AC 2011-3: ENGAGE K-12 STUDENTS IN ELECTRICAL AND COMPUTER ENGINEERING (ECE): OUTREACH WITH K-12 STEM SCHOOLS THROUGH ECE PROJECT ACTIVITIES

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Engage K-12 Students in Electrical and Computer Engineering (ECE): Outreach with K-12 STEM Schools through ECE Project Activities

Introduction

This paper discusses the set up and delivery of electrical and computer engineering (ECE) projects with science, technology, engineering, and mathematics (STEM) components to inspire K-12 STEM students to pursue higher education and careers in ECE. These projects form part of the "Engage K-12 students in ECE" program and are delivered through *outreach*[1-2] with K-12 STEM schools. The forms of *outreach* considered are (a) *direct* (b) *extended*. The focus of this paper is on the implementation of *direct outreach*. In *direct outreach*, the students in the K-12 school programs participate in the ECE Day event held in the ECE laboratories of the University. During this event, the students work on the ECE projects and are actively engaged in relating scientific theory to engineering design principles and practices. The *direct outreach* component of the program offers K-12 students the opportunity to participate in hands-on STEM-based ECE project activities at the institute of higher education. Through this participation, the K-12 students will improve their STEM preparation for admission to colleges and universities, and be motivated and encouraged to pursue degree programs in ECE and/or ECE technology.

The *extended outreach* of the "Engage K-12 students in ECE" program is planned through the cyber-learning networks and will enable K-12 students in schools within and across school districts to interact and share their STEM learning experiences. In addition, these networks create the environment for K-12 students of schools and school districts to participate in ECE project activities through a *virtual* STEM education experience. The *extended outreach* will enable K-12 students and teachers to establish dialog across schools and school districts. The K-12 teachers can adopt new and/or revised instructional practices to raise the STEM learning standards of the students.

In April 2010, the ECE department organized the ECE Day event. The ECE day event featured project activities for K-12 STEM students in electronic circuit assembly and testing, wind-based electricity generation, wireless communication, and embedded system design. The ECE laboratories accommodated approximately 60 high school students in four hour-long sessions in each laboratory with about 15 students in each session. The students were given step-by-step instructions to assemble, test, and validate the ECE project. The hands-on laboratory exercises introduced the students to ECE principles and design practices based on the requirements and specifications of the project. The ECE projects chosen were (a) electronic traffic signal control circuit (b) wind-power based electricity generation (c) logic circuit and embedded system design (d) point-to-point and point to multi-point wireless communication.

Each student completed the 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) 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.

Section 2 provides a brief description of the laboratory set-up and the laboratory activities for direct outreach through the ECE day event. Section 3 outlines the evaluation process employed for the projects. Section 4 summarizes the assessment of learning outcomes based on the on-line survey completed by the students during the project activities on ECE day. Section 5 outlines the conclusions and future plans for the *extended outreach* component of the program.

Section 2: STEM-based ECE Projects for *Direct Outreach*

The STEM-based ECE project activities on ECE day take place in the following four ECE laboratories of the ECE department.

1. Systems Integration
   Design and test electronic circuits and systems
2. Electric Drives
   Control and simulate electric machines
3. Embedded Systems
   FPGA-based system-on-chip (*SOC*) *design*
4. Personal Computing
   Programming tools and interfaces for PC workstations

The project overview and the steps required to build and validate the design are presented by the ECE faculty member in charge of the project activity. The faculty member is assisted by currently enrolled undergraduate students in the ECE program. For the ECE day in April 2010, the K-12 STEM students worked on ECE projects in the specified ECE laboratory during each of four one-hour sessions as summarized below. These project activities served as a means to rapidly engage the high school students in project design and validation rather than be a traditional classroom experience with detailed theory and explanation thereof.

Project title: *Traffic signal control circuit*
Project location: Systems Integration laboratory
Project summary: The students assembled and operated the three-light traffic signal set up on the printed circuit board (PCB) with timer and counter chips. The students worked in teams with two members per team. The project activity comprised the following steps.

(a) placement of the timer and counter chips on the PCB
(b) use the multi-meter to set the DC voltage source to +9V
(c) use the cables to interface the PCB to the DC voltage source
(d) use the screwdriver to vary the resistor on the PCB for control of the three lights

Figure 1 illustrates the stages in terms of the project (a) overview presented by the ECE faculty (b) activities (c) implementation and testing, and (d) validation.

(a) Project overview (b) Project activity

(c) Project testing (d) Project validation

Figure 1: Project activities in the Systems Integration laboratory

Project title: *Wind power-based electricity generation*
Project location: Electric Drives laboratory
Project summary: The students worked with a small-scale windmill, 5" generator, wire, and LED to convert the wind power into electricity and power the LED. Figure 2 shows some of the high school students engaged in project assembly and validation.

(a) Project assembly

(b) Project validation

Figure 2: Project activities in the Electric Drives laboratory

Project title: *Logic circuit and embedded system design*
Project location: Embedded Systems laboratory
Project summary: The students perform logic circuit design through the capture of schematics and execute their design on the Field Programmable Gate Array (FPGA) board. The students complete the design and validation of the logic circuit for a 4-bit binary adder and synthesize the seven-segment display (SSD) driver. Figure 3 illustrates the process of project instruction and project activity.

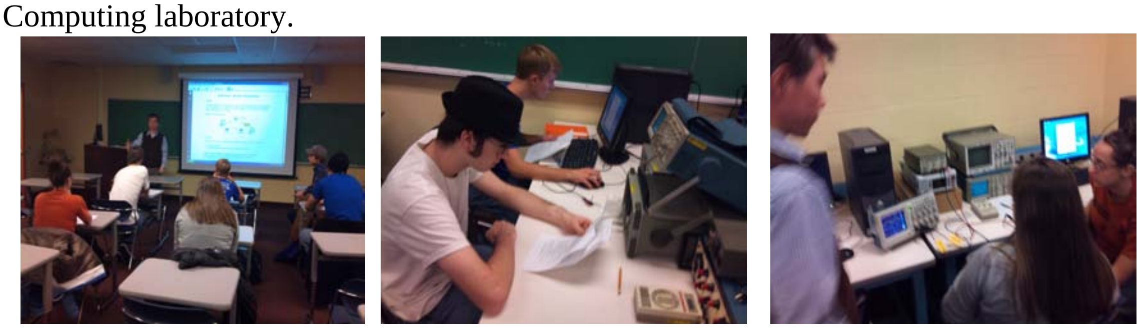
(a) Project instruction (b) Project design steps

Figure 3: Project activities in the Embedded Systems laboratory

Project title: *Wireless Communication – point to point or point to multi-point*
Project location: Personal Computing laboratory
Project summary: The students configure communication devices to create a wireless network and demonstrate "*instant messaging*" over the network. The broad steps of the project are as follows:

1. Visit the website for the download of software
2. Place the ZigBee chip on the board
3. Configure the communication port and hardware
4. Choose the type of communication (point-to-point/point-to-multi-point)
5. Modify the settings of the modem
6. The set up is ready for messaging (point-to-point/point-to-multi-point)

Figure 4 shows some of the stages of this project activity taking place in the Personal Computing laboratory.



(a) Project instruction (b) Project design steps (c) Project validation

Figure 4: Project activities in the Personal Computing laboratory

Section 3: Post-project activity - student survey

Each high school student completed a survey at the end of the project as part of the summative evaluation[3-5] following the ECE day event in April 2010. The survey consisted of two sections (a) quantitative (b) qualitative. The counselors who were present with the high school students during the project activities notified the ECE faculty that the students had been taking basic as well as advanced STEM courses in the 10^{th} to 12^{th} grade at school and that they were quite familiar with topics in ECE subjects such as electronics, electric machines, programming languages, and principles of communication. Hence, the survey questions challenged them to reflect on the system-level effectiveness of these brief project activities. Each project activity lasted about 55 minutes. In this short duration, the objective was to have the students observe and relate to the STEM aspects of electrical and computer engineering by directly engaging in project assembly and validation. The survey consisted of mostly broad questions for the students to reflect on the experience in the ECE laboratories and the effectiveness of ECE projects to relate to or reinforce some of their STEM learning at school.

Quantitative section

The quantitative section required graded responses (on a scale from 0 to 5) to the following questions. The score of 0 indicates that the student found no evidence in the project activity to support the question. The score of 5 indicates that the student found a strong correlation between the project activity and the question being asked. The score of 3 reveals that the student observed some but not overwhelming evidence of the question in the project activity.

1. Did the ECE project 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.

Section 4: Survey results and analysis

The survey was completed in each of the four ECE projects. In the qualitative section, the students felt that additional time (more than the 50 minutes allotted) and more project activities (additional steps in the assembly) would enhance the experience. In retrospect, the four ECE projects reinforced some fundamental as well as some advanced scientific and engineering principles through hands-on laboratory exercises with engineering design issues and constraints. For example, the choice of the traffic signal control using an electrical circuit included components such as diodes (science), LEDs (technology), integrated circuits or ICs (engineering), 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.

The results for the quantitative section (about 50 responses per project) are summarized in Table 1. The average score in all categories exceeded 3.1 on a scale of 5. The following categories achieved scores greater than 3.8 on the scale of 5 in all four ECE projects.

1(b) Application of STEM concepts to solve real-world problems
2(c) Test and validation of the project

Table 1: Quantitative outcomes

Question	**ECE project**			
	Traffic Signal Control	*Wind power*	*Embedded design*	*Wireless Communication*
1(a)	3.58	4.48	3.28	3.48
1(b)	3.80	4.38	3.81	3.88
1(c)	3.54	3.52	3.44	3.51
1(d)	3.17	3.74	3.15	3.54
2(a)	3.37	3.62	3.47	3.32
2(b)	3.38	3.41	3.58	3.31
2(c)	3.94	3.96	3.84	3.86

The scores received by the ECE project on wind power-based electricity generation exceeded the other projects in most of the responses. This project was most effective in delivering the strong link between STEM concepts and real-world engineering applications. The high school students could easily relate to the energy conversion process being implemented with simple electrical and mechanical components which are easy to obtain and assemble into a small scale working model.

Section 5: Conclusions and Future Plans

The “Engage K-12 students in ECE” program with direct and extended outreach components is expected to introduce and reinforce STEM concepts through engineering problem solving with both hands-on and virtual 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 have the opportunity to explore the different career paths and options for higher education in ECE.

The ECE Day event, scheduled to take place at least once in the academic year, establishes contact with and interaction between the K-12 STEM students, their teachers and counselors, and the ECE faculty members. Through this event and the cyber-learning network, the partnership between the ABET-accredited ECE program at the University and the K-12 schools and school districts is created and strengthened. The partnership ensures that institutes of higher education and K-12 schools work together to assemble the engineering workforce of the future. The K-12 students benefit from the early and frequent engagement in engineering design and practice as part of their STEM education.

The *extended outreach* component of the "Engage K-12 students in ECE" program is to engage the students in K-12 STEM schools and school districts in STEM-based project activities through cyber-learning networks. The interaction between the students and STEM project activities takes place over monitored and secure websites. Unlike *direct outreach*, *extended outreach* does not entail travel to the University, and is not limited to a day-long or week-long event but can be organized as an in-school or out-of-school program; however, it does require the set-up of internet access and proper partnership agreements between the school/school districts and the University.

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Biography:

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