Partnerships to Create Synergistic STEM Communities

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Abstract - **This Research to Practice Work-in-Progress paper discusses the use of hands-on engineering laboratory and project activities to engage pK-12 STEM educators in order to exploit the synergy between the pK-12 STEM curriculum and the undergraduate engineering degree programs. Hands-on laboratory and project-based experiences are deemed to be among the most effective means to introduce and reinforce concepts in most engineering disciplines. The pK-12 STEM educators are engaged in structured project activities through workshops. During the ninety-minute duration of the workshop, as many as five project activities, ranging from simple resistive circuit configurations to advanced transistor and RF circuits, are first outlined, then assembled and tested by the educators. Through participation in this workshop, the STEM educators gained the opportunity to identify new and/or revise laboratory activities within their pK-12 STEM curriculum. The participants were not required to or expected to know advanced concepts in circuits and electronics. The workshop provided the experiences necessary to link the theory to practice through assembly of the electronic circuit and experimental observations. The educators worked with kits containing electrical components placed on the circuit assembly board using snap connectors and connected together to create basic and advanced circuits. The survey questionnaire administered upon conclusion of each project activity provided the feedback necessary to assess the overall process and each project activity.**

Index Terms – STEM, concept-to-product cycle, project-based teaching and learning, synergy
To

INTRODUCTION

In order to exploit the synergy between the STEM communities comprising pK-12 STEM educators and students in their curriculum and the faculty and students in the undergraduate (UG) engineering degree programs offered by academic institutions of higher education, it behooves us, as faculty at the aforementioned institutions, to actively involve pK-12 students and educators in the engineering design process. Specifically, among the STEM topics in electrical and computer engineering, hands-on laboratory and project-based experiences are deemed to be among the most effective means to introduce and reinforce the concepts necessary for topics in electronic circuit design. Electronic circuit design entails the thorough understanding of electrical circuit theory and practice ranging from the fundamental to the advanced level. However, it is possible to effectively incorporate just-in-time, self-directed, and goal-oriented intentional learning in this context.

The focus of this paper is on indirect outreach intended to engage the pK-12 STEM educators in the electronic circuit assembly and testing process. The pK-12 STEM educators participate in workshops which give them the opportunity to include new and/or revised STEM content within their pK-12 STEM curriculum. This could include introduction to the engineering/electronic design process and instruction of the pK-12 STEM students on how to understand and use engineering technology to solve engineering problems with design and cost constraints.

Section 2 overviews the creation of STEM communities through partnerships based on outreach. Section 3 summarizes the outreach strategies, focusing on the STEM workshop schedule of project activities. Section 5 captures details related to each project activity. Section 6 reviews the project activity assessment.

SECTION 2: PARTNERS IN SYNERGY

Due to the fact that students graduating from pK-12 schools expect to seek and obtain higher education, undergraduate (UG) institutions with STEM-based degree programs such as electrical and computer engineering are in the prime position to establish and sustain partnerships with pK-12 STEM schools [1],[2].

Figure 1 illustrates the broad nature of the recognition and exploitation of the synergy between the pK-12 STEM community and the UG community in the undergraduate degree programs at institutions of higher education. Typically, engineering undergraduate students work on faculty-guided research projects in addition to their core and elective lecture/laboratory courses. The notion is that hands-on laboratory activities originating from UG engineering laboratories can form the bedrock for potential outreach. For example, direct outreach, implemented through STEM day events and/or summer camps target the pK-12 student while

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indirect outreach, implemented through training workshops for pK-12 STEM educators tap into the synergy of the STEM communities.

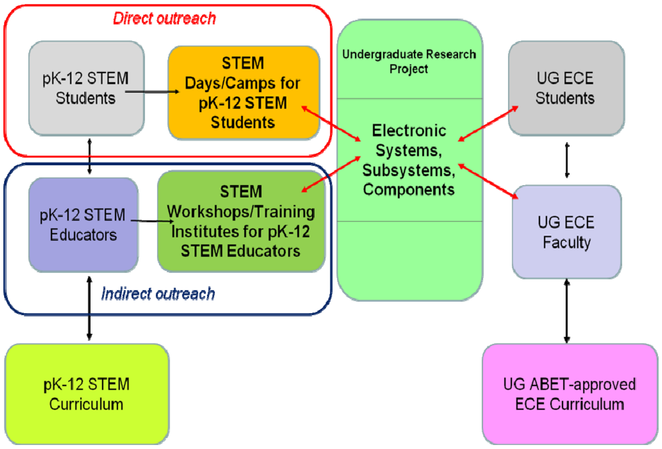


FIGURE 1
CREATING SYNERGISTIC STEM COMMUNITIES

SECTION 3: OUTREACH STRATEGIES

STEM activities categorized as direct outreach are listed as follows:

- Engineering/STEM day events at the pK-12 school
  Up to ninety minute laboratory sessions conducted at the pK-12 STEM school, tailored for each grade; UG faculty and students travel to the school for on-site engineering project activities
- Engineering/STEM day events on the UG campus
  Hour-long hands-on laboratory activities in each engineering lab
- After-school engineering program
  Weekly meetings in the engineering labs with planned laboratory activities
- Engineering summer camps
  Three-day/week-long engineering project activities with the pK-12 students in residence on the UG campus

The following list identifies partnerships through indirect outreach.

- STEM workshops by engineering faculty
  Audience comprises pK-12 educators
- Cyber-instruction and learning networks
  Web/Cloud-based dissemination of engineering laboratory and project activities

Forms of direct outreach have been implemented and discussed in [3], [4]. The next section outlines the schedule of project activities for indirect outreach using a STEM workshop in circuits and electronics. The E-in-STEM workshop titled '*E = MC*[2]*: Excite interest in electronics through projects that Motivate the learning of Concepts through Circuits*' was conducted under the auspices of the 2016 FIE conference and was attended by six K-12 educators. None of these educators had any prior experience with hands-on electronic circuit assembly and testing.

SECTION 4: STEM WORKSHOP

The workshop schedule in Table I identifies five project activities. The Table lists the sequence of activities and the expected duration of each activity. The expected total duration of the workshop is 1.5 hours (90 minutes).

TABLE I
WORKSHOP SCHEDULE

Category	Maximum Duration	Outline
Introduction & Overview	3 minutes	Schedule of topics & activities
Team formation	2 minutes	Two participants per team
Concepts: Circuit theory	5 minutes	Laws, variables, and units
Project #1: Series & parallel circuits	5 minutes	Lamp and fan configurations
Concepts: Diodes & Transistors	5 minutes	I-V relationship and operation
Project #2: Transistor circuits	10 minutes	PNP and NPN configurations
Concepts: Amplifiers	5 minutes	Operational amplifier circuits
Project #3: Amplifier circuits	15 minutes	Voltage, current, and power
Concepts: Oscillators	5 minutes	Frequency generation
Project #4: Oscillator circuits	15 minutes	Fixed and tunable oscillators
Concepts: RF circuit design	5 minutes	Modulation - AM & FM
Project #5: RF circuits	15 minutes	AM radio & FM radio

For the project activities, the participants used the *SNAP CIRCUITS PRO* kit by Elenco [5]. This kit contains electrical components are placed on the board to create basic and advanced circuits.

SECTION 5: PROJECT ACTIVITIES

The workshop schedule in Table I identifies five project activities.

Project #1: **Series & parallel circuits**
Following the introduction of basic circuit concepts through the variables, their units, and fundamental laws (Kirchhoff's Voltage and Current), the first project illustrates the configuration of the two basic electrical circuit configurations – series and parallel.

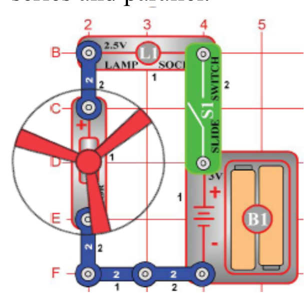


FIGURE 2
PROJECT ACTIVITY #1: SERIES CIRCUIT

The expected duration of the assembly and test activities in Project #1 was five minutes. Figure 2 shows the set-up of a lamp and a fan in series. The participants assembled the circuit shown in Figure 2 and were instructed not to touch the fan or motor during operation. Safety concerns form an integral part of electronic design and test and were enforced throughout this workshop. Upon placement of the fan blade on the motor (M1), and closure of the slide switch (S1), the fan will spin and the lamp (L1) should turn on. The light helps protect the motor from getting the full voltage when the slide switch is closed. The participants removed the fan and noticed how the lamp gets dimmer when the motor does not have to spin the fan blade.

The parallel circuit using the lamp and fan is shown in Figure 3. In this connection, the lamp does not change the current to the motor (M1). The participants removed the fan and noticed how the lamp does not change in brightness as the motor picks up speed. The lamp has its own path to the battery (B1).

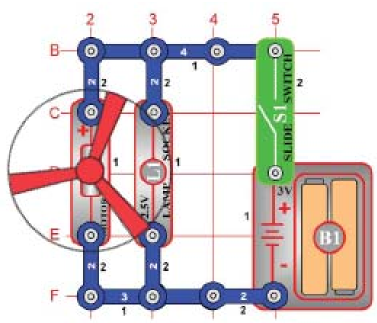


FIGURE 3
PROJECT ACTIVITY #1: PARALLEL CIRCUIT

Project #2: **Transistor circuits**
Project #2 engaged the participants in the assembly of basic transistor circuits and their applications. Figure 4 illustrates the set-up of the PNP collector circuit to demonstrate the effect of gain control (using the variable resistor, RV) on the operation of the transistor.

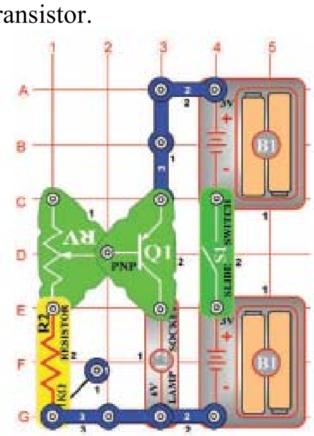


FIGURE 4
PROJECT ACTIVITY #2: PNP COLLECTOR CIRCUIT

In addition, as part of Project #2, the circuit to adjust the speed of the fan, shown in Figure 5 is assembled and its operation observed and documented. The expected duration of all the activities in Project #2 was ten minutes.

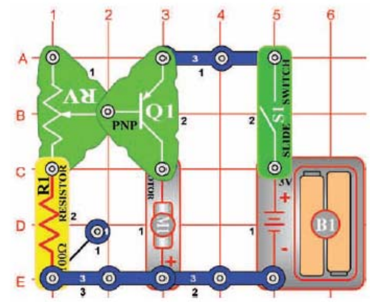


FIGURE 5
PROJECT ACTIVITY #2: PNP TRANSISTOR WITH FAN

Project #3: **Amplifier circuits**
Following a brief summary of operational amplifiers, the participants engaged in Project #3. Project #3 comprised a transistor-based current amplifier circuit (shown in Figure 6).

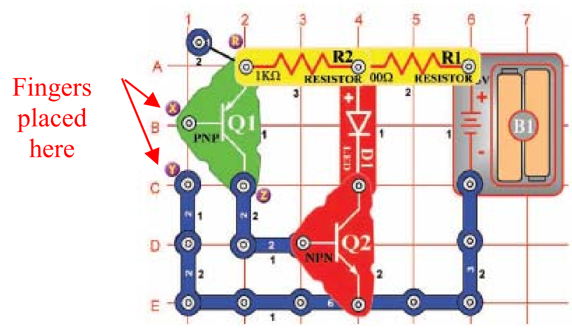


FIGURE 6
PROJECT ACTIVITY #3: TRANSISTOR AMPLIFIER

The two transistors, Q1 and Q2, in Figure 6, are being used to amplify the very tiny current going through one's body to turn on the LED. The PNP transistor (Q1) has the arrow pointing into the transistor body. The NPN transistor (Q2) has the arrow pointing out of the transistor body. Project #3 included the assembly and testing of the power amplifier circuit (shown in Figure 7).

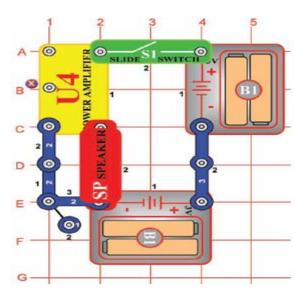


FIGURE 7
PROJECT ACTIVITY #3: POWER AMPLIFIER

When the slide switch (S1) is turned ON, the power amplifier IC (U4) should not oscillate. High frequency clicks or static should be coming from speaker (SP) indicating that the amplifier is powered on and ready to amplify signals. High gain high-power amplifiers may oscillate. The expected duration of all the activities in Project #3 was fifteen minutes.

Project #4: **Oscillator circuits**

The focus of Project #4 (fifteen minutes) was the assembly of an electronic oscillator. The electronic oscillator is an electronic circuit that produces a periodic, oscillating electronic signal, often a sine wave or a square wave. An audio oscillator produces frequencies in the audio range, about 16 Hz to 20 kHz. The RF oscillator produces signals in the radio frequency (RF) range of about 100 kHz to 100 GHz. Project #4 comprised sound generation using the transistor oscillator circuit shown in Figure 8.

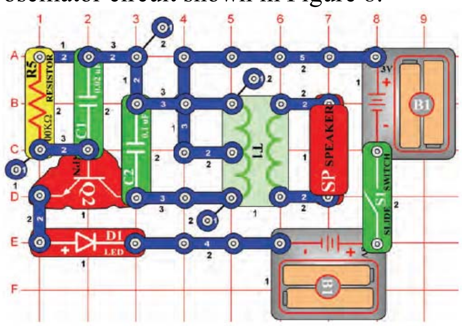


FIGURE 8
PROJECT ACTIVITY #4: SOUND OSCILLATOR

Project #5: **RF circuits**

Project #5 (fifteen minutes) involved the assembly and test of an RF circuit to demonstrate amplitude or frequency modulation (AM/FM). Figure 9 shows the AM radio and Figure 10 shows the FM radio to be assembled and tested.

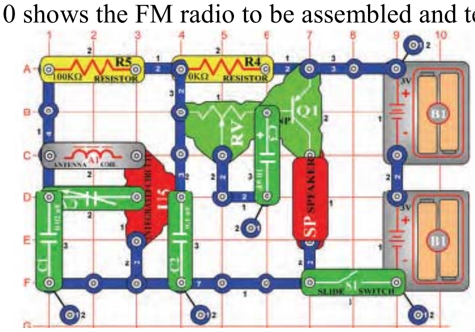


FIGURE 9
PROJECT ACTIVITY #5: AM RADIO

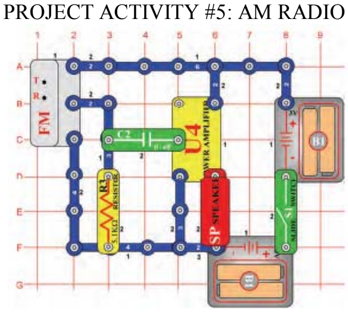
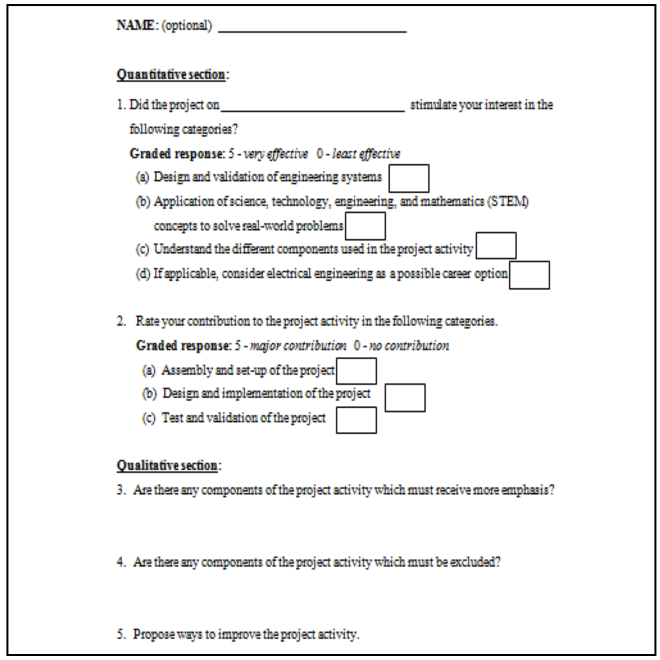


FIGURE 10
PROJECT ACTIVITY #5: FM RADIO

SECTION 6: PROJECT ACTIVITY ASSESSMENT

Figure 11 shows the survey used by the participants to assess the project activity. The survey has two sections identified as the (a) quantitative section (b) qualitative section. The quantitative section requires a graded response (scale 0 to 5) in the categories listed in the survey.



NAME: (optional) ____________________

Quantitative section:

1. Did the project on ____________________ stimulate your interest in the following categories?

Graded response: 5 - *very effective* 0 - *least effective*

(a) Design and validation of engineering systems

(b) Application of science, technology, engineering, and mathematics (STEM) concepts to solve real-world problems

(c) Understand the different components used in the project activity

(d) If applicable, consider electrical engineering as a possible career option

2. Rate your contribution to the project activity in the following categories.

Graded response: 5 - *major contribution* 0 - *no contribution*

(a) Assembly and set-up of the project

(b) Design and implementation of the project

(c) Test and validation of the project

Qualitative section:

3. Are there any components of the project activity which must receive more emphasis?

4. Are there any components of the project activity which must be excluded?

5. Propose ways to improve the project activity.

FIGURE 11
SURVEY FOR PROJECT ASSESSMENT

SECTION 7: CONCLUSIONS

The workshop comprised an effective means of indirect outreach to engage pK-12 STEM educators in the assembly, and testing of a selection of simple and complex electronic circuits. Workshops of this nature will enable the educators to learn ways to incorporate the hands-on experiences and engineering content into pK-12 STEM curricula.

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