STEM Project Activities for pK-12 Students: What it Takes to Make it Happen

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Abstract - **This paper discusses the work-in-progress to set up and deliver Electrical and Computer Engineering (ECE) project activities with critical Science, Technology, Engineering, and Mathematics (STEM) components for STEM students across the different school grades ranging from pre-Kindergarten (pK) through twelve (12). The STEM project activities are carefully chosen to relate basic and advanced engineering principles to engineering design specifications and real-world constraints and comprise simple and timely laboratory activities in ECE topics such as electronic circuits, electrical energy sources, wireless communications, and embedded systems. This forms part of the larger outreach and partnership program labeled "*Engage pK-12 students in ECE.*" It is hoped that, in the future, the outreach will include delivery of laboratory content through the cyber-learning networks, thereby enabling pK-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 pK-12 students of schools and school districts to participate in ECE project activities through a *virtual* STEM education experience. The "*Engage pK-12 students in ECE*" program aims to (a) raise the level of awareness among pK-12 students of the promising careers in the ECE disciplines upon graduation (b) establish and sustain the dialog between the pK-12 schools and the University to encourage the pK-12 school students to pursue and excel in subjects with STEM components (c) promote the interaction between the engineering faculty at the University and the pK-12 students and their teachers through activities which deliver and reinforce critical STEM components.**

Keywords – STEM-based engineering projects, Outreach

INTRODUCTION

The high drop-out rates of students from the STEM school systems and the low enrollment of school graduates in the STEM colleges and universities across the U.S. can be attributed to the (a) lack of awareness of the promising STEM-related careers after the successful completion of STEM-based school and college education (b) failure of STEM curricula in pK-12 schools to inspire the students to develop a life-long passion for STEM learning (c) inadequate preparation and lack of technological resources available to the pK-12 STEM teachers to effectively deliver STEM teaching. The outreach and partnership between the engineering departments at Universities which offer the ABET-accredited baccalaureate degrees and K-12 schools with STEM curricula can be viewed as a means to exploit the synergy between the two environments and can address the critical issues facing STEM learning and teaching in the following areas.

(1) *Introduce revisions to the K-12 STEM curriculum*
The pK-12 curriculum must include new and revised STEM courses which introduce the engineering design process and teach students how to use engineering technology to solve engineering problems with design and cost constraints. These courses will incorporate project-based and goal-oriented STEM learning experiences to supplement the traditional STEM curriculum.

(2) *Raise the motivation and desire to learn STEM concepts*
The proliferation of the internet technologies with multi-media make it possible to deliver the hands-on STEM-based project activities as a virtual educational experience to a geographically widespread audience of pK-12 students and teachers. The easy access to STEM education materials will (a) encourage the students to advance their understanding of basic and advanced STEM concepts (b) equip the pK-12 STEM teachers with the knowledge and skills required to sustain the STEM learning experience for their students.

(3) *Improve the retention of STEM concepts by the students*
The students participating in outreach will reinforce the learning of STEM components through activities and interaction that is structured, consistent, and constantly motivating. The students will improve their retention of STEM concepts learned in the classroom through hands-on project activities.

This paper documents the work-in-progress to create and implement the "Engage pK-12 students in ECE" program. Broadly speaking, the program will consist of hands-on STEM learning activities delivered through outreach [1]-[9] and collaborative partnerships between the University and pK-12 schools. The outreach is expected to include the following.

(1) pre-K through pre-middle school students participate in day-long introductory STEM-related activities

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(2) middle school students participate in day-long STEM-based engineering project activities
(3) high school students participate in day-long STEM-based engineering project activities.

The form of outreach chosen for discussion in this paper comprises ECE-related STEM activities organized and conducted at the middle school on a pre-specified STEM day and the ECE day organized in the ECE laboratory at the University. Section 2 provides details of the STEM project activities at the school. Section 3 outlines the STEM activities on ECE day. Section 4 summarizes the conclusions and the schedule of activities planned for the "Engage K-12 students in ECE" program.

SECTION 2: STEM-DAY ACTIVITIES

The STEM-day at one of the local area schools had been scheduled for the students of the eighth grade. The author was contacted to introduce and then engage these students in STEM-related engineering project activities. The students were given a brief overview of the ECE program at one of the local universities. Specifically, they were introduced to the *concept-to-product* cycle. Figure 1 summarizes the cycle in terms of the following major phases. The *concept* is usually the formulation and exploration of one or more ideas which are considered valuable and/or profitable in society. For instance, the incorporation of traffic-related information in road-to-vehicle communications can be useful to motorists.

The *concept* phase leads to the *design* phase, which, in electronics, is consummated through circuit software tools such as Pspice. This tool comprises block-level, model-based description of circuit elements, sub-system and system modules which capture the input-output behavior of the stages required to take the concept through the intended electronic circuit design phase.

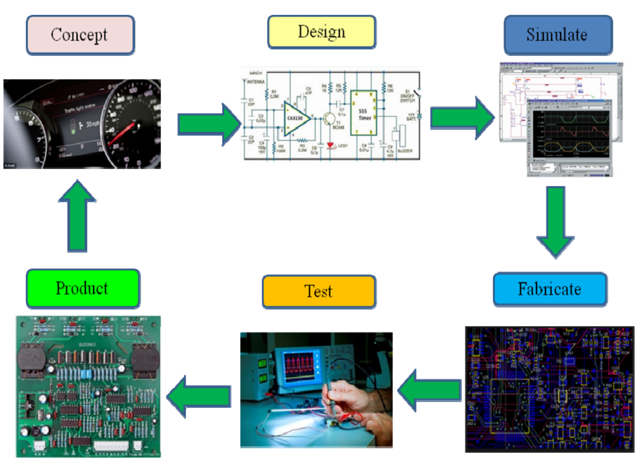


FIGURE 1
CONCEPT-TO-PRODUCT CYCLE

The *design* phase is followed by the *simulate* phase. In the *simulate* phase, which can be completed by the same Pspice tool, the software testing of the design can be accomplished. One of the major benefits of this phase is that test conditions which could result in the failure of the electronic circuit can be identified and avoided before any implementation with hardware is commenced. The *fabricate* phase comes after the *simulate* phase has been completed.

In the *fabricate* phase, the circuit is assembled onto one or more printed circuit boards (PCBs) with the hardware electronic components interconnected using etched layers of wiring. The fabricated circuit is then subject to the *test* phase, wherein the intended I/O responses of all the stages within the circuit are carefully monitored and recorded. Failure at this juncture necessitates a return to the design phase to determine what may have been overlooked or in error. Success at the test phase, obtained after thorough testing, leads to the *product* phase and possible integration into the intended application. Thus, the *concept-to-product* cycle/loop comprising the *design*, *simulate*, *fabricate*, and *test* phases is complete. Depending on the complexity of the concept, the *concept-to-product* cycle/loop can take anywhere from days to several months.

Based on this overview, the students engaged in understanding two basic concepts and assembling electrical circuits to investigate the implementation of these concepts. The entire laboratory session lasted seventy five minutes. Each session had twenty students working in pairs. There were four such sessions during the STEM day to accommodate all eighty eighth graders at the school.

Concept #1: *Series electrical circuit*
To explore the basic concept of electrical circuits, the first project activity comprised the assembly of a simple series circuit. The circuit elements such as the DC battery, the resistor, the LED, the wires for the physical connection of the components, and the protoboard on which the components (a) had to be placed (b) the complete circuit assembled, validated, and tested were explained in some detail. The students had to assemble the circuit shown in Figure 2 using the protoboard and the electrical components discussed during the introduction.

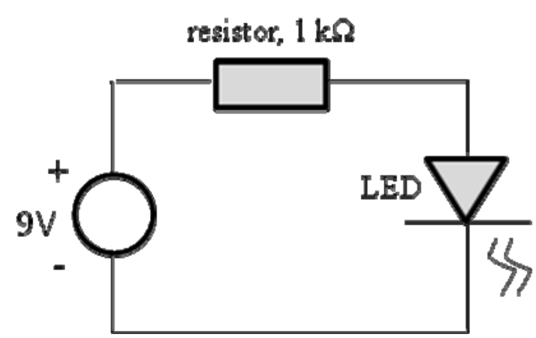


FIGURE 2
SERIES CIRCUIT

Although, the eighth grade students had some fundamental knowledge of science and mathematics as these would apply to this concept, they did not possess any useful or structured knowledge of the engineering and technology components required for this project activity. Those aspects were covered in the introduction. The goal of the project was to demonstrate the working of a circuit mesh or loop and the voltage law that applied.

Concept #2: *Parallel electrical circuit*
The second project activity comprised the assembly of the parallel electrical circuit. The goal of this project exercise was to introduce the notion of a node, and the current law that applied at each node. Figure 3 shows the circuit to be assembled by the students.

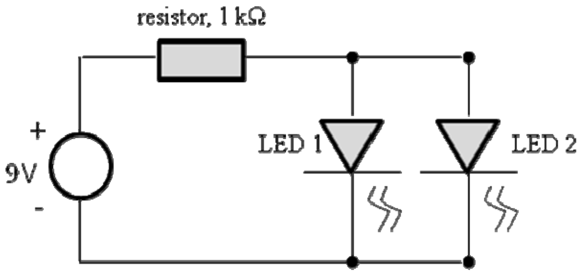


FIGURE 3
PARALLEL CIRCUIT

Figure 4 displays snapshots of the sequence of STEM-related activities during one of the laboratory sessions for the two project activities. The sequence comprised (a) the overview (b) the assembly of the circuit (c) the testing of the circuit (d) the validation of the circuit.

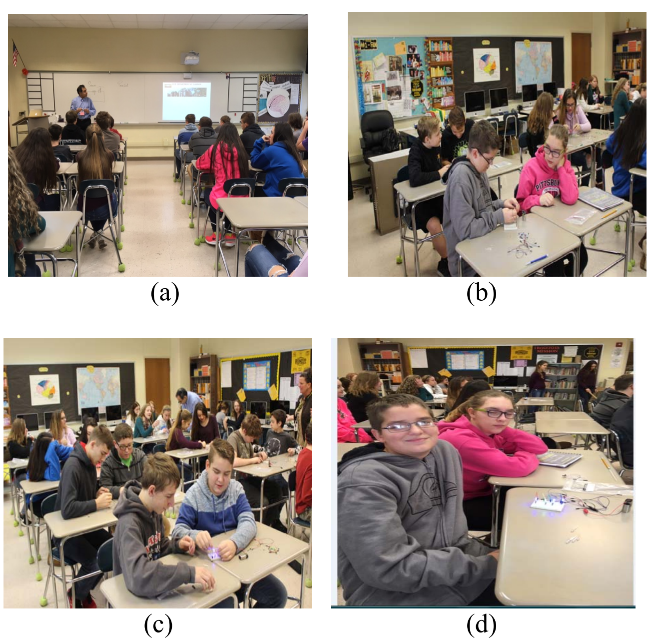


FIGURE 4
STEM-DAY PROJECT (a) OVERVIEW (b) ACTIVITY (c) TEST (d) VALIDATION

SECTION 3: STEM-DAY FOLLOW-UP

The ECE department at our University hosts *ECE day* [5] during its spring session (typically, the month of April). ECE day features project activities for pK-12 STEM students in electronic circuits, wireless communication, wind-based electricity generation, and embedded system design through hands-on laboratory activities related to project design, test and validation. The students work on the project under the guidance and supervision of the ECE faculty member and undergraduate students assigned to coordinate the project activity. The project activity lasts for about one hour and is intended to stimulate the student interest in practical, real-world STEM-based applications of engineering principles. For instance, one of the ECE projects is as follows:

Project title: *Traffic signal control circuit*
Project summary:
The students completed the assembly and then operated the three-light traffic signal set up on the printed circuit board (PCB) with timer and counter chips.

The circuit diagram shown in Figure 5 was overviewed. The components used and the operation of the circuit was carefully presented to the students.

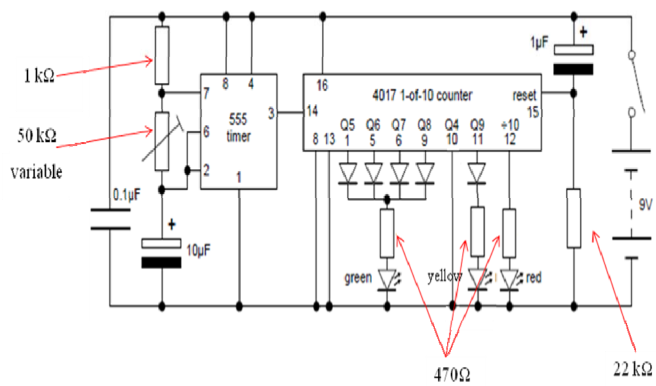
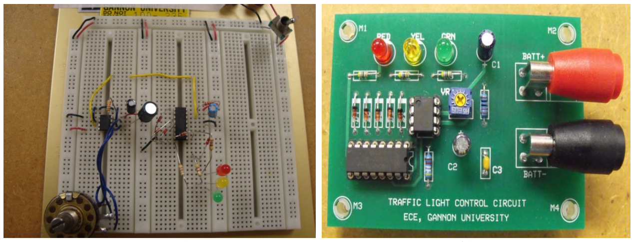


FIGURE 5
CIRCUIT DIAGRAM

The project activities comprised the following steps.

- Place the 555 timer in the circuit.
- Place the 4017 counter in the circuit.
- Set the DC power supply to generate +9V.
- Connect the DC power supply to the PCB.
- Turn on the DC power supply to apply the DC voltage to the circuit.
- Adjust the potentiometer and observe the LEDs.

The protoboard-based circuit, shown alongside the PCB-based circuit in Figure 6, served to link back to the *Design*, *Fabricate*, and *Test* phases of the *concept-to-product* cycle in Figure 1.



(a) (b)

FIGURE 6
TRAFFIC LIGHT PROJECT (a) PROTOBOARD-BASED b) PCB-BASED

SECTION 4: CONCLUSIONS & FUTURE WORK

The "*Engage pK-12 students in ECE*" program adopts outreach and partnership between the undergraduate engineering institution and pK-12 schools through ECE project activities for the pK-12 students. The outreach is aimed at year-round engagement with the pK-12 STEM schools in order to inspire and guide the pK-12 students toward undergraduate engineering education and careers in engineering disciplines.

The set up for the ECE Day event to take place at least once in the academic year is shown in Table 1. The Table shows the sequence of pre-activity and post-activity components required to improve the effectiveness of this form of outreach.

TABLE 1
PREPARATION AND DELIVERY OF ECE DAY

Pre-activity items	Activity	Post-activity items
Admissions contacts schools; schedules date for ECE Day	Mail invitations	Create the roster of participants and their contact information
ECE department at the University prepares for ECE Day	ECE-Day	Department follows through with the participants (coordinate with admissions)
Admissions contacts schools; determines students with interest; offer incentives to enroll in the ECE program	Invite these students to meet with the ECE faculty	Continue the dialog with these students; set-up the mentoring process for students who confirm enrollment
Assessment setup for identifying "intend" to major in eng or others	Matrix tracking of student's development to apply to other schools in eng fields	Track students enrollment in engineering at other universities/colleges

The pK-12 students learn to work on teams, acquire the skills to communicate with team members, lead teams, and work across teams. These students have the opportunity to explore different career paths and options for higher education in ECE. The ECE day is identified as the '*in-school'* program component of outreach. The ECE summer camps are considered the '*out-of-school'* program component of outreach. The pK-12 students will be guided by the ECE faculty member and undergraduate students to build, test, and validate intermediate and advanced ECE projects. Unlike the *in-school* program, the *out-of-school* program engages the pK-12 students over the duration of one week during the summer. During the week, the students learn to apply basic ECE principles to build, test, and validate models for engineering system design. This experience will reinforce their understanding of STEM concepts and strengthen their preparation for college education in STEM disciplines.

The ECE projects will target critical learning competencies within the discipline. These competencies include the understanding of basic engineering concepts (E in STEM) to reinforce the importance of mathematics (M in STEM) and the role of science (S in STEM) in problem solving with engineering design and cost constraints, and the recognition of the role of technology (T in STEM) in product design and development.

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