

Engage and Educate: Engineering Laboratory Activities for First-Year Engineering Students

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Abstract

This paper discusses the importance and effectiveness of structured hands-on STEM-related project-based engineering laboratory activities in the critical entry-level course, *First-Year Seminar in Engineering*, for undergraduate engineering majors at ABET-accredited institutions of higher education. At our institution, the *First-Year Seminar in Engineering* is offered once each year during the fall term. The enrollment in this course ranges from ninety to hundred first-year students who are expected to graduate with engineering degrees from the four-year ABET-accredited programs. One component of this course comprises hands-on engineering laboratory activities in sessions of short duration (fifty-five minutes apiece) in disciplines such as Biomedical Engineering (BME), Electrical and Computer Engineering (ECE), Environmental Engineering (ENV), and Mechanical Engineering (ME). In the short interval of time allotted for STEM-based laboratory experiences, the motivation, commitment, and level of engagement can range from total indifference to unbridled enthusiasm with the desire but inability to do and learn more. The broad goal is to deliver key aspects of the engineering design process, from concept-to-product (the *E* in *STEM*), during this short interval of time. Therefore, it behooves us to develop STEM-based, project-oriented laboratory activities that focus the student on well-defined, easy-to-attain, yet insightful experimental objectives. Breadth or system-level thinking is emphasized over depth or detailed analysis of the applicable engineering concepts. Since these students are just being introduced to the disciplines of engineering, the laboratory experiences are driven more by their powers of observation i.e. following the ‘seeing is believing’ paradigm rather than any rigorous analysis of the circuit and its outcomes. The learning of *M* in *STEM* which is associated with the observed evidence is expected to be addressed in subsequent engineering courses.

1. Introduction

The critical entry-level course at our university, titled *First-Year Seminar in Engineering*, is designed to orient the new student to the university and to introduce engineering as a professional field¹. The *First-Year Seminar in Engineering* intends to stimulate the interest of the incoming freshman undergraduate engineering student in broad and specific issues related to professions in engineering disciplines. In this regard, hands-on problem-based²⁻⁴ and project-based⁵⁻⁷ engineering laboratory activities and experiences form an integral part of this course. The students are expected to engage in laboratory activities, lasting about fifty-five minutes apiece, in each of the following laboratories – Biomedical Engineering (BME), Electrical and Computer Engineering (ECE), Environmental Engineering (ENV), and Mechanical Engineering (ME). Although the time interval for the engineering laboratory experience is short, it is possible to involve the student in structured and thought-provoking laboratory activities which emphasize some of the aspects crucial to STEM learning. One must note that these are students fresh out of high school, where they have been exposed, possibly to a greater degree, to the science (S) and mathematics (M) components rather than to the technology (T) and engineering (E) components of STEM. Therefore, any laboratory experience must target the T and E aspects of STEM and stimulate the interest in and process of integration of all four components within each student.

This paper discusses the implementation of laboratory activities in the ECE discipline which emphasize the importance of assembly, test, and validation steps of engineering design⁸. In order for the future engineers to gain some understanding of the concept-to-product process, these activities are focused more on experimental observation and data collection than on the critical evaluation of the design process and rigorous mathematical analysis. These aspects are expected to be the theme of the courses to be taken by these students in later years of the undergraduate degree program. This paper is organized in four sections. Section 2 outlines the set of structured ECE laboratory activities. Section 3 discusses the rubric for assessment of student participation. Section 4 summarizes the quantitative performance of the students. Section 5 presents the conclusions.

2. ECE laboratory activities

Figure 1 illustrates the flow of events during and after the ECE laboratory session. The duration of the session was fifty-five minutes. There were about twenty students, grouped into ten pairs, in each of four sessions across two weeks of the semester.

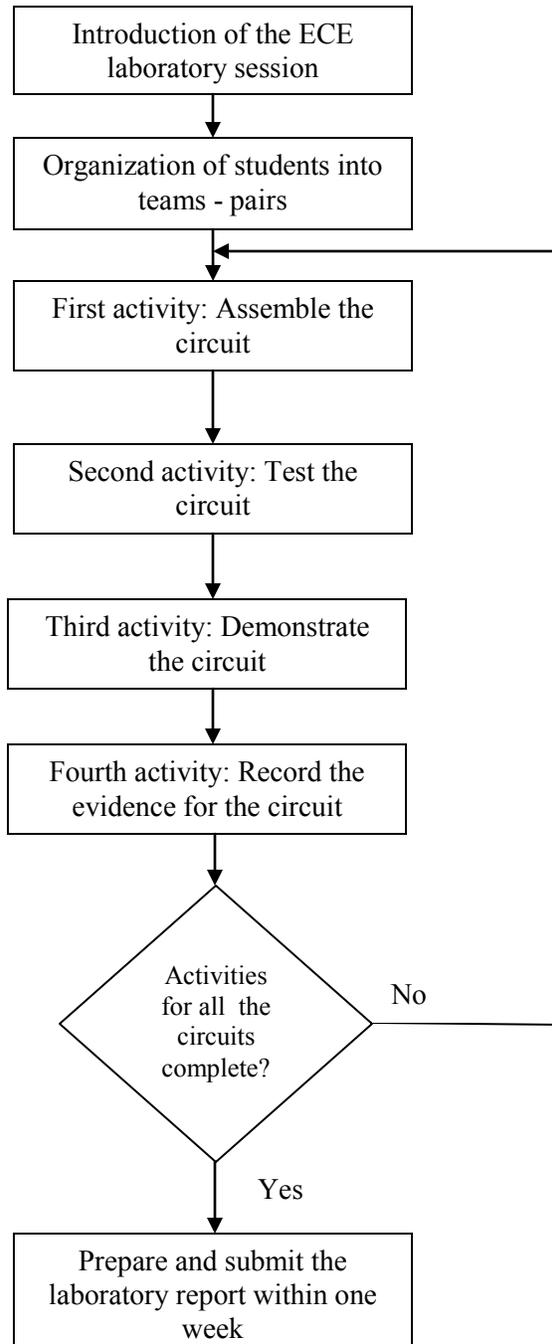


Figure 1: Flow of the ECE laboratory session

The ECE laboratory session is titled “ASSEMBLE AND TEST THE TIMER AND LOGIC CIRCUITS”. The theme or broad objective of the laboratory session is to configure and test the operation of electric circuits such as the timer and logic gates. The specific objectives are as follows:

- Build the timer circuit using a transistor and a relay
- Assemble logic gates using switches and LEDs
- Test the operation of the timer circuit and the logic gates

The introduction of the laboratory session comprised a brief overview of the circuit and the related laboratory activities. First, the equipment to be used is introduced. Each team of students would need to use the *SNAP CIRCUITS PRO* by Elenco. This is a kit that 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.

Timer Circuit

In this part of the laboratory activities, the students create a timer circuit that at the press of a button will turn on a light attached to the circuit, then after a set time, the light will turn off. The timer circuit is configured as shown in Figure 2.

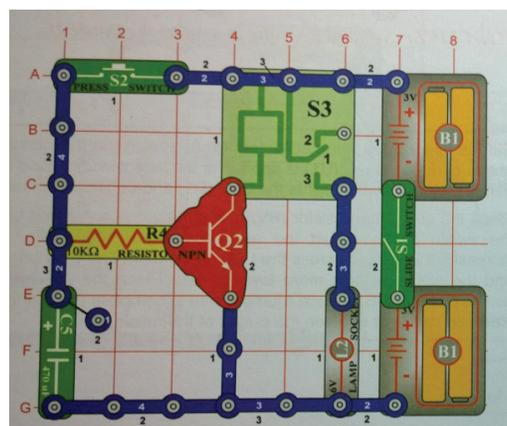


Figure 2: Timer circuit

The students are provided the following summary of the action of the timer circuit. Switch S1 is the main power source, allowing the current to flow from the batteries to the

circuit. When the switch S2 is pressed, the capacitor C5 charges, and this brings power to the base of the transistor Q2 through resistor R4. The transistor then allows current flow through the collector and emitter activating the relay S3, switching on the lamp L2. After a set time, the capacitor becomes de-energized, and the current through the base of the transistor no longer flows, deactivating the transistor, switching off the relay, turning off the lamp L2.

Lab exercises based on the timer circuit

First, the student teams demonstrate the operation of the circuit to the instructor. Then, they record the duration of time for which the light stayed on due to changes made to the value of the resistor R4 and the value of the capacitor C5. The settings and outcomes are tabulated for at least four choices of values shown in Table 1.

Table 1: Results for the test of the timer circuit

Resistor, Ohms (Ω)	Capacitor, Farads (F)	Duration, seconds (s)

Logic gates

In this part of the laboratory activities, the goal is to assemble and test logic gates using electric circuits. Typical logic gates perform the Boolean operations known as NOT, AND, NAND, OR, and NOR. For instance, the circuit shown in Figure 3 is the AND gate. This circuit required two switches.

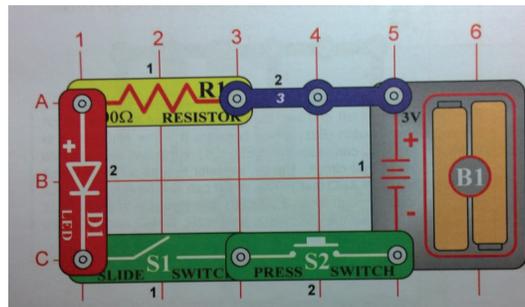


Figure 3: AND logic gate

Likewise, the students assemble and test the NOT, NAND, OR, and NOR logic gates. The lab exercises comprise demonstration of the operation of each circuit followed by recording of the outcomes in truth tables as illustrated in Table 2.

Table 2: Truth table for each logic circuit

Position of the switch S1 (ON/OFF)	Position of the switch S2 (ON/OFF)	LED LIGHT (ON/OFF)

Laboratory report

Each team is expected to prepare and submit the laboratory report with strict adherence to the guidelines that are provided. The report is due one week after the laboratory session.

3. Rubric for assessment

Table 3 illustrates the rubric for assessment of the student reports.

Table 3: Rubric for assessment

Laboratory Component	Level of Achievement			% of total
	5	3	1	
Design method and process	Clear specification and explanation of the design method and process	Unspecified and/or unexplained steps in the design method and process	No specifications or explanation of the design method and process	15
Implementation	Tools for implementation are identified and effectively used; working model submitted with accurate documentation	Tools are identified but not effectively used; working model is submitted but lacks accuracy in the documentation	No tools are identified and used; working model not submitted	20
Test & Validation	Complete and detailed test plan; evidence of validation of the method through results of the implementation	Test plan is not complete; results are presented without validation	Test plan does not exist; no results to validate the design method and process	30
Report	Organized in sections with accurate grammar and punctuation in the discussion; use of figures and/or tables to analyze the data; presents clear conclusions based on the validation	Some sections lack organization; contains inaccuracies in the use of grammar and punctuation; some use of figures and/or tables to analyze the data; incomplete conclusions	Lacks any organization of the content; poor use of grammar and punctuation; no figures and/or tables for data analysis; no clear conclusions	35

For each laboratory activity, the discussion of the design method and process, the implementation, the test and validation plan, and the flow of the overall report are judged to lie within levels of achievement as shown in the table. The percentage of the total points assigned to each category is clearly identified.

4. Student Performance

Table 4 illustrates the quantitative performance of the first-year students who engaged in this laboratory activity. The students were grouped into four sessions. In each session, the students worked in teams of two and prepared one laboratory report per team.

Table 4: Performance Data

Session #	Student count	Average score	Deviation
1	14	7.4	3.2
2	14	9.1	0.7
3	18	7.2	4.1
4	19	7.9	2.8

The laboratory activities of each student and the report of each team were graded according to the rubric shown in Table 3. Although this represents the activities in one of the engineering laboratories, i.e. ECE, it is clear that the students are engaged and committed to the learning process, with the attainment of at least a 70% average as the quantitative measure of their performance.

It should be noted that the 91% average performance of the students in session #2 represents a group of first-year students with both the proclivity and propensity to pursue ECE for their undergraduate degree. The students in this session appeared to be more familiar with the basic ECE concepts than those in the other sessions, likely having focused on this aspect of *S* in their *STEM* learning at the high school level. The activities conducted in the other engineering laboratories, such as BME and ME, reveal similar outcomes. The evidence is documented and used by the faculty members responsible for those activities.

5. Conclusions

The use of structured laboratory activities in the introductory First-Year Seminar course in Engineering helped achieve the following.

- Understand and perform engineering laboratory exercises
- Cultivate skills related to experimental observation and evidence collection
- Gain useful STEM experiences for future courses and engineering professions

Additional benefits of this learning experience are (a) *goal-oriented, self-directed learning* (SDL)^{9,10} to supplement *instructor-driven learning* (b) promotion of *pairing*¹¹ and *swarming*¹² to help student teams be more productive and produce higher quality work on the engineering design project.

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