AC 2007-920: INTRODUCING GLOBAL STEWARDSHIP TO ENGINEERING STUDENTS IN THE ARAB WORLD: THE PETROLEUM INSTITUTE'S STEPS PROGRAM FOCUSES ON SUSTAINABILITY

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Introducing Global Stewardship
To Engineering Students in the Arab World

Abstract

The STEPS Program (Strategies for Engineering Problem Solving) at the Petroleum Institute in Abu Dhabi introduces second-year student design teams to authentic engineering problem solving in the 21st century, with special emphasis on environmental and humanitarian issues facing engineers in both our local and broader global communities. The responsibilities of professional global engineers is stressed, including stewardship of our planet and its resources; the health, safety, and welfare of its inhabitants; engineering ethics, and intercultural communication. Student teams are mentored through an "experience" of engineering design methodology that incorporates creativity and inventiveness, technical thinking, decision-making, communications skills, and graphical demonstration.

The authors wanted to know what our Arab engineering students knew about sustainability. What were their perceptions about their responsibilities as engineers in the 21st century? Did they care? What's being done to foster awareness in this part of the world? Should environmental sustainability and global stewardship be at the core of our engineering design program? How could we introduce our students to humanitarian engineering? The answers to these questions along with data collected over two semesters are discussed in this paper.

The Fall 2006 STEPS II project involved the development of a Plastics Recycling Plan for the Petroleum Institute, with applications locally and globally. The project exposed students to the concept of reusable energy resources, the societal impact of recycling, environmental issues in engineering design, data collection and analysis, manufacturing processes, safety, modeling techniques, graphics communication as well as economic considerations. At the beginning of the course our students were uneducated about the seriousness of the plastics waste problem, relatively unaware of what was happening at the PI and in their community with regard to recycling, and doubtful that their personal efforts could produce an innovative and effective solution to a serious global dilemma. They had limited vision with regard to researching the topic, and were perplexed by the open-ended nature of the project. Throughout the semester the students gained confidence in their abilities as global citizens and engineers to help solve global problems facing their generation and future generations. They gradually learned how to think "outside the box" about possible solutions, and were excited about the possibility of real implementation of their ideas in the real world. The students "footwork" and visibility on campus and in the community at large was an important first step in building public awareness. Details of the experience the students went through in this project and their interactions with the community and the PI administration are discussed in this article.

The Petroleum Institute's STEPS Program: The Challenge of Translating Western Models into Effective Curricula in the Arab World

The STEPS Program (Strategies for Team-Based Engineering Problem-Solving) is designed to introduce engineering students at the Petroleum Institute to the theoretical and intellectual concepts as well as the practical methods used in engineering design in an integrated two

semester sequence at a very early stage in their engineering education. The STEPS program is unique to the United Arab Emirates, and is the first of its kind in the Arabian Gulf region. Teaching students the concepts and practices required to successfully tackle an open-ended engineering design problem is one of the more challenging jobs for any engineering educator but is especially challenging when the students belong to a culture vastly different from their Western counterparts in origin, experience, and custom. This paper describes the process of establishing a new curriculum for the STEPS program designed to address our students' needs to develop and exercise open-ended problem-solving skills, develop environmental sensitivity in engineering design, perform research that supports their decision-making, and work on interdisciplinary teams to tackle authentic problems in their local and global careers.

With funding from a consortium of major oil companies including The Abu Dhabi National Oil Company, Shell, BP, and JODCO and led by a team from the Colorado School of Mines, the Petroleum Institute was established in 2001. The goals of the Institute include educating United Arab Emirates nationals in fields of engineering (Chemical, Electrical, Mechanical, Petroleum and Petroleum Geosciences) that will serve the on-going needs of the oil and gas industry in the Gulf region. Experienced design faculty from the Colorado School of Mines were brought to the Petroleum Institute in the fall of 2003 to foster and implement a program modeled after the CSM EPICS Program (Engineering Practices Introductory Course Sequence).

As expected, many of the paradigms and expectations consistent with Western engineering design programs simply do not yield the same outcomes in the Arab culture. Our students have exhibited different strengths and weaknesses from their Western counterparts. For instance, our students' teamwork is enhanced by their heritage in the etiquette of Arab friendship, and oral presentations are strong and natural as a result of an oral cultural orientation. On the other hand, writing skills are naturally impeded by the fact that English is their second language. The design-and-build nature of the projects is often hindered by a lack of familiarity with tools and construction techniques. And so on. The authors are constantly adapting and modifying the course content and delivery methodologies in order to provide appropriate learning outcomes for our students.

Rationale for the Development of a New Model in STEPS II

Need to Develop Independent Open-ended Problem-solving Skills

As part of a two-semester sequence, STEPS I presents students with a well-defined design-and-build problem, and then leads them through the process using the concepts of guided design. The students are also given extensive instruction in the application of soft skills that are important to successful design, namely teamwork, project planning, and professional oral and written communications. Faculty advisors from engineering and communications programs serve the role as mentors for this project. During the first three years of the program's development, the STEPS II semester was characterized by a similar format to STEPS I, but with discipline specific design-and-build projects. After three years the program's new Coordinator, Dr. Jamal Ahmad, and Co-mentor, Dr. Suzanne Scott, looked for ways to improve STEPS II.

By the fall of 2006, the authors had identified some problem areas in our curriculum. The supposedly sequential two semesters were looking too much alike. Although our students were confronted with more technically challenging discipline specific projects in the second semester, they were still not thinking creatively about problem solutions. They had difficulty applying their scientific and mathematical skills to their project problems. Their research and data collection efforts rarely extended beyond the Internet. Students had difficulty seeing their ideas and project solutions as having any impact or effect on anyone beyond their team and the semester. Although by the end of STEPS I most of the students were willing to concede that engineering problems often have many possible solutions, in STEPS II they still needed a great deal of guidance thinking "outside the box." They wanted us to supply them with "the right answers." Kasim Randeree, a former lecturer in the College of Engineering at UAE University identified these characteristics. "Students in the UAE exhibit certain characteristics emerging from a variety of cultural and historical traditions, as well as from methodologies of education used at the pre-tertiary levels. These characteristics include expecting to be passive recipients of taught information and lack of independence in their approach to problem solving."[1]

We realized that we needed to come up with a model that helped our students develop their open-ended problem-solving skills. In STEPS I, the projects thus far had included design models, such as solar miniature race cars, Rube Goldberg machines, and an egg relocation device. The students expected STEPS II to follow the same somewhat formulaic design sequence within the same parameters. We decided that we needed to give the students a sense of more authentic, less-defined engineering problems. We needed a theme that would connect their thinking with their authentic community, not just with their teammates in the classroom.

Need to Teach Environmental Sensitivity in Engineering Design

Abu Dhabi and the larger UAE have experienced rapid growth in the past 3 decades. This oil-rich nation has experienced unprecedented economic and social development, especially in the urban areas of Abu Dhabi and Dubai. Along with rapid modernization, urban development, and 5% per year population increases, the cause for sustainable development and waste management has recently become vocalized in a few agencies and concerned groups. One agency taking up the cause of sustainable development, the Emirates Environmental Group (EEG), is a non-government group located in Dubai that encourages education for sustainable development, waste management, conservation, renewable energy production, and other issues, by targeting stakeholders such as the UAE government, businesses, communities and civil society groups.[2] While the EEG has spearheaded community projects in recycling, and has mounted awareness campaigns in the Dubai area, we were aware of little activity in our Abu Dhabi community.

We wondered what our students knew about sustainability. What were their perceptions about their responsibilities as engineers in the 21st century? Did they care? What's being done to foster awareness in this part of the world? Should environmental sustainability and global stewardship be at the core of our engineering design program? We wondered if focusing the STEPS II semester on environmental projects would serve several objectives. While giving the students authentic, challenging, open-ended problems through environmental projects we would also be exposing and educating our students to topics such as reusable energy resources, the

societal impact of recycling, environmental issues in engineering design, sustainable design, humanitarian design.

Connecting with the PI Community and Beyond

We then brainstormed the possibilities for improvement in different design skills. Would the students' research skills and data collection skills improve because of the authenticity and "concern" related to the issue? Could a model similar to Purdue University's EPICS Program (Engineering Practices in Community Service) serve our program? At Purdue, students operate in a service-learning context to fulfill the complementary needs of engineering undergraduates and the community. Purdue identifies the educational need for undergraduates as "facing a future in which they will need more than just a solid technical background to be successful…expected to interact effectively with people…work with people from many different disciplines" and the community need as "community service agencies, schools, local governments…face a future in which they must rely to a great extent upon technology for the delivery, coordination and improvement of the services they provide to the community. They thus need the help of people with strong technical backgrounds."[3] Does the idea of doing something creative to help solve serious problems affecting the students and future generations serve to motivate students in problem solving? Would caring and concern be engendered? How would an environmental theme support skills in graphics, professional interaction, and economics analysis?

Preparing our Students for Global Careers

Downey [4]et al., have identified the need to prepare our students for global careers. We felt that the environmental emphasis would give us an opportunity to introduce the topics of global stewardship, environmental ethics, engineering codes and the environment, the possibilities of working on international teams, intercultural communication and international problem-solving.

Russel C. Jones and Bethany S. Oberst have identified the need for reform in engineering education in the Arab world and all parts of the world, "as universities prepare graduates to enter the profession of engineering which has been transformed by massive technological developments and by globalization of all aspects of concern to engineers. Engineering educators in the Arab states region face particular challenges in addition to those facing similar educators in other parts of the world (including) tailoring programs to fill the needs of countries that are undergoing rapid modernization."[5]

Existing Models Teaching Sustainability in and Across Engineering Curricula

We found several Western models upon which to draw ideas for the new course emphasis. One of them, Michigan Tech's Sustainable Futures model, is intended to "foster education and research on sustainability for society, the environment, and economic/industrial development…so that …engineers can manage projects that reach across borders to raise the global standard of living and environmental quality." These engineers will acquire the capacity "to work on interdisciplinary projects (and) solve problems while working in foreign cultures."[6] Surely the future careers of our students will require them to work on interdisciplinary teams.

Charles D. Turner, Wen-Whai Li, and Alfredo Martinez of the University of Texas at El Paso describe their efforts at UTEP in "Developing Sustainable Engineering Across a College of Engineering" and point out that ABET … criteria require that all engineering students develop an understanding of the impact of engineering solutions in a global context as well as have knowledge of contemporary issues as they relate to engineering. They [7] state, "there is evidence that many engineering programs do not perform well in these areas. Sustainable Engineering initiatives can provide an avenue for improving performance." The College of Engineering at UTEP has developed a program for the teaching and learning of sustainable engineering concepts in each and every engineering program.

Probably one of the best-known efforts to incorporate sustainability/green design into engineering is the Carnegie Mellon program. Carnegie Mellon began a campus-wide Green Design Initiative in 1992 to promote environmentally conscious engineering.[8] Stanford Engineering's Civil and Environmental Engineering department has organized its teaching and research around the theme of sustainability, with efforts focused on five areas: water, urbanization, health, the Earth's life support systems, and buildings. [9]

Identifying Learning Objectives, Outcomes, and Format

After considering the nature and scope of the potential new model for STEPS II, we ultimately decided on the following statement of our learning objectives:

Through mentored class work, interdisciplinary teamwork, and campus and community interaction in an environmental project students will acquire the knowledge, awareness, and problem-solving skills needed to assimilate sustainable development factors when solving community and global engineering problems.

The following outcomes, along with their relationship to ABET criteria, are listed below.

At the end of STEPS II students should be able to demonstrate the following:

1. Demonstrate competency in oral and written technical communication (g).
2. Demonstrate understanding of the principles of project management (d).
3. Demonstrate effective teamwork (d).
4. Demonstrate ability to gather, analyze, and interpret data. (b)
5. Apply engineering design process to solve an open ended project (b,c,e).
6. Apply appropriate engineering practices to solve engineering problems (a,c)
7. Demonstrate competency in graphics applications (k).
8. Demonstrate awareness of professional ethics and codes of conduct (f)
9. Demonstrate awareness of global issues facing contemporary engineers, including environmental sensitivity and intercultural communication (h, j)

A syllabus was created that led the students through the iterative steps in the design process, with special emphasis on authentic interactive experiences (speakers, surveys, and interactive

demonstrations). Deliverables were added over the course of the semester to focus the students on various topics associated with the project.

The Project: A Plastics Recycling Plan for the Petroleum Institute

The chosen project for the fall of 2006 involved the development of a Plastics Recycling Plan for the Petroleum Institute. The student teams were required to address the issues of collecting, sorting, baling, transporting, cutting, processing, marketing and selling plastics recyclable waste. The project also emphasized building public awareness and involving all stakeholders in the process of reducing waste. Project requirements included innovation in the development of a plan (including a patent search), data collection and analysis concerning the magnitude of the problem, types of plastics used, the most common types found in the waste stream, and the proportion of these plastics that get recycled. The teams' research had to provide information on previous recycling efforts, governmental and non-governmental agencies involved, and existing recycling systems put in place. A feasibility study was required, along with a study of societal and environmental impact. Ultimately the teams were to discuss the feasibility of scaling up the plan for Abu Dhabi and the UAE.

Students' Expectations vs. Reality of Solving Real Engineering Problems

Our students were initially bewildered by the scope of the project and had difficulty brainstorming and envisioning problem solutions. They expected the course to follow the same formula as STEPS I, i.e., guided design with design-and-build models. "Show us the right answer and we'll build it." Isn't this what engineers did? This was their comfort zone. How could an environmental project be considered engineering? The project felt too ambiguous. The students resisted and procrastinated assignments that stretched their thinking. We realized that this sort of problem-solving was new to them.

In *Definition of the Engineering Method*, B.V. Coen states that "(a) primary goal of collegiate education is to help students mature into skilled and responsible open-ended problem solvers…(C)omplex real world problem solving requires a wealth of skills including technical competence, teamwork, self-education, creativity, and evaluation of alternatives. These all feed into the most important ability, being able to make reasoned decisions in an ambiguous situation and taking responsibility for the consequences."[10] We realized we had to push our students to experience and develop more complex thinking and evaluating skills. This was a struggle, but the experiential nature of the project helped to foster these skills in a natural progression. At other times we had to focus and direct their attention to a task at hand and demand its completion. Our students progressed (albeit uncomfortably) from the expectation of a previous paradigm with a single right answer to the seeming acknowledgement of uncertainties and unknowns in the project that required them to think differently.

Development of the Awareness Campaign

Very early in the semester the authors posed to the students the question of how to create awareness of the plastics waste problem on our campus and in our community. The students were quick to come up with a number of options, which were in turn asked of their survey participants. The idea of an "Awareness Campaign" was formed, based on survey results that

indicated that the respondents would be more receptive to an ongoing campaign, rather than sit and listen to lectures on the subject. The students' plans consisted of activities leading up to a "Plastics Recycling Awareness Day" which was held near the end of the semester. Brochures were created and posters were displayed to advertise the upcoming event. The students videotaped "mini-commercials" to attract attention to the plastics waste problem and to demonstrate possible solutions at the PI. On "Plastics Recycling Awareness Day" the students set up their displays and activities in a highly trafficked lobby on the campus. Their mini-commercials, as well as a video of "Plastics Man" demonstrating correct disposal of plastics, caught the attention of students. A popular activity was "Identify the Plastics," in which several types of plastics in various forms were displayed and the students were asked to see if they could identify them. But perhaps the most eye-catching exhibit was an enormous bag of plastic cups (approximately 4,000) that the students displayed as the amount of cups consumed at the PI in one day.

The Students' Plans: Two Teams and One Solution

Each of 2 five-member teams produced three conceptual solutions (plans) and applied a decision-making matrix to narrow down the solutions to one plan. The two teams produced solutions that addressed the main functions of a recycling plan, including collecting, sorting, baling and marketing the sorted plastic waste. The 2 teams' conceptual solutions emphasized specific functions over others. The Newland Team, for example, realized the importance of public participation in making the recycling plan successful, so they made building public awareness a key function in their plan. The other team, PIPRS (Petroleum Institute Plastics Recycling System) focused on reducing plastic waste by reusing it. They introduced an additional initial function of sorting the plastic waste according to its reusable condition. After selecting a concept solution, the teams further developed the selected concept into a detailed solution. This included breaking down the plan into subsystems and specifying the tasks, milestones and deliverables in each subsystem. Toward the end of the semester, the two teams produced detailed plans that had considerable overlap. The authors and the general services department (GSD) at the institute then advised the students to combine their efforts into one detailed plan. The two teams discussed the merger and agreed to combine efforts. In the process of combining the plans decisions had to be made on which subsystems of each plan should be eliminated. The final recycling plan that emerged was very similar to that of Newland Team and consisted of these subsystems: public awareness; collecting; sorting; baling; and marketing. In addition, a detailed economical feasibility analysis was completed for the plan.

Results of Student-administered PI-Wide Survey

From the beginning the students appropriately identified their PI peers and PI faculty as the most important stakeholders in the recycling effort. It was necessary to assess the stakeholder's awareness of the plastic waste problem at the PI and their willingness to take an active role in any recycling effort. For this purpose, the students developed and administered a survey. The survey was administered to 100 students and 50 faculty and staff (roughly 10% of the student population and 3% of the faculty and staff). After the survey, the students developed and conducted the awareness campaign, described in this article. Results from the survey were used to tailor the awareness campaign to the public need. For example, the survey indicated that the

majority of the participants had no idea of the size of the plastic waste problem at the PI. In the awareness campaign, the students created a visual effect demonstrating the number of plastic cups consumed every day at the PI. After the campaign, the students conducted a follow-up survey in ordered to assess the impact of the campaign on the public. The following are some results from the two surveys showing an increase in public awareness.

How many plastic cups are consumed at the PI every day?

12% guessed the correct number before the campaign.
59% guessed the correct number after the campaign.

Do you know the meaning of this symbol (a plastic recycling code is shown)?

47% said yes before the campaign.
75% recognized the symbol after the campaign.

Did the Plastics Recycling Awareness Campaign increase your awareness of the plastic waste problem at the PI?

87% of those who participated in the campaign answered yes.

Evaluation of the Fall 2006 "Experiment:"
A New Curriculum Model that Promotes Environmental Sensitivity in the Solution of Open-ended Problems in Engineering Design

Classroom Survey of our Students' Awareness of Environmental Issues

The authors conducted a survey of the students' awareness of recycling in general and their assessment of the impact of engineering practices on the environment. The first survey was conducted at the beginning of the semester, and a follow-up survey was conducted at the end of the semester. Results from the two surveys indicated that the students became more aware of the importance of engineering in solving societal and environmental problems, of their role as key players in solving existing problems, and of opportunities to improve their communities. The following are some results from the two surveys.

Does Abu Dhabi/UAE have an environmental agency that addresses recycling?

40% said yes at the beginning, while 100% said yes at the end.
90% of the students could name these agencies at the end of the semester.

How can you identify which plastics are recyclable?

50 – 70% of the students could identify plastics by their physical and mechanical properties at the end of the semester.
Only 10% could do the same at the beginning.

Does the PI recycle? If so, what does it recycle?

80% thought that the PI had a recycling activity at the beginning of the semester.
At the end of the semester 20% still believed that there is a recycling activity at the PI.

Some other opinions that were not benchmarked at the beginning of the semester may also indicate an increased awareness of the students' (or engineers') responsibility toward the environment. For example, 80% of the students believed that engineers are responsible for protecting the environment, 100% would consider protecting the environment a priority, and 60% would consider a career in the environment protection sector.

Concluding Thoughts

At the beginning of the semester our students were uneducated about the seriousness of the plastics waste problem, relatively unaware of what was happening at the PI and in their community with regard to recycling, and doubtful that their personal efforts could produce an innovative and effective solution to a serious global dilemma. Throughout the semester the students gained confidence in their abilities as global citizens and engineers to help solve problems facing their generation and future generations. The authors watched them progress from timid offerings of ideas and solutions they had found on the Internet to proudly presenting their own creative and appropriate solutions for the PI and their community. We observed their problem-solving skills progress from unenthusiastic and shortsighted attempts to find solutions, to confident and excited research, a positive desire to communicate and disseminate their ideas, and satisfaction in making a difference.

The students are excited about acting as advisors to the student teams in next semester's project, seeing their recycling plan implemented at the PI, and attending a conference to share their experience.

Credits

Although the Petroleum Institute had few efforts in recycling (paper only) we found that our PI community was not completely without concerned faculty and students with regard to the environment. Our point persons on the two PI campuses were Mr. Michael Ford (Women's Campus) and Mr. Yahya Al Rayyes, (Men's Campus). We also found the PI's Health, Safety and Environment Committee helpful and supportive in our efforts. Supporters included Dr. John Williams and Ms. Sireen Salman. Members of the PI's General Services Department, Mr. Mahmoud Shehada and Mr. Eliot Mengote, supplied needed answers to feasibility and implementation questions of any plan for the campus. We were also aware of an Environmental Club on campus, but that attendance and regularity of meetings was spotty. Faculty also supplied our students with the names of their contacts in business and industry. Speakers included Dr. Barry Posner, an expert on environmental economics, and Dr. Sulafudin Vukusic, chemistry professor, who gave an interactive presentation on identifying types of plastics.

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