Workshop: Hands-On Design Activities for Introduction to Engineering Courses to Accommodate Students of Varying Backgrounds

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Summary

In this workshop, participants will be introduced to three different design projects specifically intended for introductory engineering courses that include students with a wide range of prior exposure to engineering. The design projects engage students with a tentative interest in engineering and limited prior hands-on experience, while also challenging the skills and creativity of those students already committed to an engineering career. This workshop will allow participants to learn about and carry out some of these hands-on projects for themselves. At the workshop, participants will be provided with materials that they can take with them back to their home institutions.

The efforts to increase diversity in engineering have resulted in a challenge for introduction to engineering classes of supporting students with a wide range of prior exposure and degree of interest in engineering. Introductory courses now include some students, possibly from groups currently underrepresented in the engineering profession, that have been successfully recruited to consider engineering as a career. These students may have only a tentative interest in engineering and limited prior experience in hands-on activities. Simultaneously, introduction to engineering courses include students with a well-established interest in an engineering career and a considerable background in design and fabrication work. Successful introduction to engineering courses must engage and support both types of students. Design projects in these courses must meet several criteria that are challenging for the instructor. They should appeal to students' intrinsic interests; support hands-on skills development; be completed during a typical laboratory period; not require specialized equipment; be carried out in a range of physical spaces; and illustrate general engineering principles beyond the details of the project. We have developed and tested several projects that meet these requirements including a solar-powered phone charger, an electrodynamic loudspeaker, and a suite of microcontroller-based activities with a biomedical project.

The series of projects include scaffolding to support novices, while also containing relevant open-ended design elements to challenge the creativity of the more experienced. Students show increases in confidence and interest along with decreases in anxiety concerning engineering. Females attained par with male students in design self-confidence. This workshop will allow participants to learn about and carry out these hands-on projects for themselves.

Schedule

0 – 15 minutes: Introduction
15-45 minutes: Design Activity 1
45-75 minutes: Design Activity 2
75-90 minutes: Intro to Activity 3 and Discussion
(Attendance limited to maximum of 25 due to availability of materials)

Significance of the Work

Instructors of Introduction to Engineering courses are challenged to include hands-on design activities in these courses. Generally, these design activities must be simultaneously accessible to students with tentative interest in engineering and challenge student with an established commitment to engineering and possibly considerable prior exposure to engineering design activities in an educational setting. The project must support a range of skill level and prior exposure to hands-on work and also reflect actual engineering design practice. The design problems should be both open-ended and "doable" and have a range of potentially. acceptable solutions.

Nature of the Projects

To address these needs, we have created what we have termed: Domain-Situated Design Projects. A technological domain is created around the project. The project is then embedded in an appropriate domain.

Each activity includes a domain familiarization project or projects. The purpose is to allow all students to gain the familiarity needed to carry out a design project. In this way those students without significant prior hands-on experience are not disadvantaged compared to other students. The familiarization project is followed by an open-ended design problem within the domain. A grade incentive is given for innovation beyond the essential requirements.

Project 1: Solar-Powered Power Bank Charger

The ultimate goal of this activity is the design of a photovoltaic charger for a small power bank. In the initial familiarization activity students assemble and test a photovoltaic powered device that can recharge AA batteries. This provides familiarization with the hands-on procedures, materials, and measurements involved in this type of system.

The familiarization is followed by an open-ended design challenge to design a PV system to recharge power bank or batteries. Students are allowed to either keep or recycle the completed system after testing to establish the design criteria have been meet. The students are provided with a catalog of available components that provide useful functions for the intended systems. They are able to create and assemble their design by "purchasing" components up to a fixed maximum budget. Figure 1 is an example of a student's final design.

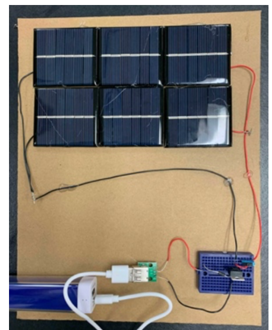

Figure 1: Example of student-designed PV power bank charger.

Project 2: Microcontroller-based Infusion Pump

The goal of this activity is for students to design a simplified microcontroller-based infusion pump similar to the type commonly used in hospital settings. The familiarization activities consist of two laboratory periods in which students learn the basics of coding and hardware implementation using the Arduino microcontroller. Familiarization projects include use of input sensors such as toggles switches, potentiometers, light-sensors, and temperature sensors. Familiarization with output devices include LEDs, LCD displays, audio alarm buzzers, electric heaters, and motors. Relevant coding for using these input and output devices in learned (Figure 2).

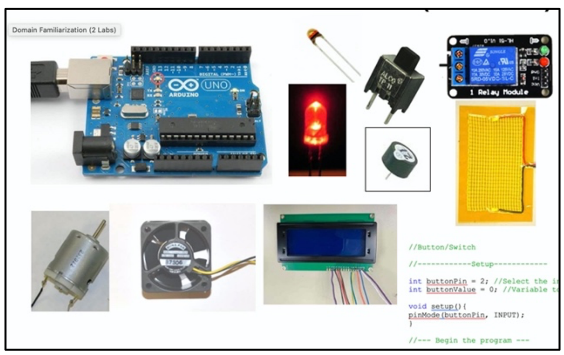

Figure 2: Microcontroller domain-familiarization components.

For the open-ended design project students are asked to design a simplified infusion pump. The system must meet minimum requirements for pumping of an intravenous fluid as a specific rate and alerting the caregiver appropriately as to the status of the system. Additional incentive offered for design capabilities beyond the minimum using the components available from the familiarization activities. The systems are tested in lab using a mannikin or similar artificial "patient."

Project 3: Electrodynamic Loudspeaker Design
In this design project students design and fabricate a working electrodynamic loudspeaker from simple materials. The speaker can be connected to their computer or other source of an audio signal or music. For familiarization students construct an electromagnet. This provides familiarity with use of magnet wire, soldering, glue guns, and hand tools.

The open-ended design project requires students to design and construct a working electrodynamic loudspeaker from simple materials and some provided standard components. The provided components are appropriate gauge coil wire, a neodymium magnet, and a standard connector. Students create their own design for the speaker cone, cone support, coil form, surround, and base. A collection of simple materials is made available including various sizes of paper cups and plates, construction paper, cardboard, foam core, craft sticks, wire, and Styrofoam containers.

Figure 3: A working electrodynamic loudspeaker designed by students.

Results: Incorporation of these and other similar projects in our Introduction to Engineering course is associated with improvements student perceptions as measured using the Engineering Design Self-Efficacy instrument [1]. Results are summarized in Figure 4. Students show increases in confidence and the belief that they can be successful in engineering. Of particular note, women start with lower confidence than men but later reach the same level of engineering self-confidence as male students. Anxiety was found to decrease for both males and females.

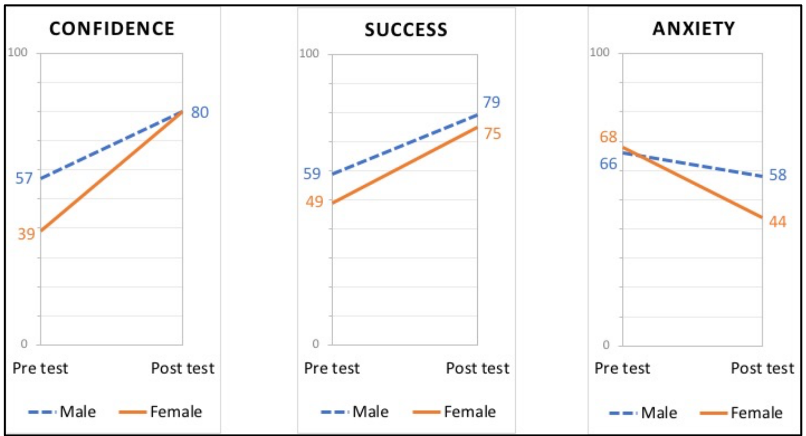

Figure 4: Increases in engineering students' confidence and success and decrease in anxiety as measured using [1].

What Participants will Gain: In this 90-minute interactive session participants will carry out some of the essential steps in conducting these hands-on design projects. Materials will be provided for those interested so they can try some of these activities with their own students. The workshop organizers will be available via teleconference after the FYEE Conference to help instructors that would like to try the projects in their own classes.

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References:

1. Carberry, A.R, Hee Sun Lee, Matthew W. Ohland, Measuring engineering design self-efficacy, *Journal of Engineering Education*, V99n1, January 2010.