AC 2011-556: INTEGRATED STEM-BASED PROJECTS TO INSPIRE K-12 STUDENTS TO PURSUE UNDERGRADUATE DEGREE PROGRAMS IN ELECTRICAL AND COMPUTER ENGINEERING

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Integrated STEM-based Projects to Inspire K-12 Students to Pursue Undergraduate Degree Programs in Electrical and Computer Engineering

Introduction

This paper discusses how integrated electrical and computer engineering (ECE) projects with science, technology, engineering, and mathematics (STEM) components can inspire the K-12 students to pursue the undergraduate degree programs in ECE. These projects are presented through Engineering day and Electrical and Computer Engineering (ECE) Day events hosted at the undergraduate baccalaureate degree institution by the ECE department with ABET accreditation.

In the fall of 2009, the ECE department at our university organized two Engineering Day events in its system integration laboratory [1]. The laboratory accommodated nearly 105 high school students in six hour-long sessions with up to 20 students in each session. During each session, the students worked on a traffic signal control circuit. The project activities comprised the following steps (1) complete the design of the circuit (2) test the operation of the circuit. Two ECE faculty members and sixteen ECE students currently enrolled in the undergraduate ECE program coordinated the project activities. The students followed step-wise instructions to assemble and test the circuit. Each student completed a survey at the end of the session. The survey consisted of two sections. The quantitative section asked the student to grade (on a scale from 0 to 5; 0 - *least effective* and 5 - *very effective*) the effectiveness of the project activity to stimulate their interest in ECE system design. The qualitative section asked the student to comment on the overall experience.

Due to the unreliable nature of breadboard-based systems and the students limited skills with wiring, the concepts of integrated product design and the relationship between scientific theory and engineering design principles and practice were not delivered as effectively as had been envisioned. In order to overcome this shortcoming and to demonstrate the integrated project design and development process to the K-12 students, a printed circuit board (PCB) was designed for the traffic signal control circuit. In the spring of 2010, the ECE department hosted the ECE Day event in their Systems Integration laboratory in which 50 high school students engaged in the hour-long session to assemble and test the PCB-based circuit. This project activity has demonstrated that (a) the K-12 student is more actively engaged in the integrated project, (b) gains the system level appreciation of the design problem, and (c) has the confidence to complete the project.

The ECE department plans to host ECE day events with STEM-based integrated project activities in ECE to (a) encourage K-12 students to consider careers in ECE, (b) strengthen the undergraduate enrollment in ECE, and (c) link the undergraduate ECE program with the K-12 STEM curriculum.

This paper is organized as follows. Section 2 provides a description of the experimental set-up, the laboratory activities, and the execution of the STEM-based ECE project. Section 3 summarizes and compares the assessment of learning outcomes based on the on-line survey completed by the students for both breadboard test and PCB-based test. Section 4 outlines the conclusions.

Section 2: STEM-based ECE Project

The broad objectives of the STEM-based ECE project chosen for the Engineering Day event were to (a) complete the design, and (b) test the operation of the circuit to control the operation of a three-light traffic signal.

Project Description

The project comprises the timer and the counter circuit to operate the red, yellow, and green light-emitting diodes (LEDs) in the sequence as shown in Figure 1. The timer circuit provides clock pulses to the counter. The counter produces ten outputs. Each output becomes high in turn as the clock pulses are received. The red LED is connected to the divide-by-ten output which is high for the first five counts. The appropriate outputs are combined through diodes to supply the yellow and green LEDs.

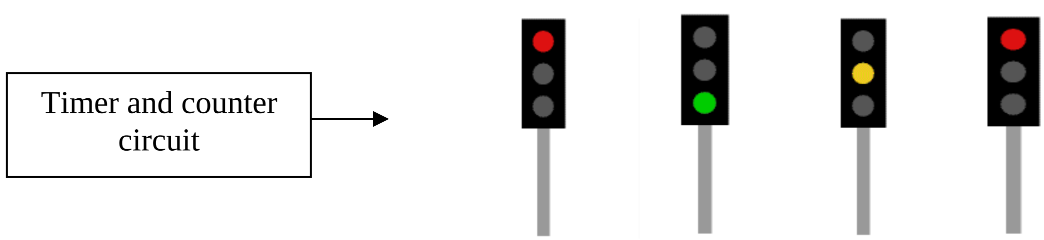


Figure 1: Three-light traffic signal sequence

Project setup

Figure 2 shows the circuit diagram of the components used to control the three-light LED traffic signal. The 555 timer is used to provide the clock pulses for the 4017 decade (1-of-10) counter. The outputs of the decade counter are connected to the red, yellow, and green LEDs through diodes and resistors.

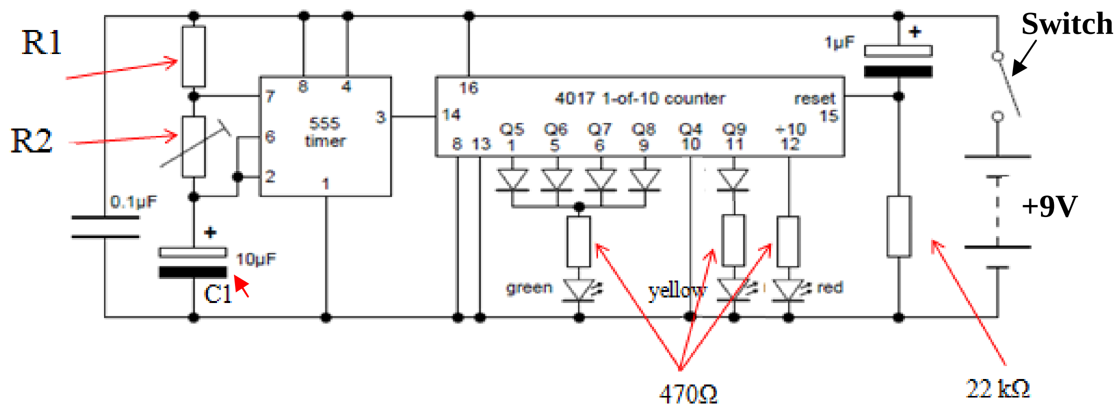
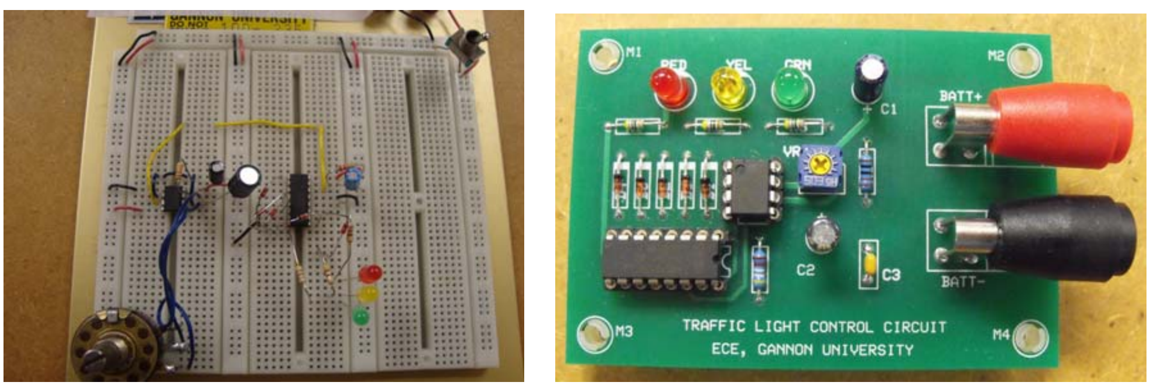


Figure 2: Circuit diagram

The circuit components and the equipment required are described in a project write-up. This write-up is provided to each student and served as the reference for circuit analysis and validation. In addition, the students have access to the slide presentation which overviews the project and the video which illustrates the steps required to complete the assembly of the circuit. Figure 3 shows the views of the breadboard-based protoboard and PCB-based protoboard after the assembly is complete.



(a) breadboard-based protoboard (b) PCB-based protoboard

Figure 3: Completed design before test

Project activities

Before the lab starts, the 555 timer and the 4017 decade counter are taken out from the PCB. The students are required to perform the following activities:

1. *Place the 555 timer in the circuit.*
   Make sure the timer chip is oriented with the notch facing upward as shown in Figure 3.

2. *Place the 4017 counter in the circuit.*
   Make sure the counter chip is oriented with the notch facing right as shown in Figure 3.

3. *Set the DC power supply to generate +9V.*
   Use the multimeter (yellow hand-held unit) and cables to measure and set the DC

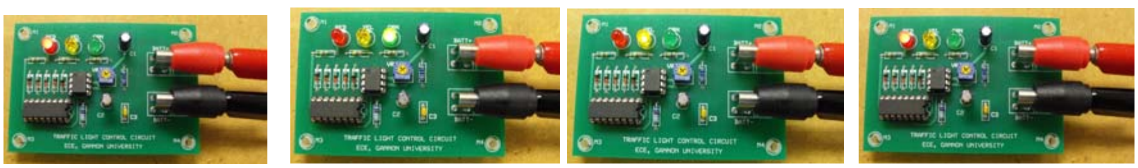
voltage to +9V.

4. *Connect the DC power supply to the PCB.*
   Use the red cable to connect the positive terminal of the DC power supply to the red banana jack on the PCB. Use the black cable to connect the negative terminal of the power supply to the black banana jack on the PCB. Also, connect the negative terminal on the DC power supply to the ground terminal on the power source.

5. *Turn on the DC power supply to apply the DC voltage to the circuit.*

6. *Adjust the potentiometer and observe the LEDs.*

Project execution and outcomes
The students observed the operation of the completed circuit and Figure 4 illustrates the outcomes captured for a cycle of the traffic light.



(a) red (b) green (c) yellow (d)red

Figure 4: LED sequence of working circuit (a) red (b) green (c) yellow (d) red

Section 3: Survey and Learning Outcomes Assessment

Each student completed a survey at the end of the project as part of the summative evaluation [2-6]. The survey consisted of two sections (a) quantitative (b) qualitative.

Quantitative section
The quantitative section required graded responses (on a scale from 0 to 5; 0 - *least effective* and 5 - *very effective*) to the following questions.

1. Did the project on *Traffic signal control* stimulate your interest in the following categories?
   (a) Design and validation of engineering systems
   (b) Application of STEM concepts to solve real-world problems
   (c) Understand the different components used in the project activity
   (d) Consider electrical engineering as a career option

2. Rate your contribution to the project activity in the following categories.
   (a) Assembly and set-up of the project
   (b) Design and implementation of the project
   (c) Test and validation of the project

Qualitative section
The qualitative section asked each student to comment on the project, and propose approaches to streamline and improve the presentation of the project as identified by the following questions.

- Are there any components of the project activity which must receive more emphasis?
- Are there any components of the project activity which must be excluded?
- Propose ways to improve the project activity.

Survey results and analysis
Two survey results are shown in this section for comparison purpose. Figure 5 shows the survey for the quantitative section completed by 102 students across the two Engineering Day project activities using the breadboard-based protoboard in the fall 2009. Figure 6 shows the survey for the quantitative section completed by 49 students in the ECE Day project activities using the PCB-based protoboard in the spring 2010. Figure 7 shows the errors of average scores on quantitative survey questions between using breadboard-based protoboard and the PCB-based protoboard. It can be observed that the students performed more effectively with the PCB-based platform.

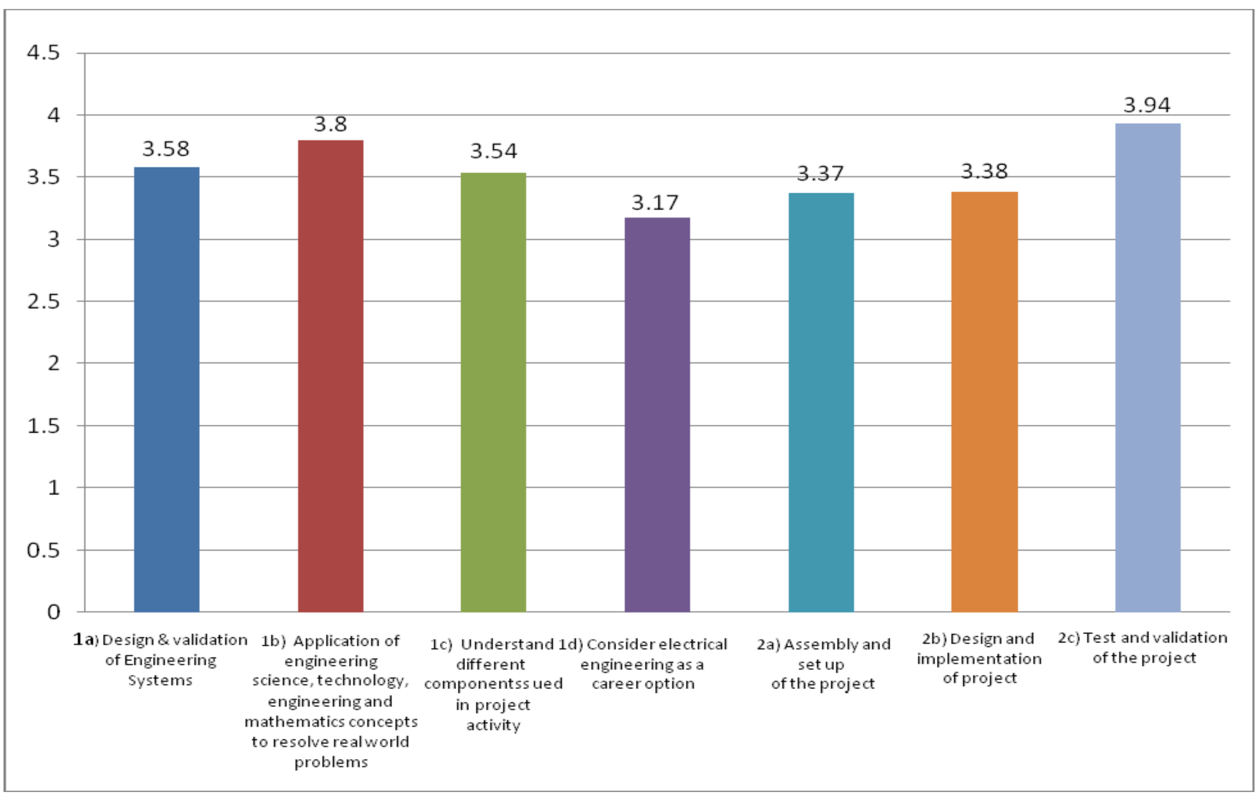


Figure 5: Average scores on quantitative survey questions with the breadboard-based protoboard test

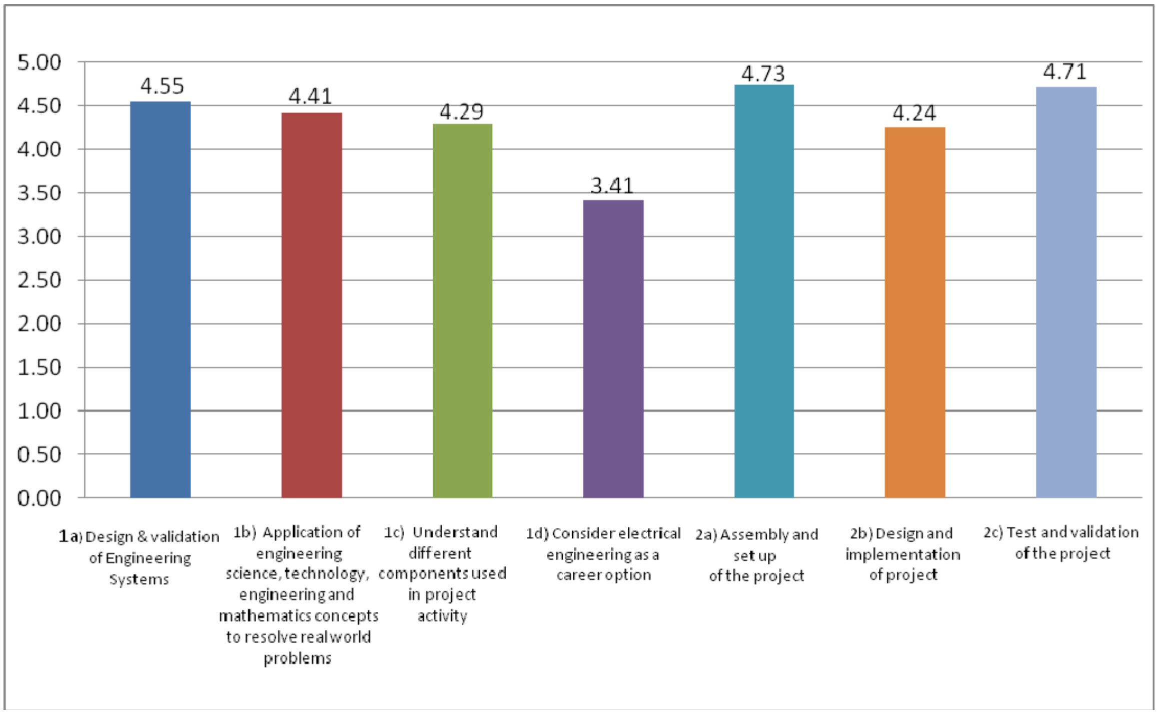


Figure 6: Average scores on quantitative survey questions with the PCB-based protoboard test

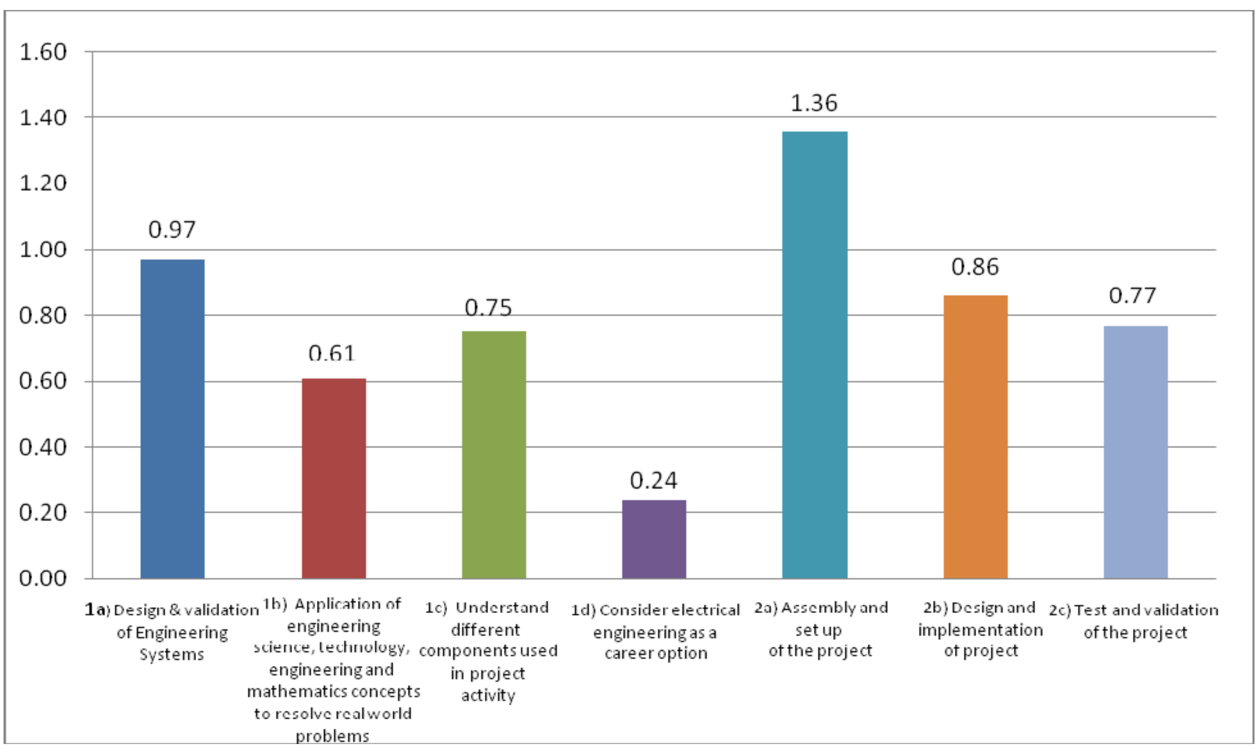


Figure 7: The errors of average scores on quantitative survey questions between using breadboard-based protoboard and the PCB-based protoboard

In the qualitative section, the students felt that the team should include male and female students and adding more components to assemble would enhance the experience. In retrospect, the choice of the traffic signal control using an electrical circuit does contain significant STEM components in diodes (science), LEDs (technology), engineering (integrated circuits or ICs), and boolean algebra/combinatorial logic (mathematics). The project activities focused more on the aspects of system integration and less on the specific operation of each component. The activities were intended to engage the K-12 students at the system level so that they recognized how real-world problems have engineering solutions that can be designed and tested in the laboratory using relatively simple and inexpensive components. Considering students' response, next step we will consider a four-way traffic light signal control circuit as the system integration project.

Section 4: Conclusions

The STEM-based ECE project activities to engage K-12 students on Engineering Day and ECE Day at our university make a conscious and concerted effort to introduce and reinforce STEM concepts through engineering problem solving with hands-on STEM learning experiences. The K-12 students learn to work on teams, acquire the skills to communicate with team members, lead teams, and work across teams. The students' evaluations show that the K-12 students are more actively engaged in the integrated project and demonstrate greater confidence to assemble and validate the project with the PCB-based platform. From the follow-up survey for the Engineering Day and the ECE Day events, it has been shown that these events had a very positive effect on high school students for considering careers in ECE.

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