine project success. In the sustainability course, students found most success when they could demonstrate project benefits, cost savings, precedents, and feasibility to campus officials and staff. Still, staff may be resistant to change operations, even when benefits seem clear, because of reasons beyond the students' direct control. Implementation often depends not only on top-level administration, but also on middle- and lower-level staff responsible for daily activities. Thus, students need to work directly with the individuals who would carry out the work, understand how their projects could assist them, and gain their support.

A sixth is course preparation, delivery, and evaluation. On the surface, it may appear that teaching a course based on PBL would be less time intensive than a lecture course (because, for instance, students take initiative in PBL). Yet from experience, a PBL course requires more time in preparation, administration, and evaluation. One reason is that helping students learn, and coaching them throughout a learning process, can require more effort

and attention than delivering information through a lecture. Similarly, evaluating a learning process can be more complex than testing knowledge through exams. In addition, part of the instructor's preparation for this sustainability course, each year, was working with campus administrators and staff, obtaining their support, and identifying suitable sustainability problems. This helped students to gain access to staff on campus, and to pursue promising projects. Further, the course and its projects helped to forge the academic and administrative functions of the university toward goals of sustainability.

Conclusion

This course experience has demonstrated not only a way to implement sustainability, but also a way to help students learn critical skills for problem solving and professional practice. Both sustainability and problem-based learning are relatively young within a university environment, and will require commitment and creativity. In this course, students were able to learn about sustainability through the problem-based learning process. In turn, problem-based learning provided a motivating context for learning and for acquiring practical problem-solving skills. Moreover, implementing sustainability through PBL allowed students to create projects that helped the campus community, and that bridged education and practice.

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References

- Albanese, M., and Mitchell, S. (1993). "Problem-based learning: A review of the literature on its outcomes and implementation issues." *Acad. Med.*, 68(1), 52–81.
- ASCE. (1996). "Code of ethics." (<http://www.asce.org>) (July 14, 2003).
- Barrows, H. S. (1991). "Cognitive apprenticeship (problem-based learning)." *Educacao Medica*, 2(2), 5–13.
- Barrows, H. S., and Bennett, K. (1982). "Experimental studies on the diagnostic (problem-solving) skill of the neurologist: Their implications for neurological training." *Arch. Neurol.*, 26, 273–277.
- Barrows, H. S., and Tamblyn, R. (1976). "An evaluation of problem-based learning in small groups using a simulated patient." *J. Med. Educ.*, 51, 52–54.
- Bransford, J. D., Sherwood, R. S., Vye, N. J., and Rieser, J. (1986). "Teaching thinking and problem-solving: Research foundations." *Am. Psychol.*, 41, 1078–1089.
- "Campus Ecology." (2002). (<http://www.nwf.org/campusecology/>) (July 14, 2003).
- Chameau, J. (1999). "Changing a mind-set, not just a problem-set: Sustainable technology in engineering programs." *Ethics in technology and social responsibilities, Proc., 1999 Engineering Deans Institute*, American Society for Engineering Education, Washington, D.C., 1–2.
- Chen, S. W., Cowdroy, R., Kingsland, A., and Ostwald, M., eds. (1994). *Reflections on problem based learning*, Wild & Woolley, Sydney, Australia.
- Collins, A., Brown, J. S., and Newman, S. E. (1989). "Cognitive apprenticeship: Teaching the crafts of reading, writing and mathematics."

- Knowing, learning and instruction*, Erlbaum, Hillsdale, N.J.
- “CO-operation programme in Europe for research on nature and industry through coordinated university studies.” (1994). *The Copernicus Charter*, Association of European Universities (CRE), Geneva, (<http://www.unesco.org/iau/sd/copernicus.html>).
- “Creating a common future: An action plan for universities. Follow-up to Halifax conference on university action for sustainable development.” (1991). *Halifax declaration*, Dalhousie University, Halifax, N.S., Canada, (<http://www.unesco.org/iau/sd/halifax.html>).
- Dutson, A. J., Todd, R. H., Magleby, S. P., and Sorensen, C. D. (1997). “A review of literature on teaching engineering design through project-oriented capstone courses.” *J. Eng. Educ.*, 86(1), 17–28.
- Eisenstaedt, R. (1990). “Problem-based learning: Cognitive retention and cohort traits of randomly selected participants and decliners.” *Acad. Med.*, 65(9), 511–512.
- Grigg, N. S. (1995). “Case method for teaching water-resources management.” *J. Prof. Issues Eng. Educ. Pract.*, 121(1), 30–36.
- Hendley, V. (1996). “Let problems drive the learning.” *ASEE Prism*, (Oct.), 30–36.
- “Higher education for sustainable development: Towards the world summit on sustainable development 2002.” (2001). *The Lüneburg declaration*, University of Lüneburg, Lüneburg, Germany, (http://www.ulsf.org/pub_declaration_spotvol51.htm).
- Johnson, P. A. (1999). “Problem-based, cooperative learning in the engineering classroom.” *J. Prof. Issues Eng. Educ. Pract.*, 125(1), 8–11.
- “Report of the United Nations conference on environment and development. Agenda 21, Chapter 36: Promoting education, public awareness, and training.” (1992). *Earth Summit Agreements*, (<http://www.un.org/esa/sustdev/documents/agenda21>).
- “Second Nature.” (2002). (<http://www.secondnature.org/>) (July 14, 2003).
- Shepherd, A., and Cosgriff, B. (1998). “Problem-based learning: A bridge between planning education and planning practice.” *J. Plan. Educ. Res.*, 17, 348–357.
- “The Swansea Declaration.” (1993). *Proc., Association of Commonwealth Universities’ 15th Quinquennial Conf.*, Swansea, Wales, U.K., (<http://www.unesco.org/iau/sd/swansea.html>).
- “The Talloires Declaration.” (1990). *Proc., Rep. and Declaration of the Presidents Conf.*, Tufts European Center, Talloires, France, (<http://www.unesco.org/iau/sd/talloires.html>).
- “Talloires Declaration institutional signatory list.” (2002). (http://www.ulsf.org/programs_talloires_signatories.html), (July 14, 2003).
- World Commission on Environment and Development (WCED). (1987). *Our common future*, Oxford University Press, New York.