Freshman Design Experience: Solar Powered Irrigation System for a Remote farm

Oguz A. Soysal
Frostburg State University

Abstract

"Introduction to Engineering Design" is offered at Frostburg State University for freshman students interested in engineering major. The main objective of this freshman design course is to introduce basic design concepts and to motivate the students towards their majors. The selected design topic in Fall-1999 was an automatic irrigation system powered by solar energy. During the design and prototype development process, students learned energy conversion principles, discussed various issues related to power generation, and gained hands-on experience on technical drawings and workshop activities. The paper discusses the educational impacts of the freshman design course on the motivation and professional orientation of students.

I. Introduction

Frostburg State University (FSU) started electrical and mechanical engineering programs in fall 1997 in collaboration with University of Maryland College Park (UMCP). Students enrolled in the FSU/UMCP Collaborative Engineering Program take all science, math, general education, basic engineering and design courses on campus from resident faculty. Upper level engineering courses are offered from UMCP over distance. The main objective of the Collaborative Engineering Education is to provide students located on a remote campus the opportunity to access advanced engineering courses of a metropolitan university[1]. The developed model is an economical way to extend engineering education possibility to remote areas without loosing experimentation and design activities and student-instructor interactions, which are essential for technical education.

Although the program is based on delivery of upper level engineering courses over distance (via ITV), active learning is considered as one of the major characteristics of the curriculum. As a constituent institution of the ECSEL (Engineering Coalition of Schools for Excellence in Education and Leadership) program, University of Maryland has developed the concept of learning by design to "renovate undergraduate engineering education through the infusion of design experiences across the curriculum and to increase the diversity of the profession" as the "Year 9 Report for ECSEL[2,3]" states. This approach yielded the idea of introducing engineering design at the freshman level, starting the first day students enter the school of engineering[4,5,6].

At FSU, "Introduction to Engineering Design" is the first engineering course in both electrical and mechanical engineering collaborative programs. The course is modeled on its counterpart at UMCP, and coordinated by resident faculty on FSU campus. The objective of this course is to motivate the students towards an engineering career by introducing basic design concepts, communication and survival skills through a practical problem. Students learn characteristics and different phases of a design process, such as brainstorming, refining the ideas, prototype development, and product evaluation. Professional communication skills including technical drawings, report writing, data analysis by using spreadsheets, and preparation of presentations are learned and applied in different phases of the product development. Students work in teams throughout the product development process.

The selected theme for fall 1999 was a "Solar Powered Irrigation System for a Remote farm." The paper will present the experience gained throughout the course from the engineering education perspective.

II. Student Enrollment and Distribution

Introduction to Engineering Design (ENES 100) has been offered as a required course for all engineering students on the FSU campus since 1997, when the collaborative engineering programs started. In 1999-fall semester, 41 students are enrolled to ENES 100 offered in three sections. One of these sections reserved to a "Learning Community" class, where all students take a particularly selected set of interrelated courses. Data and observations presented in this paper are collected in the other two sections, totaling 27 students.

At FSU, students usually choose their majors by the end of the first year (or even later). Most of the enrolled students have not yet declared a major however; they are primarily interested in engineering. Some upper level students from other disciplines (especially from physics and computer science) also take this course as elective to become familiar with engineering design concepts and develop their hands-on skills. Fig. 1 illustrates the distribution of students interested in engineering and other majors.

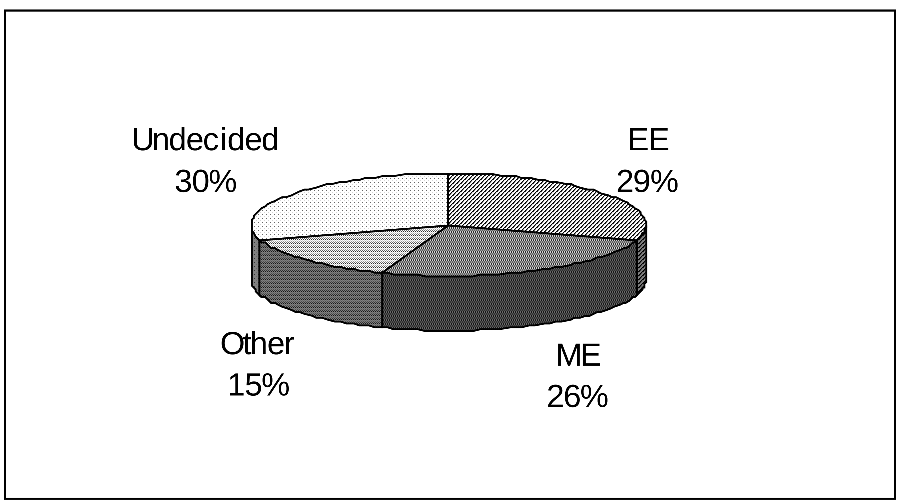


Figure 1 Areas of interest of students enrolled in "Introduction to Engineering Design."

A class profile survey on career plans of engineering students shows the distribution illustrated in Figure 2. At the freshman level, the majority of the students wish to work in R&D and production areas. The diagram gives also an idea about the expectations of students from the education they have just started.

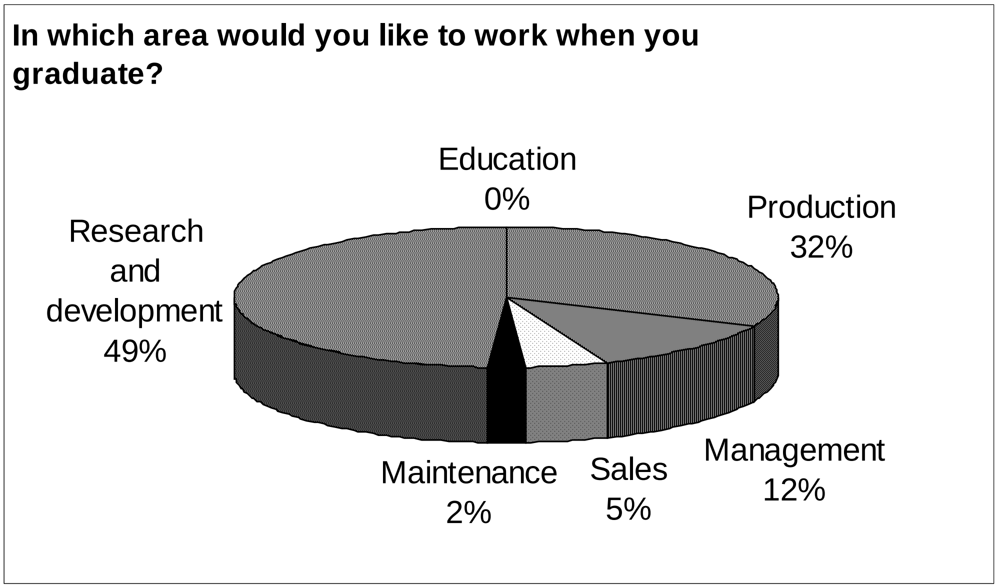


Figure 2 Distribution of engineering students by their career plans.

III. Course Outline

The course is offered to two sections with 12 and 15 students. Each section meets twice a week. One of the class meetings is one hour of lecture session. The other class meeting is for laboratory and workshop activities, and lasts two hours. The outline of the course is shown in Table-I.

During the first two weeks, the concept of "engineering design" is introduced to the students. Various aspects of a design problem and phases of the product development process are discussed. "Idea triggering method" described by Horenstein[7] is explained, and some brainstorming exercises on simple design problems are performed in the class.

In the following 5 weeks, work, energy, power, energy conversion, and power generation concepts are introduced in lecture hours. During this period, students discussed various issues related to energy resources, power production from conventional and alternative sources. In the lab session, they learned AutoCAD LT software to draw three view machine parts. They also practiced with MS Excel® and Power Point® to develop their technical communication skills.

During the rest of the semester students worked on their design and built a reduced scale prototype of the system. The classroom environment and activities are particularly organized to stimulate teamwork. Students developed important communication skills both in team meetings and design presentations.

Table-I Outline of "Introduction to Engineering Design."

Week	Lecture sessions	Lab and Workshop sessions
1	Engineering design and product development	Survey tests
2	Creative thinking and brainstorming exercises	Introduction to AutoCAD LT
3	Work, energy, power, efficiency	Three view drawings of a machine part
4	Basic principles of water pumps	Dimensioning
5	Midterm Exam 1	Team work: brain storming on the design project
6	Principles of energy conversion, power generation	Data analysis using MS Excel
7	Electric power generation using solar cells	Team work: Preparing presentation slides using MS Power Point
8	Preliminary design presentation	Team work: Revision of the design
9	Development teams and product development process	Team work: Drawings of prototype parts
10	Technical report writing	Team work: Drawings of prototype parts (cont.)
11	Midterm Exam 2	Team work: Making the parts
12	Product testing and feedback	Team work: Making the parts (cont.)
13	Basics of the engineering profession	Team work: Assembling the prototype
14	Team work: Testing	Team work: Revision of the design
15	Review and discussion	Final Presentation

III. Theme of the Design Project

The design topic, requirements, and restrictions are briefly stated to the students in the third week as shown below:

Design a water pumping system for a remote farm, and make a reduced scale prototype. The requirements are below:

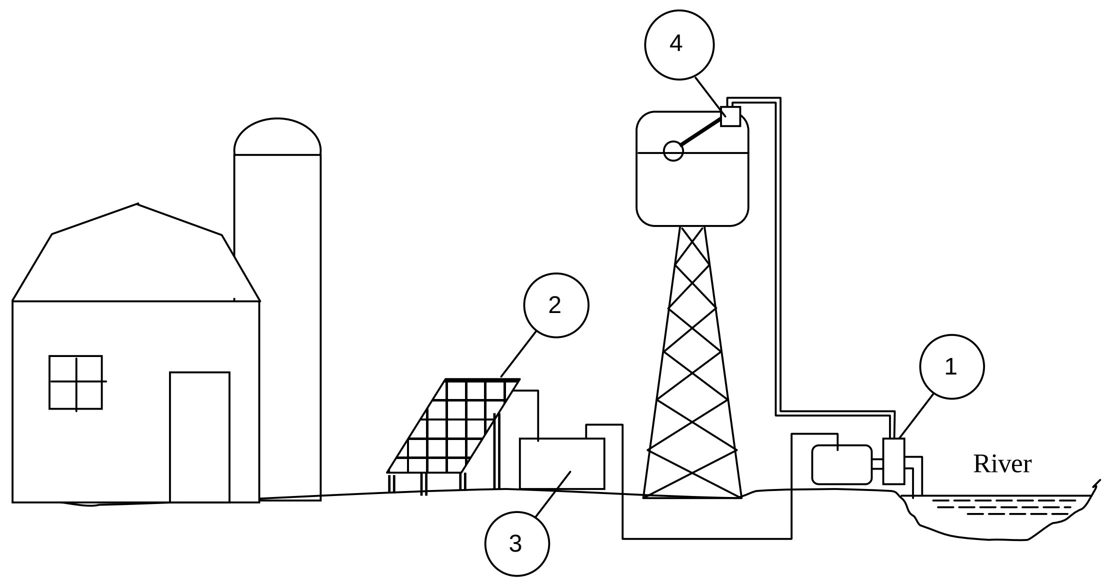
- *The system will provide 200 Gallons of water per day for plant irrigation and general usage in the farm.*
- *The primary water source is a river, where the flow rate is not regular. To have a reliable water supply we want to store at least 200 Gallons of water in a tank.*
- *No electric power is available near the river to energize the pumping system.*
- *We want to use solar energy to produce the required electric supply for the system.*
- *The system will operate automatically, with minimum manual operations.*

A reduced scale model of the system will be made and tested.

The rationale for this particular design theme is explained below.

- It is a multidisciplinary problem that combines both mechanical and electrical engineering
- Material and components are available for reasonable prices at hardware stores
- Photovoltaic energy conversion is original and interesting for the students
- Invokes the idea of using alternative energy sources to generate electric power
- Justification for the practical needs and usage is apparent
- The system consists of several units interacting with each other
- It is suitable for a hierarchical team work
- It is an open ended problem with multiple alternative solutions

Figure 3 illustrates the general layout of the irrigation system supplied by solar energy, to be developed for a remote farm.



1. Motor and pump
2. Solar cell panel
3. Electronic control and battery unit
4. Water level control

Figure 3 Layout of the solar powered irrigation system for a remote farm.

Teamwork is one of the important components of the design course. In order to form well-balanced and functional teams, student interests, abilities, strengths, and weaknesses are determined by a "class profile survey" at the beginning of the semester. In each section, three teams are formed to work separately to design and develop the following parts of the system:

Team A: Water pump
Team B: Photovoltaic power supply and motor
Team C: Tank and control system

By the end of the semester, each section is supposed to make a reduced scale model of the irrigation system that meets the stated requirements and restrictions.

IV. Generated Design Ideas

Students in two different sections of the class worked separately to generate design ideas and make a prototype. The highlights of their designs are summarized below:

- Both sections decided to use a centrifugal pump, but size and impeller designs were different. Both sections concerned about water leakage from the pump. They both decided to immerse the pump in water, and keep the motor out of the water. One section decided to make a cage structure that will keep the motor above water surface, and a long shaft between the motor and the pump. The other section decided to make a motor-pump assembly floating on the water surface, the pump being immersed.
- Sections selected different types of solar cells by browsing the Internet. One section purchased 12 V solar cell that provides maximum 50 mA. The other section purchased 9 V solar cell with 50 mA maximum current.
- Both sections saw the need to for energy storage. One section purchased Ni-Cd battery, the other section purchased a lead battery.
- Both sections expected the solar cell would run the motor directly. They were surprised to see that even at full sunlight conditions the solar cell could not provide enough power to run the motor. After measuring the terminal voltage and current at different light conditions, they understood the importance of the energy storage.
- Teams working on the control system generated several ideas to control the water level. Some of these ideas were based on using a mercury switch, taking advantage of the electrical conductivity of water, optical sensor, etc. Finally they both decided to make a simple contact, which is turned on or off by means of a float.

V. Student Motivation

The introduction to engineering design course has a very important impact on student motivation and orientation. A student taking this course faces for the first time a practical design problem. Usually in high school science and math classes they deal with problems which have single correct solution. In general , the solution of these problems does not involve the cost as a parameter. In other words, they learn how to solve physics problems by using a basic unit system, such as MKSA. From the first day of their engineering education we try to highlight the importance of the cost in engineering problems, by introducing a currency component and modifying the unit system as "MKSA$." The last element is without doubt the most significant characteristic of a design problem.

To emphasize the importance of the cost, the students are requested finance the product development costs themselves. Each team prepared an itemized part list with estimated prices. They formed a fund, and assigned a team member to keep track of the expanses.

Another characteristic of a design problem is feedback loops between different phases. After brainstorming and completing the design, teams make a preliminary design presentation. During the presentation they discuss possible problems that might arise due to the interaction between parts made by different teams. Students gain further experience in moving back and forth through the prototype development process to modify their design to correct mistakes or improve the characteristics. Particularly during the last weeks, they feel the frustration of seeing that the actual system does not work as they expected. They develop their own methods to deal with this frustration and discover survival skills to correct mistakes and find practical solutions to make the system work.

The design course includes also a self appraisal process. After finishing the design, each team make a "preliminary design presentation." At this presentation students fills appraisal forms to evaluate their team and the other teams. The form to evaluate their own team contains questions about the effectiveness of the team meetings, and contribution of team members. The form used to evaluate other teams include questions on the quality of design and presentation.

Figure 4 A group of ENES 100 students and the instructor at the final design presentation

VI. Conclusion

Introduction to engineering design at the freshman level stimulates the curiosity and creativity of the students. It creates an active learning environment, so the students understand the basic concepts by active experimentation. Students develop technical communication skills such as computer aided drawing, use of word processing, spreadsheet, and presentation software; gain hands on experience in workshop activities. Throughout the course, they experience different phases of product development. In the same time, the course gives a general idea about different aspects of the engineering profession and helps students test their abilities, strengths, and weaknesses, in order to make the correct decision in selecting their major.

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Oguz A. Soysal received the B.Sc., M.Sc., and Ph.D. degrees from Istanbul Technical University, Turkey. In 1983, he joined ABB-ESAS Power Transformer Company (Istanbul, Turkey) as an R&D engineer. From 1986 to 1993, he worked for Black-Sea Technical University, Turkey, as Assistant and Associate Professor. In 1987, he visited The Ohio State University (OSU) as a Post Doctoral Scholar, and in 1991-1992, he spent a sabbatical leave at the University of Toronto. From 1993 to 1997, he has been with Istanbul University, Turkey, and Bucknell University, Lewisburg, PA, USA. At present, Dr. Soysal is with Frostburg State University, MD, USA.