Abstract #1402

Developing Sustainable Engineering Across a College of Engineering

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Abstract

ABET 2000 criteria require that all engineering students develop an understanding of the impact of engineering solutions in a global context as well as have a knowledge of contemporary issues as they relate to engineering. 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 the University of Texas at El Paso (UTEP) has developed a program for the teaching and learning of sustainable engineering concepts in each and every engineering program. The departments impacted are Civil, Computer Science, Electrical, Materials & Metallurgy, and Mechanical & Industrial Engineering. The program is the result of self-assessment at UTEP and has the support of a National Science Foundation initiative for Model Institutions of Excellence. The program is introducing sustainable engineering concepts in the teaching of specific existing courses and developing a sustainable engineering certification program. This paper reviews the need for sustainable engineering being taught across the curriculum and how that is being accomplished at UTEP.

I. Background

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. The initiative has formed partnerships with industry, foundations, and government agencies to develop research and education programs that encourage sustainable economic development. The initiative developed educational modules similar to those under development by the Sustainable/Green Engineering Initiative at UTEP.[1] Carnegie Mellon's environmental modules and case studies were developed with the support of a NSF project. They include modules on radioactive waste management, disposition of personal

computers, full cost accounting, reverse engineering for green design, rechargeable battery management and recycling, and life cycle assessment for asphalt versus concrete.

Virginia Tech has also implemented a green engineering program. Departments offer courses devoted to or containing significant green engineering content. As a result, regardless of discipline, Virginia Tech engineering students are being exposed to green engineering. Students begin considering environmental impact from the very start in the mandatory introduction to engineering course. Sample syllabi from the Virginia Tech Green Engineering Program[2,3] were used in the Sustainable Engineering packets for UTEP faculty. Virginia Tech students consider the cost of raw materials, manufacturing, transportation, use, recycling/reuse, and the associated cost of air, water, and solid waste generation. Students are urged to consider the overall economic and environmental cost of selecting each material for their specific application, and consider the difficult decision of which material is the ”best” choice for a consumer beverage container.

The ASEE Prism online web page is a source of sustainable engineering information as well.[4] Two approaches to incorporating sustainability perspectives into the engineering curriculum have evolved: 1) the center approach and 2) the whole curriculum approach. Each uses different strategies to achieve the same end: cultivating sensitivity to sustainability issues in students in all engineering disciplines.

Jennifer Bogo discusses sustainable engineering programs at Georgia Tech and Northern Arizona University. Georgia Tech is well known for its eco-options and has committed itself to taking the "elective" out of environmental citizenry by moving the concepts of sustainability into the core curriculum.[5] Another valuable source of information is the Second Nature Web page that contains sustainable information and syllabi for a wide variety of disciplines including engineering.[6]

The Department of Industrial Engineering of the University of Sonora, Mexico, has designed an educational model called Sustainable Cell in order to integrate the principles of Agenda 21 into their Industrial Engineering Department. This educational model is based on developing a proactive conscience towards ecological and social problems which ensure, in the future, responsible participation of these professionals at their workplaces.[7]

Engineers as well as the Heinz Family Foundation have recognized the need to incorporate sustainable/green principles into engineering education curriculum.[8,9,10] These papers and articles all reflect the need to integrate sustainability concepts across the engineering curriculum.

II. Genesis

In 1997, Virginia Tech (VT) and UTEP joined forces to submit a proposal to ENRON, a large energy corporation, for the development of a student and faculty exchange that would initiate a greening program in the Colleges of Engineering and Science at UTEP. UTEP would build on Virginia Tech’s existing green program and Virginia Tech students and faculty would have an experience at a culturally diverse institution that has been shaped by

environmental challenges and opportunities along the U.S.-Mexico border. The proposal was not funded but it sparked an interest in moving ahead with sustainable/green academic initiatives at UTEP. Funding for these initiatives was secured in the 1999 proposal to the National Science Foundation (NSF) for the second phase of UTEP's Model Institution of Excellence (MIE) program. Participants in the MIE program serve as models for improving the quantity and quality of science, engineering and mathematics (SEM) graduates and doctoral degree recipients. MIE is intended to be a catalyst for developing new approaches to higher education. As a result, the College of Engineering is developing a college-wide Sustainable/Green Engineering Initiative that will impact each of the five departments in each year of their four-year degree programs. The College of Science is implementing a Bachelor of Science degree in Environmental Science.

III. Strategy

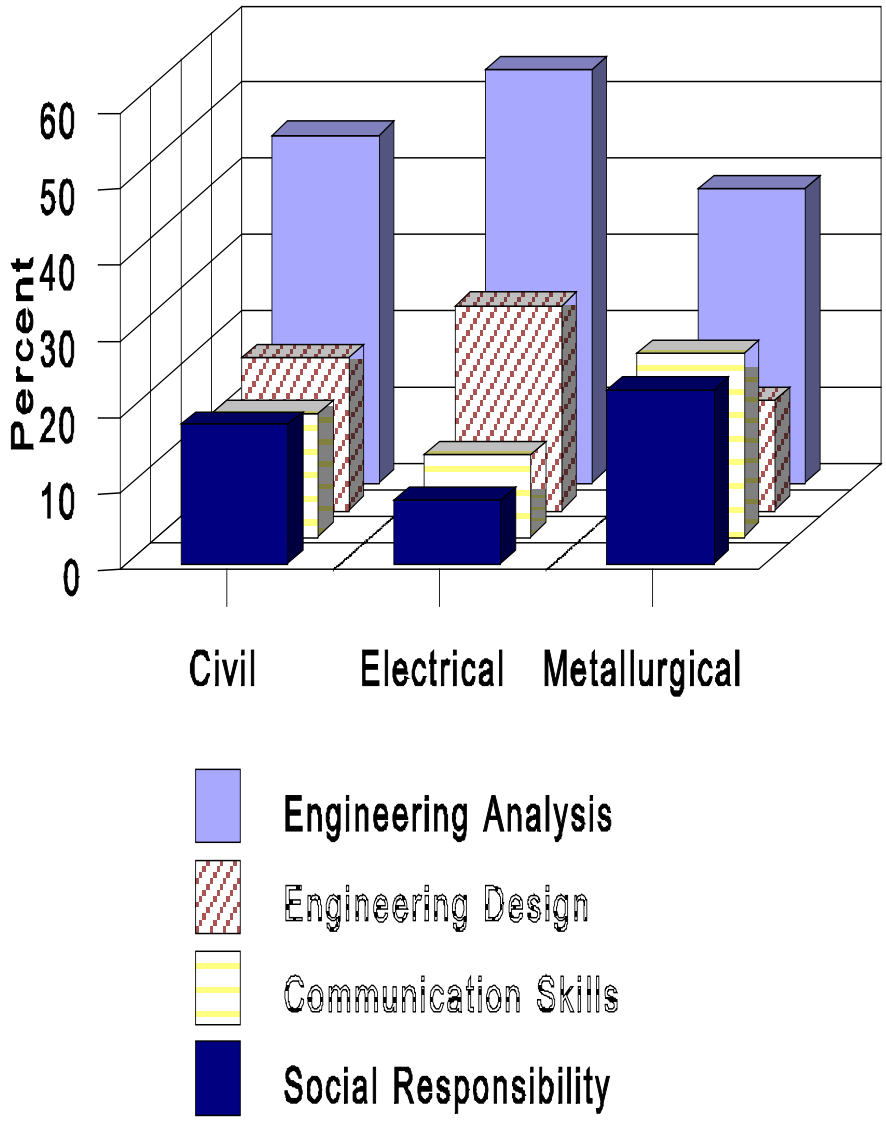
The challenge for sustainable/green engineering initiative is to instill sustainable concepts in all students in each and every year of their degree program. This can only be accomplished with the cooperation of the faculty. This is not an easy task. Faculties are hard pressed for time and do not readily accept additional workloads. Additionally, degree programs are already credit hour heavy and engineering colleges throughout the U.S. are cutting back degree credit hour requirements to meet state legislative restrictions. How, then, can an initiative such as sustainable/green engineering be successful?

A significant part of the answer arises out of the new Accreditation Board for Engineering and Technology (ABET) 2000 Criterion 3 "Program Outcomes and Assessment". Criterion 3 states, "Engineering programs must demonstrate that their graduates have" the ability/skills to meet criteria "a" through "k". Programs that incorporate sustainable/green engineering principles into the curriculum can have a direct and positive impact on three of these criteria. The sustainable/green engineering criteria are "h", "i" and "j" and they are listed below:

h. the broad education necessary to understand the impact of engineering solutions in a global and societal context,
i. a recognition of the need for, and an ability to engage in life-long learning,
j. a knowledge of contemporary issues.

Previous work by Turner is summarized in Figure 1.[11] The category in Figure 1 labeled as "Social Responsibility" contains criteria "h", "i" and "j". The results in this graph are

Figure1. Rational outcome classifcation by department



based on a self-evaluation of course content by UTEP faculty teaching the courses that make up the degree plans for each of the three departments. Clearly, the faculty believed they were not giving social responsibility criteria nearly as much emphasis as the more traditional design and analysis criteria. Including sustainable/green engineering elements into the curricula clearly address these three ABET criteria and can significantly strengthen engineering degree programs.

Faculty evaluated their programs using ABET criteria and recognized the need to modify their curriculum in order to address the weakness. A sustainable/green engineering committee was formed once the 1999 MIE Phase II funding proposal was approved. The need to make the committee representative of the College of Engineering was recognized by the authors who are both Civil Engineers. They recruited committee members from Electrical & Computer Engineering, Mechanical & Industrial Engineering, and Metallurgical & Materials Engineering Departments. A member from the Computer Science Department was not sought out because the committee believed this program was not directly impacted by the Sustainable/green engineering initiative. A presentation was made to the College of Engineering faculty as a single body during the Fall of 2000. Not only was the presentation well received by the faculty but near the end of the question and answer period the chairman of the Computer Science Department wanted to know why they had been left out. Today, all departments in the College of Engineering are represented on the committee.

The Plan

The college-wide committee began to meet regularly in the spring of 2000 to draft a plan for the sustainable/green engineering initiative. The initiative would promote the teaching and learning of sustainable engineering concepts in each and every engineering program in the College of Engineering through the implementation of the initiative. The word "sustainable engineering" is defined as engineering practice that provides solutions to today's problems so that future generations will have at least the same opportunities to live and prosper that the present generation enjoys. By going through a four-year college-wide sustainable/green engineering program, students would increase their understanding of 1) environmental issues and the global impact of engineering solutions; 2) the legal framework that guides engineering solutions and protects the environment and resources; and 3) the need for efficient and effective resource conservation and energy utilization. In the end, all engineering graduates will be introduced to the concept of sustainable engineering and practice those principles during their engineering careers. This surpasses the educational objectives set forth for ABET 2000 accreditation.

The impact of the program needs to be pervasive across the students' degree plans and minimal with respect to additional credit-hour requirement. The impact should be pervasive so that students will learn sustainable engineering concepts through the existing required courses in their own disciplines. The impact should be minimal on the students' credit-hour requirements. Students who elect to complete additional course work and an internship will earn sustainable/green engineering certifications. The incentive for the students to take additional coursework required by the program is the increased market

value over their peers in a competitive job market. Indeed, "many companies have found that they had significantly under estimated the price of end-of-controls, the importance of environmental functions to overall corporate health and the synergy between environmental and manufacturing technologies".[12]

The plan consists of three components:

- Introduction of sustainable engineering concepts in the teaching of specific existing courses;
- Development of a sustainable engineering certification program; and
- Identification and development of new courses for the certification program.

Table 1 shows a matrix of courses appropriate for introducing sustainable engineering concepts, as identified by the committee. We targeted required courses for insertion of materials related to sustainable engineering. The idea was to ensure that students would be continuously exposed to the concepts of sustainable engineering without interfering with their degree plans or discounting the contents of the courses. A packet containing sustainable engineering concept examples and modules has been distributed to the instructors of the targeted courses. Instructors of the targeted courses are expected to revise the contents of their courses to incorporate the sustainable engineering concepts in class examples, course projects, special topics, team projects, or homework. Each instructor is developing a “sustainable module” for their course which will be subsequently published on the project web-site.

We plan to institute a Sustainable Engineering Certification Program in the College of Engineering at UTEP. Two additional courses are tentatively identified as a) Environmental Regulations; and b) Life Cycle Analysis/Pollution Prevention. All Departments will add these two courses to their lists of acceptable elective courses.

Course Matrix

	CE	EE	IE	ME	MME	CS
Freshman	ENGR 1401	EE 1305	ENGR 1401	ENGR 1401	ENGR 1401	CS 1401
Sophomore	BE 2326 BE 2377 BE 2303 BE 2375	EE 2351	BE 2326 BE 2377 BE 2303 BE 2375	BE 2326 BE 2377 BE 2303 BE 2375	BE 2326 BE 2377 BE 2303 BE 2375	CS 1420
Junior	GEOL 3321 CE 3325 CE 3336 CE 4456	EE 3329 EE 3339	IE 3332	MECH 3376	MME 3306	CS 3320
Senior	CE 4340 CE 4348 CE 4388 (SD)[2]	EE 4220 (SD) EE 4230 (SD) (EE 3385)[3] (EE 4350) (EE 4395)	IE 4466 (SD) IE 4384	MECH 4466 (MECH 4395)	MME 4303 MME 4404 MME 4419 (SD) (MME 4309)	CS 4310 CS 4311

1. (SD): Senior Design course
2. ( ): Departmental elective courses

ENGR 1401 - Intro. to Engineering and Design
BE 2303 - Intro to Materials Science and Eng.
BE 2326 - Engineering Economy
BE 2375 - Introduction to Thermal-Fluid Science
BE 2377 - Electrical Circuits and Motors
CE 3325 - Environmental Engr. Fundamentals
CE 3336 - Civil Engineering Materials
CE 4340 - Transportation Engineering
CE 4348 - Geotechnical Engineering
CE 4456 - Hydraulic Engineering
CE 4388 - Senior Design
CS 1401 - Introduction to Computer Science
CS 1420 - Computer Programming for Scientists and Engineers
CS 3320 - Intro. To Computer Architecture
CS 4310 - Software Engineering I
CS 4311 - Software Engineering II
EE 1305 - Introduction to Electrical Engineering
EE 2351 - Networks I
EE 3329 - Electronic Devices
EE 3339 - Electronics I
EE 3385 - Energy Conversion
EE 4220 - Senior Project Laboratory
EE 4230 - Senior Project Lab II
EE 4350 - Integrated Circuits and Semiconductor Devices
EE 4395 - Special Topics in Electrical Engineering: Power Electronics
GEOL 3321 - Geology for Engineer
IE 3332 - Safety Engineering
IE 4384 - Industrial Layout
IE 4466 - Senior Design
MECH 3376 - Thermodynamics II
MECH 4466 - Senior Design
MECH 4395 - Special Topics in Mech. Engr.
MME 3306 - Rate Processes
MME 4303 - Metals Processing
MME 4309 - Corrosion
MME 4404 - Materials Processing
MME 4419 - Metallurgical & Materials Engr. Design

V. Will they come?

Initiating a new program is one issue. Whether students will enroll in the new program is another. The UTEP MIE program has an advisory board that reviews all issues related to the program. The board is composed of 16 industry and academic representatives from across the U.S. A central issue related to their support, which is critical, was the willingness of students to participate in the proposed program. Therefore, a questionnaire on sustainability/green engineering was prepared for incoming freshmen at UTEP. A copy of this questionnaire is shown in Table 2. Since freshmen are likely to have little knowledge concerning sustainability/green engineering, each group was given a 10-minute presentation by co-author Alfredo Martinez to provide the basis for and informed response. Responses to three of the questions follow.

Table 2: Sustainable Engineering Survey

SUSTAINABLE ENGINEERING SURVEY:
DEVELOPING ENGINEERING SOLUTIONS
TO BALANCE ENVIRONMENTAL AND ECONOMIC INTERESTS[1]

There is an increasing demand in industry, business and government for people trained in **sustainable engineering** to work in areas such as air quality, water and waste water treatment, minimization and disposal of hazardous wastes, conservation of natural resources, and the preservation and restoration of the environment. Industry, business and government agencies are increasingly interested in people who have training in developing solutions that find a balance between environmental and economic interest in all engineering fields.

Sustainable engineering provides solutions to today's problems so that future generations will have at least the same opportunities to live and prosper that the present generation enjoys. The University of Texas at El Paso (UTEP) is considering developing a sustainable engineering program and wishes to explore your interest in this type of program. To help UTEP develop quality programs in science, mathematics and engineering we would like to know about your interest in **sustainable engineering**. Thank you for your participation.

Instructions. Use a #2 pencil and bubble in your responses to the items.

Social Security Number

☐ 0	☐ 0	☐ 0	☐ 0	☐ 0	☐ 0	☐ 0	☐ 0	☐ 0
☐ 1	☐ 1	☐ 1	☐ 1	☐ 1	☐ 1	☐ 1	☐ 1	☐ 1
☐ 2	☐ 2	☐ 2	☐ 2	☐ 2	☐ 2	☐ 2	☐ 2	☐ 2
☐ 3	☐ 3	☐ 3	☐ 3	☐ 3	☐ 3	☐ 3	☐ 3	☐ 3
☐ 4	☐ 4	☐ 4	☐ 4	☐ 4	☐ 4	☐ 4	☐ 4	☐ 4
☐ 5	☐ 5	☐ 5	☐ 5	☐ 5	☐ 5	☐ 5	☐ 5	☐ 5
☐ 6	☐ 6	☐ 6	☐ 6	☐ 6	☐ 6	☐ 6	☐ 6	☐ 6
☐ 7	☐ 7	☐ 7	☐ 7	☐ 7	☐ 7	☐ 7	☐ 7	☐ 7
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Intended Major:

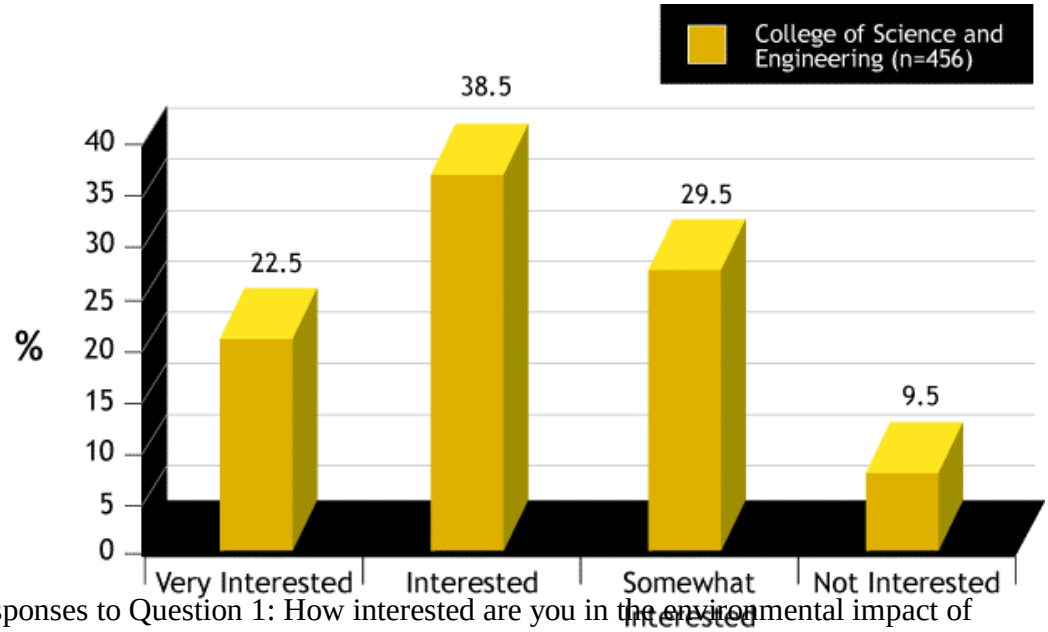
Engineering
- ☐ Civil Engineering
- ☐ Computer Engineering
- ☐ Computer Science
- ☐ Electrical Engineering
- ☐ Industrial Engineering
- ☐ Mechanical Engineering
- ☐ Metallurgical and Materials Engineering

Science
- ☐ Biological Sciences
- ☐ Chemistry
- ☐ Geological Sciences
- ☐ Mathematical Sciences
- ☐ Microbiological Sciences
- ☐ Physics

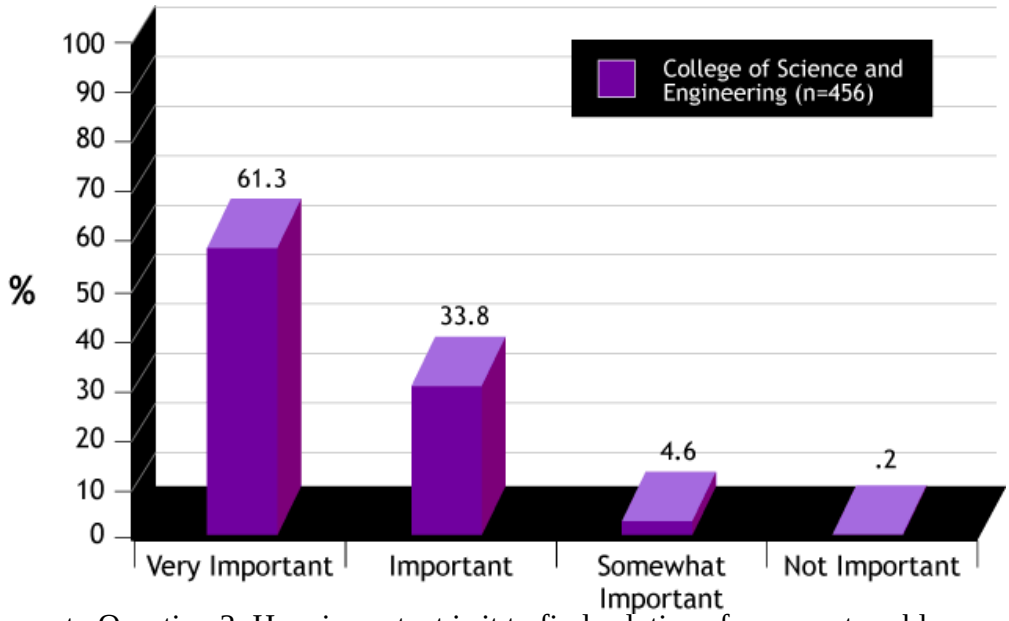
☐ Other: _____

1. How interested are you in the environmental impact of engineering practice?
   ☐ Very interested ☐ Interested ☐ Somewhat interested ☐ Not interested
2. How important is it to find solutions for current problems so that future generations will have the same opportunities to live and prosper that the present generation enjoys?
   ☐ Very important ☐ Important ☐ Somewhat important ☐ Not important
3. What is your degree of interest in learning how to develop solutions to engineering problems that take into account environmental factors?
   ☐ 100% ☐ 75% ☐ 50% ☐ 25% ☐ less than 25% ☐ Not sure
4. What is the likelihood that you would enroll in **engineering courses** that address sustainable issues in engineering?
   ☐ 100% ☐ 75% ☐ 50% ☐ 25% ☐ less than 25% ☐ Not sure
5. If courses in sustainable engineering were available, what is the likelihood that you would enroll in these courses?
   ☐ 100% ☐ 75% ☐ 50% ☐ 25% ☐ less than 25% ☐ Not sure
6. What is the likelihood that you would enroll in **courses outside of engineering** (such as courses in Environmental Science, Environmental Policy and Regulations)?
   ☐ 100% ☐ 75% ☐ 50% ☐ 25% ☐ less than 25% ☐ Not sure
7. What is the likelihood that you would participate in a summer job or research project that involves sustainable engineering?
   ☐ 100% ☐ 75% ☐ 50% ☐ 25% ☐ less than 25% ☐ Not sure
8. Additional Comments - What would make you want to take courses in sustainable engineering?

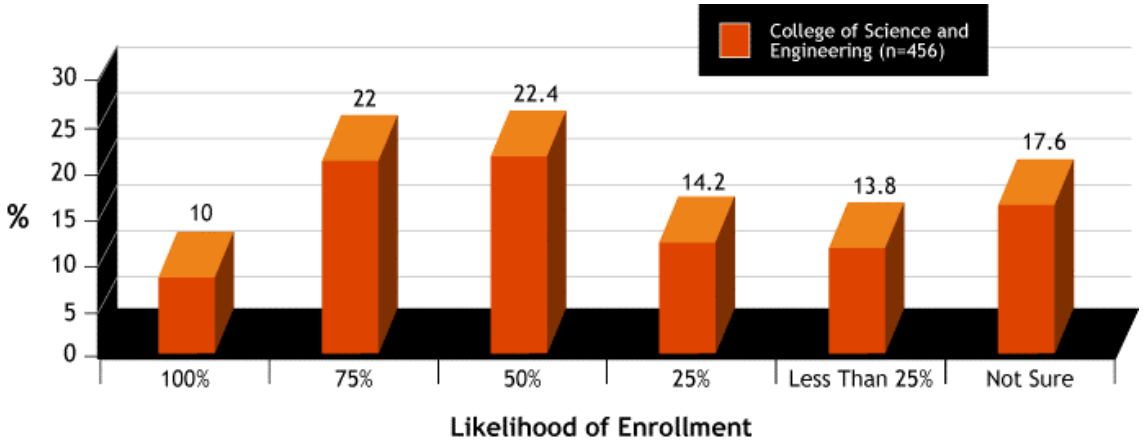
[1] Development of the questionnaire was supported by the National Science Foundation/Model Institutions for Excellence (HRD#9550502). If you have questions, call Dr. Connie Kubo Della-Piana, 747-5821 or e-mail connie@eng.utep.edu



Responses to Question 1: How interested are you in the environmental impact of engineering practice?



Responses to Question 2: How important is it to find solutions for current problems so that future generations will have the same opportunities to live and prosper that the present generation enjoys?



Responses to Question 5: If courses in Sustainable Engineering were available, what is the likelihood that you would enroll in these courses?

VI. Implementation

Implementation of the sustainable engineering initiative consists of three phases. The first phase of implementation was completed during the Fall 2000 semester. During this period of time, the committee identified all courses appropriate for incorporating sustainable engineering concepts, discussed the program with the Department chairs and individual instructors, received commitments from instructors, provided each instructor a guideline packet of class examples and relevant materials, and identified two new courses required for the certification program. The second phase of implementation began in the Spring of 2001. During the second phase of implementation, the committee assisted the instructors in preparing course syllabi and class examples/projects. Two members of the committee are assigned the task of developing course materials for use in the two required new courses. The committee also worked with the College of Engineering to make sure that the two new courses could be counted as technical electives or substituted for certain common courses. This phase of implementation was completed during the Spring 2001 semester.

The third phase of implementation will focus on the advertising of the sustainable engineering initiative and recruiting students for the certification program. The committee intends to secure a number of summer internships with UTEP's industrial partners, state and federal agencies, and national laboratories. All freshman courses revised under the sustainable/green engineering initiative will be offered in Fall 2001 and the two new courses will be offered to upper-division students in Spring 2002.

VII. Conclusions

Sustainable/green engineering has being embraced by many groups in the industrial sector of the economy. This influence is reflected in the ABET 2000 "a-k" criteria, particularly criteria "h", "i" and "k". Now that engineering colleges in universities across the country are addressing ABET 2000 requirements, deficiencies in meeting these criteria are becoming evident. Sustainable/green engineering has the potential to provide a balanced performance in meeting the ABET 2000 "a-k" criteria. The opportunity to make these changes has presented itself at UTEP. The primary goal of integrating sustainable/green engineering concepts into every degree plan and reinforcing them in each year of the undergraduate program is being implemented. The secondary goal of placing a sustainable/green certification program in place is still being developed. Students enthusiastically embrace these concepts and faculties seem willing to implement them. Engineering is responding to societal changes and this reflects the strength and flexibility of the system.

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