Paper ID #17946

Project Activities in Electronics to Spark Interest in STEM from PK-12 through Life

Dr. Ramakrishnan Sundaram, Gannon University

Dr. Sundaram is a Professor in the Electrical and Computer Engineering Department at Gannon University. His areas of research include computational architectures for signal and image processing as well as novel methods to improve engineering education pedagogy.

Work-in-Progress: Project Activities in Electronics to Spark Interest in STEM from PK-12 through Life

Introduction

This paper discusses the work-in-progress to use engineering project activities in electrical circuits and electronics so as to train PK-12 STEM educators in the step-by-step process of assembly and testing of electronic circuits. It is well known that electronic circuit design requires fundamental and advanced knowledge of STEM concepts. The concept-to-product cycle[1-6] forms an integral part of electronic circuit design, assembly, test, and validation. Hands-on laboratory and project-based experiences are deemed to be among the most effective means to introduce and reinforce concepts in electronics. In order to exploit the synergy between the PK-12 STEM curricula and the undergraduate engineering degree programs, PK-12 STEM educators are engaged in structured project activities through workshops such as the *E-in-STEM* workshop[7] held as part of the Frontiers in Education conference in October 2016. 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, were first outlined, then assembled and tested by the educators. Through participation in this workshop, PK-12 STEM educators were expected to gain the opportunity to identify new and/or revise laboratory activities within their PK-12 STEM curriculum. Through these activities, PK-12 educators can introduce and teach PK-12 STEM students the use of engineering technology to solve engineering problems with design and cost constraints.

The participants were not required to know advanced engineering design concepts. The training offered by this workshop will consist of (a) overview and only the necessary detail of the STEM concepts that apply to electronic circuit design and analysis (b) application of these concepts to hands-on project-based laboratory activities. The participants build the essential knowledge base from basic STEM principles and are expected to see and experience the link between the theory and practice of electronics. The educators work with kits containing electrical components which can be 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 provides the feedback necessary to assess the overall process and each project activity.

Section 2 overviews the *concept-to-product* approach in the context of electronic circuit design and outlines the agenda and timetable of the workshop. Section 3 summarizes the project activities in electronic circuit design which were performed by the participants during the workshop. Section 4 documents the outcomes of the workshop. Conclusions appear in Section 5.

Section 2: Concept-to-Product Cycle

The electronics industry survives on the successful implementation of 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.

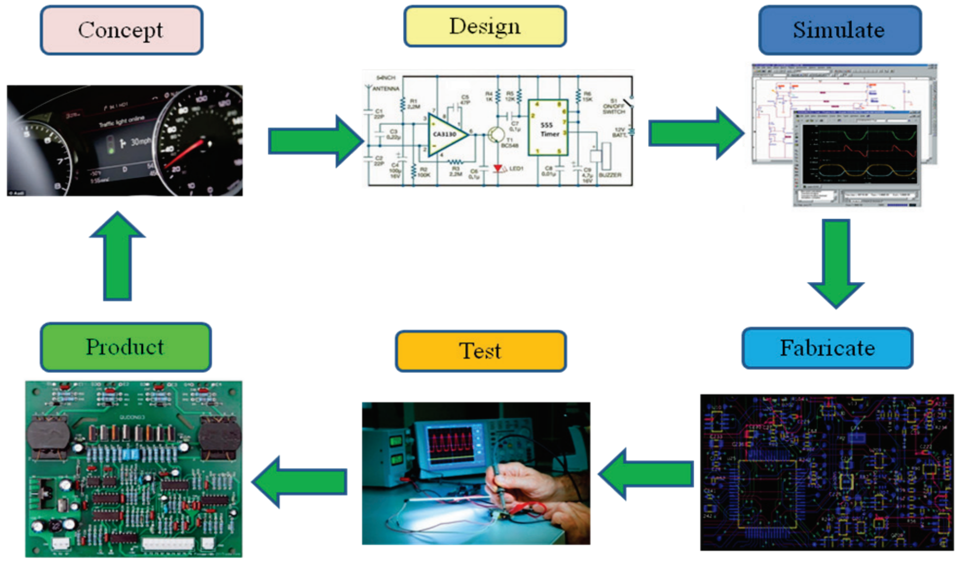


Figure 1: Concept-to-Product Cycle

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 few days to several months.

Table I lists the sequence of activities and the expected duration of each activity planned for the workshop. The total duration of the workshop was 1.5 hours (90 minutes). For the project activities, the participants used the *SNAP CIRCUITS PRO* kit by Elenco[8]. This kit contains electrical components that can be easily placed onto their own circuit assembly boards. The components are placed onto the board using snap connectors, and are connected together to create basic and advanced circuits. These kits are very easy to use and assemble, and learning how to use them is very intuitive.

Table 1: Workshop Schedule

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

Section 3: Project Activities
The workshop schedule in Table I identified 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 illustrated the configuration of the two basic electrical circuit configurations – series and parallel. The 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.

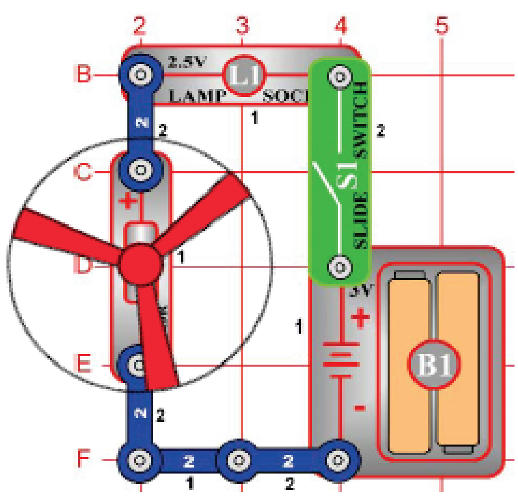


Figure 2: Project Activity #1(a) - Series circuit

The participants assembled the circuit shown in Figure 2. They 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 spins and the lamp (L1) turns on. The light helps protect the motor from getting the full voltage when the slide switch is closed. A part of the voltage from the battery source drops across the lamp and the rest drops across the motor. The participants remove the fan and notice 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 draws current independent of the motor (M1) and does not change the current to the motor (M1). The motor starts a little faster than in the series circuit. 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).

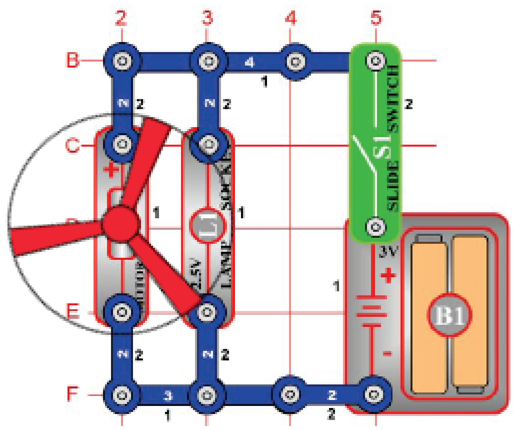


Figure 3: Project Activity #1(b) - Parallel circuit

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.

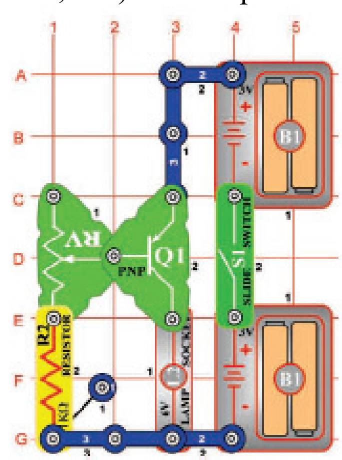


Figure 4: Project Activity #2(a) - PNP collector circuit

In addition, as part of Project #2, the circuit to adjust the speed of the motor (M1), shown in Figure 5 is assembled and its operation observed and documented. The duration of all the activities in Project #2 was ten minutes.

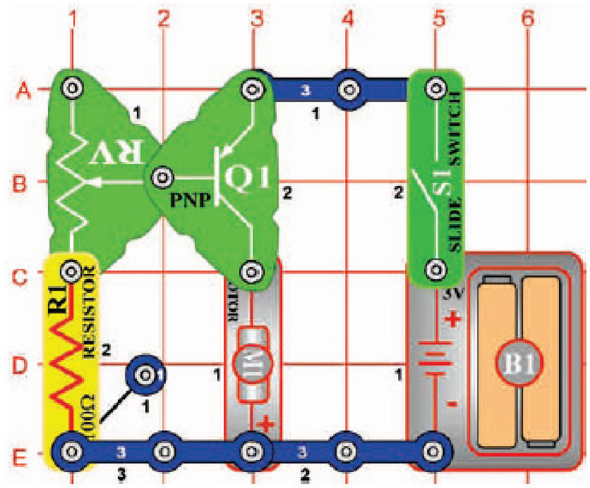


Figure 5: Project Activity #2(b) - PNP transistor with fan

Project #3: **Amplifier circuits**

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

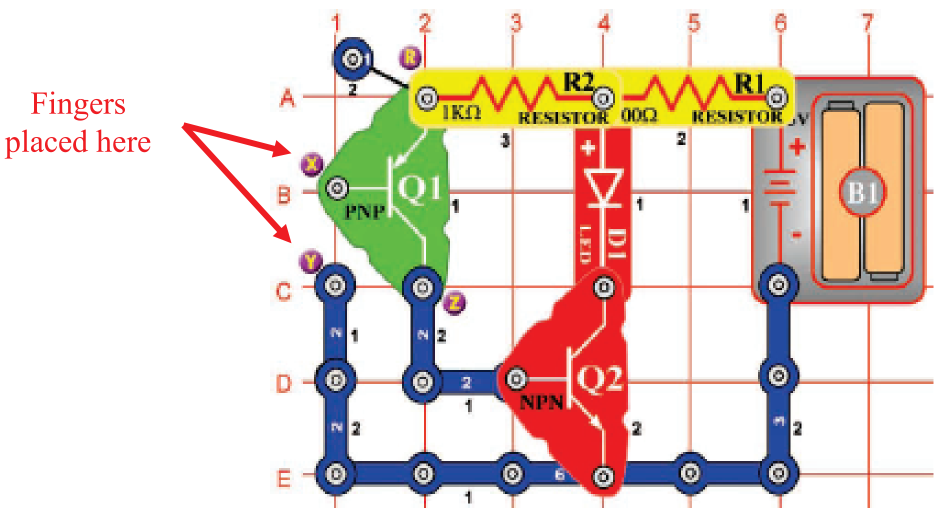


Figure 6: Project Activity #3(a) - Transistor amplifier

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. The PNP amplifies the current from one's fingers first, and then the NPN amplifies it more to turn on the LED. Project #3 includes the assembly and testing of the power amplifier circuit (shown in Figure 7).

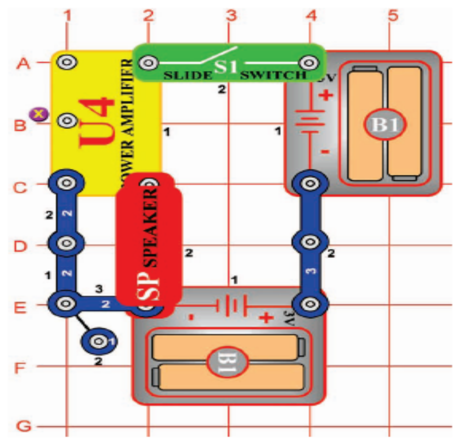


Figure 7: Project Activity #3(b) - Power amplifier

When the slide switch (S1) is turned ON, the power amplifier IC (U4) should not oscillate. One should be able to touch point X with his/her finger and hear static. If one does not hear anything, listen closely and wet one's finger that touches point X. 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 duration of all the activities in Project #3 was fifteen minutes.

Project #4: **Oscillator circuits**

The focus of Project #4 (fifteen minutes) was oscillator design. The electronic oscillator is an electronic circuit that produces a periodic, oscillating electronic signal, often a sine wave or a square wave. There are two main types of electronic oscillator: the linear or harmonic oscillator and the nonlinear or relaxation oscillator. Oscillators are characterized by the frequency of their output signal. Oscillators designed to produce a high-power AC output from a DC supply are usually called inverters. Project #4 comprises sound generation using the transistor oscillator circuit shown in Figure 8. Turning on the slide switch (S1) causes the LED (D1) to light up as the speaker (SP) emits a tone. The circuit oscillates and generates an AC voltage across the speaker through the transformer (T1).

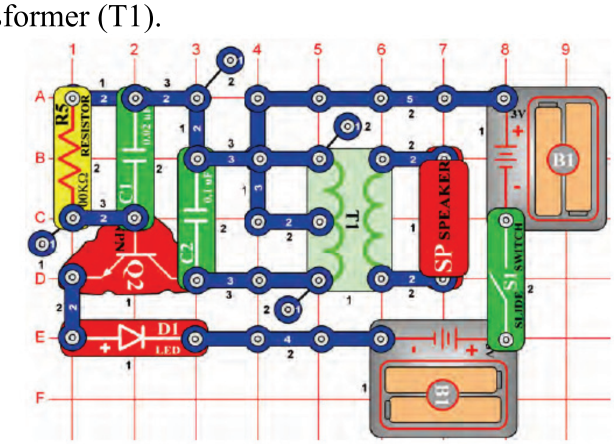


Figure 8: Project Activity #4(a) – Oscillator for sound

Project #4 also included the assembly of an oscillator circuit to produce frequencies ranging from 0.5 Hz to 30 kHz. This circuit was then to be used to turn on an LED. Figure 9 shows the oscillator circuit for the operation of an LED.

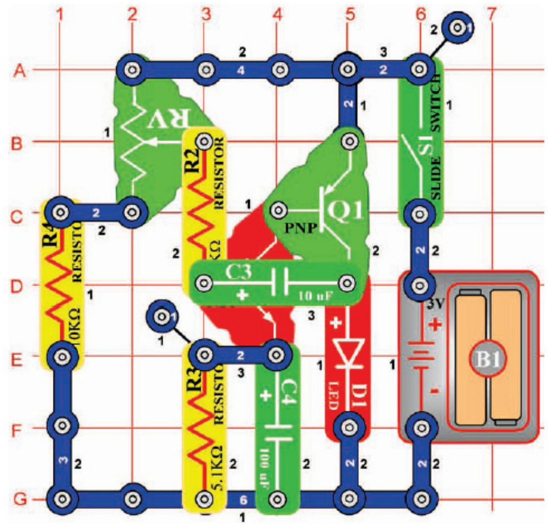


Figure 9: Project Activity #4(b) – Oscillator for light

The operation of this circuit comprises setting the adjustable resistor (RV) to the bottom position and then turning the slide switch (S1) on. The LED (D1) will start flashing. The flash rate and the flash period are to be determined. Gradual variation of the adjustable resistor (RV) is made and the values of the LED flash rate and flash period are calculated and recorded. Thereafter, the capacitor (C3) is replaced by capacitor (C1) and the capacitor (C4) is replaced by capacitor (C2), respectively. As before, the measured values of the LED flash rate and flash period are recorded. Finally, the resistor (R4) is replaced by resistor (R1). The values of the LED flash rate and flash period are calculated and recorded.

Project #5: **RF circuits**

Project #5 (fifteen minutes) involved the assembly and test of RF circuits to demonstrate amplitude modulation (AM) and frequency modulation (FM). Figure 10 shows the AM radio. The steps required for the testing of this circuit are as follows:

- Turn on the slide switch (S1)
- Adjust the variable capacitor (CV) to select an AM radio station
- Set the variable resistor (RV) control to the left for the sound to be louder
- Tune the variable capacitor (CV) to another AM radio station
- Adjust the variable resistor (RV) to increase the loudness level of the sound heard

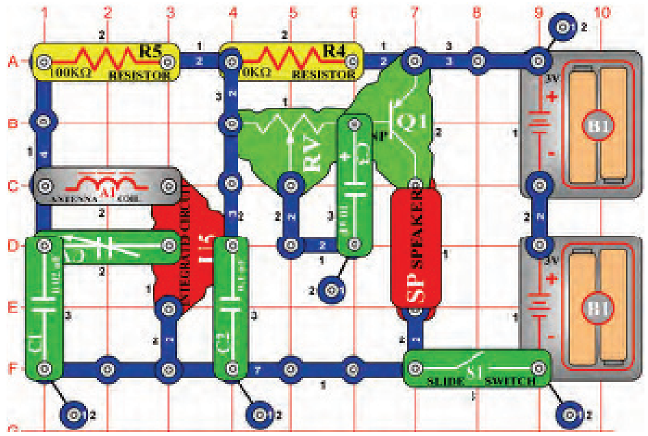


Figure 10: Project Activity #5(a) – AM radio

Figure 11 shows the FM radio which was assembled and tested.

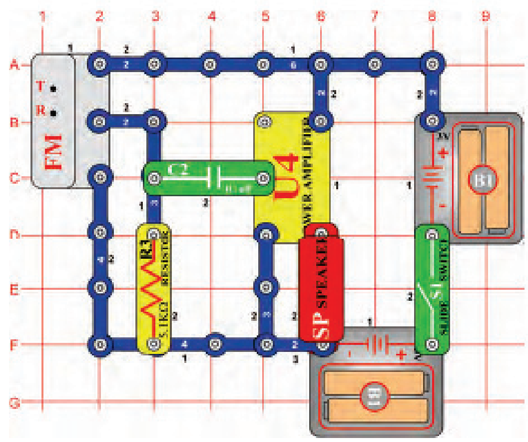


Figure 11: Project Activity #5(b) – FM radio

The FM module (FM), provided by the kit, contains a scan (T) and a reset (R) button. The R button resets the frequency to 88MHz. This is the beginning of the FM range or frequency band. The basic steps required for the operation of this circuit are as follows:

- Press the T button, the module scans for the next available radio station
- Turn on the slide switch (S1) and press the R button
- Next, press the T button so that the FM module can scan for an available radio station

When a station is found, it locks on to it and you hear it on the speaker. Then, perform the following step.

- Press the T button again for the next radio station

The module will scan up to 108MHz, the end of the FM range or frequency band, and stop. To test the circuit, the participants replace the resistor (R3) and the capacitor (C2) with two other choices and repeat the previous steps.

The workshop was planned for as many as the ten project activities summarized in this section. In order to facilitate individual and team participation, the attendees received the summary write-up for each project activity. The summary write-up included the following items.

- Title for the theme of the project activity
- Broad objective of the project activity
- Electronic circuit diagram (to be assembled)
- Steps in the assembly process
- Operation of the circuit
- Test and validation of the circuit

Figure 12 shows a sample summary project activity write-up comprising the items listed above. Upon completion of each project activity, the participants completed a survey related to that project activity. The survey comprised a quantitative section and a qualitative section.

Quantitative section
The broad question in this section was as follows:

1. Did the project on [*specify the project activity being surveyed*] 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

Qualitative section
The participants also provided feedback and general comments in the following categories.

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

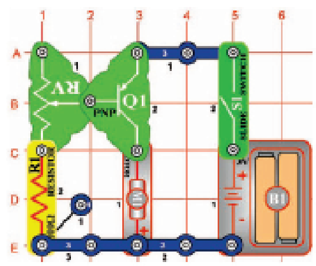
4. Are there any components of the project activity which must be excluded?

5. Propose ways to improve the project activity.

PROJECT ACTIVITY #2_B: FAN SPEED CONTROL WITH TRANSISTOR CIRCUIT

OBJECTIVE: To adjust the speed of a fan using a PNP transistor circuit.

CIRCUIT TO BE ASSEMBLED:



STEPS IN THE ASSEMBLY:

1. Assemble the circuit shown above by placing all the parts with a black number 1 next to them on the base grid first.
2. Then, assemble part(s) marked with the black number 2. Note that the PNP transistor (Q1), the resistor (R1), and the slide switch (S1) are assembled as part of Step 2.
3. Be sure to orient the motor (M1) with the positive (+) side down as shown in the Figure above. Place the fan blade on the shaft of the motor (M1).
4. Assemble part(s) marked with the black number 3 following Step 2.

WARNING: There are moving parts in this circuit. Do not touch the fan or motor during operation!! Do not lean over the motor!!!

OPERATION:

Press the slide switch (S1) to turn the circuit on. Set the adjustable resistor (RV) for the desired fan speed. If you set the speed too fast then the fan may fly off the motor. Observe if the fan blade spins for different settings of the resistor (RV). If the fan does not move at any resistor setting, then replace your batteries (B1).

Figure 12: Sample summary project activity write-up

Section 4: Workshop Outcomes

The E-in-STEM workshop titled '*E = MC*^{2}*: Excite interest in electronics through projects that Motivate the learning of Concepts through Circuits'* and conducted under the auspices of the 2016 FIE conference was attended by six K-12 educators. These educators came primarily from K-12 schools/school districts in Pennsylvania. One of the participants expressed the need for additional analytic discussion, at both the component and system level, to go alongside the steps of assembly and validation of each project activity. There was a consensus on enhancing the cause and effect with STEM related interactions which incorporated the M in STEM component.

The participants felt that they should be exposed to several such workshop sessions so that they could then educate the students in their K-12 classrooms on the electronic circuit assembly and testing process. It was suggested that the presenter of the workshop regularly visit a set of schools to promote the learning of basic and advanced skills among the PK-12 educators according to a well-defined instructional timetable, thereby instilling the necessary and sufficient preparation of the PK-12 educators to translate their E-in-STEM learning to PK-12 classrooms and laboratories as part of their PK-12 curriculum.

Section 5: Conclusions

This paper purports to successfully communicate the following primary goals or learning outcomes.

- Understand the application of electrical engineering concepts through projects in electronic circuit design
- Assemble, test and validate simple and complex electronic circuits
- Gain vital hands-on laboratory experiences working as individuals and on teams
- Learn ways to incorporate the workshop experiences and engineering content into K-12 STEM curricula

These goals provide hands-on, best-practice activities to nurture the skills, knowledge, and/or materials that can then be used by PK-12 STEM educators in their own teaching practice or scholarship of learning and teaching.

Bibliography

1. Parraguez, P. et al, “Information Flow Through Stages of Complex Engineering Design Projects: A Dynamic Network Analysis Approach,” *IEEE Transactions on Engineering Management*, Volume: 62, Issue: 4, Oct. 2015.

2. Ulrich, Karl and Eppinger, Steven (2000), Product Design and Development, 2nd edition, Irwin McGraw-Hill.

3. Leisher, P., “An Activity in Design for Manufacturability – Concept Generation through Volume Production in less than Three Hours,” Paper ID: 9232, *Proceedings of the* 121st *ASEE Conference and Exposition ,* Indianapolis, IN, June 2014.

4. Fredriksson, C. et al., “Facilitating the Teaching of Product Development,” Paper ID: 9776, *Proceedings of the* 121st *ASEE Conference and Exposition ,* Indianapolis, IN, June 2014.

5. Chang, G. A., & Peterson, W. R., “*Using Design for Assembly Methodology to Improve Product Development and Design Learning at MSU*,” *Proceedings of the 2012 ASEE Annual Conference*, San Antonio, Texas., June 2012; https://peer.asee.org/22182, ISSN # 2153-5965.

6. Devon R. & Jablokow, K., “Teaching Front End Engineering Design (FEED),” *Proceedings of the Fall 2010 Mid-Atlantic ASEE Conference*, October 15-16, 2010, Villanova University.

7. Sundaram, Ram, “*E = MC2: Excite Interest in Electronics through Projects that Motivate the Learning of Concepts through Circuits*,” Workshop at the 46th FIE conference, Erie, PA, October 12-15, 2016.

8. http://www.snapcircuits.net/