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 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.**

Keywords – STEM engineering education, ECE laboratory

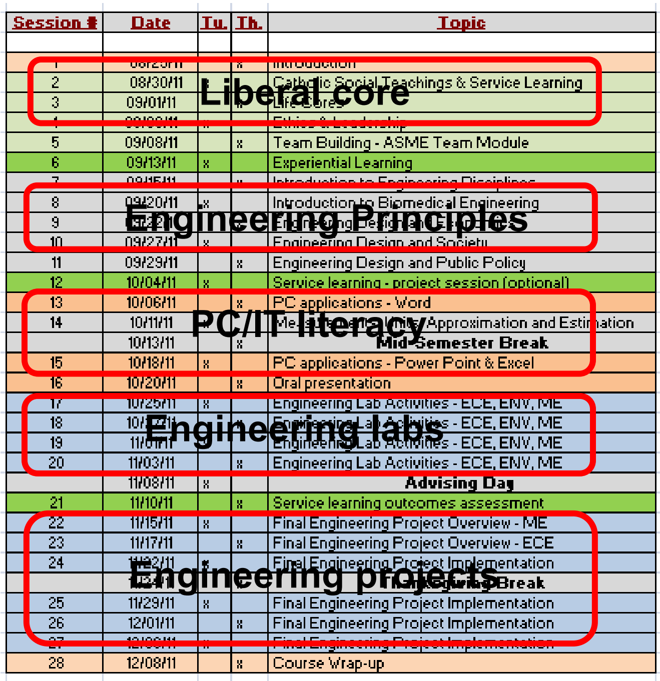
INTRODUCTION

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 field [1]. 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-based [2]-[4] and project-based [5]-[6] 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. Since this is a first-year seminar course which offers the student a broad overview of key aspects of the engineering profession and very limited specifics and details related to any engineering topics per se (to be experienced by these students in future courses within their chosen engineering discipline) , the intent of this paper is simply to expose each engineering student to a specific yet meaningful laboratory experience which targets the T and E aspects of STEM and serves to stimulate the interest in integrating all four components.

This paper discusses the implementation of laboratory activities in the ECE discipline which emphasize the importance of assembly, test, and validation steps of engineering design [8]. 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 six sections. Section 2 overviews the intended outcomes of the first-year seminar course. Section 3 outlines the set of structured ECE laboratory activities. Section 4 discusses the rubric for assessment of student participation. Section 5 summarizes the quantitative performance of the students. Section 6 presents the conclusions.

SECTION 2: COURSE OVERVIEW

The content of the seminar course is delivered in modules which focus on a *central engineering project* comprising *service learning components*. Service learning is of vital importance in the engineering profession and must be integrated into the engineering curriculum at an early stage of career development. Engineering projects with aspects of service learning are both challenging and motivating to students entering the engineering profession after STEM studies at the high school level. In addition to teaching the students engineering design and practice in the context of society and values, and instilling the recognition of engineering issues and concerns, engineering project activity with service learning incorporates reflection and collaboration as the critically required facets of engineering education. The course meets in 30 sessions during the term (15 weeks at 2 sessions per week). Figure 1 illustrates the grouping of the sessions as course modules each with the underlying theme as indicated. The underlying Session and Topic related details are only for broad reference and not the subject of discussion in this paper.



Session #	Date	Tu.	Th.	Topic
1	08/25/11		x	Introduction
2	08/30/11	x		Catholic Social Teachings & Service Learning
3	09/01/11		x	Life Cores
4	09/06/11	x		Ethics & Leadership
5	09/08/11		x	Team Building - ASME Team Module
6	09/13/11	x		Experiential Learning
7	09/15/11		x	Introduction to Engineering Disciplines
8	09/20/11	x		Introduction to Biomedical Engineering
9	[illegible]		x	[illegible]
10	09/27/11	x		Engineering Design and Society
11	09/29/11		x	Engineering Design and Public Policy
12	10/04/11	x		Service learning - project session (optional)
13	10/06/11		x	PC applications - Word
14	10/11/11	x		Measurement/Units/Approximation and Estimation
	10/13/11		x	Mid-Semester Break
15	10/18/11	x		PC applications - Power Point & Excel
16	10/20/11		x	Oral presentation
17	10/25/11	x		Engineering Lab Activities - ECE, ENV, ME
18	10/27/11		x	Engineering Lab Activities - ECE, ENV, ME
19	11/01/11	x		Engineering Lab Activities - ECE, ENV, ME
20	11/03/11		x	Engineering Lab Activities - ECE, ENV, ME
	11/08/11	x		Advising Day
21	11/10/11		x	Service learning outcomes assessment
22	11/15/11	x		Final Engineering Project Overview - ME
23	11/17/11		x	Final Engineering Project Overview - ECE
24	11/22/11	x		Final Engineering Project Implementation
	11/24/11		x	Thanksgiving Break
25	11/29/11	x		Final Engineering Project Implementation
26	12/01/11		x	Final Engineering Project Implementation
27	12/06/11	x		Final Engineering Project Implementation
28	12/08/11		x	Course Wrap-up

FIGURE 1
THEMES OF THE COURSE MODULES

The first-year students must work on experiments in the engineering laboratories to gain skills with assembly, testing, and validation of engineering systems. The students gather experimental evidence and write a laboratory report. This report measures the ability of the student to conduct experiments and analyze data, which are identified in the list of course and ABET student outcomes.

SECTION 3: ECE LABORATORY ACTIVITIES

The duration of each laboratory 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.

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 uses a kit that contains electrical components which 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 interval, the light will turn off. The timer circuit is configured as shown in Figure 2.

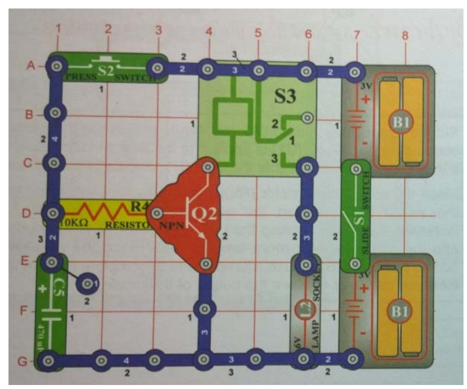


FIGURE 2
TIMER CIRCUIT

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 as shown in Table I.

TABLE I
RESULTS FOR THE TEST OF THE TIMER CIRCUIT

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

LEARNING GOALS OF THE TIMER CIRCUIT
Each student is expected to understand how changes in the value of the resistor and capacitor affect the duration for which the lamp stays lit. Specifically, the systematic experimentation process of altering one of the two (resistor, capacitor) at a time was expected to be implemented and the appropriate conclusions drawn thereof to be documented.

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.

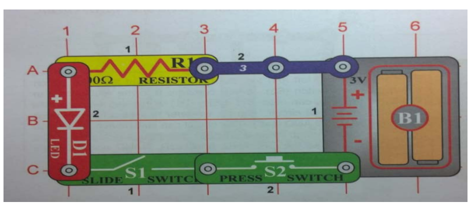


FIGURE 3
AND LOGIC GATE

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 II.

TABLE II
TRUTH TABLE FOR EACH LOGIC CIRCUIT.

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

LEARNING GOALS OF THE TIMER CIRCUIT
Each student is expected to understand how analog circuits can be employed to explain digital phenomena. The link between logic operations and the construction of the truth table is emphasized as part of the take-away from this activity.

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.

SECTION 4: RUBRIC FOR ASSESSMENT

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

TABLE III
RUBRIC FOR ASSESSMENT

Laboratory Component	Level of Achievement			%
	5	3	1	
Test & Validation	Complete and detailed test plan; evidence of validation of the method	Test plan is not complete; results are presented without validation	Test plan does not exist; no results to validate the design method and process	**40**
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	**60**

For each laboratory activity, 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 identified.

The course outcomes to which this engineering laboratory activity contributes are the following.

- Comprehend the basic topics in mathematics, science, and problem solving tools common to the engineering fields
  Ability to apply knowledge of mathematics, science, and engineering

- Demonstrate the ability to conduct experiments and analyze data
  Ability to design and conduct experiment, as well as to analyze and interpret data

The corresponding ABET student learning outcomes are highlighted in italics. The course outcomes and the corresponding student outcomes are assessed as follows: Excellent (E) is scoring 90 or better of the total points possible, Adequate (A) is 75 or better, Minimal (M) is 60 or better, and Unsatisfactory (U) is anything below 60.

SECTION 5: STUDENT PERFORMANCE

Student performance is assessed in the following two categories.

(1) In-lab activity
(2) Post-lab report

(1) In-lab activity
The instructor and one teaching assistant monitored the activity of each team. The assessment comprised categorizing the commitment of each team member to assemble, test, and validate the laboratory exercises in the following broad categories – highly motivated, moderately motivated, lacking and/or completely unmotivated. Each circuit assembled by the team was tested in the presence of the teaching staff. The in-lab activity contributed to the first category in the rubric shown in Table III wherein the test and validation was evidenced during the lab session.

(2) Post-lab report
The guidelines to prepare the post-laboratory report as well as the assessment rubric for this component (shown in Table III) were provided. Each team submitted one report which included the evidence and discussion pertinent to each laboratory activity.

Additional evidence from the assessment
Table IV 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.

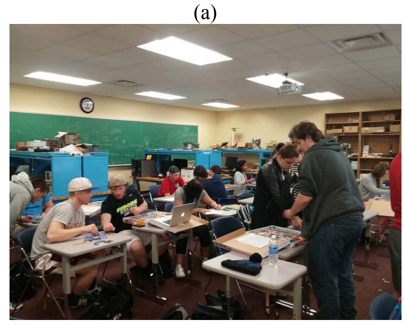
TABLE IV
STUDENT PERFORMANCE

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 III. 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. Figure 4 shows sample evidence of instruction and student activity during each ECE lab session. The teams are observed to be actively engaged in the exercises. Due to the short duration of these laboratory activities (fifty-five minutes), the assembly and testing must be completed in a timely and efficient manner.

(a)



(b)

FIGURE 4
ACTIVITY IN THE ECE LABORATORY

SECTION 6: 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) [8], [9] to supplement *instructor-driven learning* (b) promotion of *pairing* [10] and *swarming* [11] to help student teams be more productive and produce higher quality work on the engineering design project.

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