

A Hands-on First-year Electrical Engineering Introduction Course

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Abstract

In this paper, we present successful endeavors in establishing a new first-year introduction to Electrical Engineering (Intro to EE) course curriculum at Western Washington University. This course embraces a unique combination of seminar-style guest lectures in conjunction with a series of hands-on laboratory exercises. This course was developed to achieve a number of goals: providing an overview of the EE profession, careers, and the field in general; introducing the pre-major students about the EE curricula and have an understanding of various course sequences in the EE program; exposing students with essential EE lab instruments and common software tools; and inspiring students to study the EE major.

To achieve the aforementioned goals, we have designed this pilot course which consists of a 50-min lecture session and a two-hour hands-on laboratory session each week for a ten-week span. In each lecture, a guest speaker from local industry and/or professional societies gives a talk on subjects related to their EE profession. Each weekly laboratory session is composed of fun hands-on exercises which focus on a variety of aspects including software, circuitry, and microcontroller programming through real-life examples.

In order to gauge the effectiveness of the Intro to EE course, we conducted student surveys from the group of students who took this class in winter 2016 and were admitted to the EE program in spring 2016. The students' feedback from the survey results and their final exam performance demonstrated that this course has achieved the targeted goals and desired learning outcomes to a satisfactory level.

I Introduction

For most Electrical Engineering programs, the first major course that students would typically take is an introductory course, often named as Introduction to Electrical Engineering (Intro to EE) or a similar name. For such introductory courses, there might be dramatic differences in terms of course content, targeted learning outcomes, and assessment¹ which require different teaching and delivering methods. There are typically two major formats of such introductory courses. The first type is what we refer to as the traditional course type (e.g., the intro class offered at Columbia University², MIT³, Northwestern University⁴, etc.) which covers fundamental elements of electrical engineering and focuses on topics in circuit analysis, system models, op-amp, RL/RC circuits, or other selected topics as needed. Some common features of this traditional type of introductory classes include:

- Students learn the technical topics in lectures taught by an instructor and
- Students work on hands-on laboratory exercises that are aimed to enhance students' understanding of the topics and/or to achieve other learning outcomes. The labs are aligned with topics introduced in lectures.

The Intro to EE course offered at our institution is very different from the aforementioned traditional introductory courses. It represents the other type of introductory course which does not focus on technical topics (i.e., circuit laws, op-amp, and so on) during the lecture portion. Instead, the lectures are structured in a seminar style which consists of a series of sub-topics that are aimed at motivating students and exposing students with the EE profession, career options, project design and development fundamentals, ethics, professional societies, and the EE curriculum and program overview. The Intro to EE course also includes a weekly hands-on laboratory session aimed at introducing students to common EE instruments, software and hardware tools, and providing a fun design experience using a simple and low-cost microcontroller (MCU) platform.

This second type of introductory course has gained popularity nationwide. For instance, University of Arkansas in 1990's redesigned its Introduction to EE course with an emphasis on motivating EE Freshmen⁵ and introduced various teaching elements such as guest speakers and senior students' presentations. The Introductory course (entitled as "Exploring Electrical Engineering") at Portland State University was recently created for improved motivation and early introduction of design⁶. At University of Florida (UFL), the Introduction to Electrical Engineering course⁴ resembles our intro course and has similar pedagogical goals as ours at Western Washington University. It focuses on "Introduction to electrical and computer engineering tools -- hardware and software. Professional ethics, career development. To provide hands-on experience, students assemble and test hardware projects."⁷

As a summary, it can be stated that the common attribute of the second type of introductory courses is the combination of overview of the electrical engineering field, career opportunities, and other non-technical topics delivered in lectures with a hands-on design experience using simple circuits, sensors, and software tools in order to achieve a number of course outcomes.

Despite of these similarities, our Intro to EE course presents a few unique aspects that are different from the one offered at UFL or other institutions. In particular, the lectures in our intro class are in the form of guest talks given by industry professionals (working and/or retired engineers, managers, and engineering consulting firm founders/owners) rather than by a single instructor (from the EE program).

In addition, to facilitate student preparation for a successful engineering learning experience, we also have selected a well-received textbook as the reading material

for students to study outside of class and complete regular weekly homework assignments. Details of the textbook and homework are provided in Section II.

The hands-on laboratory exercises and course projects of this course have been carefully designed and offer promising benefits. These labs focus on a variety of topics including software, circuitry, and microcontroller programming through real-life examples. Through these hands-on activities, we strive to make this introduction class a fun and engaging experience and to keep students engaged while taking other general subjects such as math, chemistry, and physics courses. The team-experience gained through the final course project also helps students develop essential teamwork skills.

As indicated by student survey results, the guest talks have been well acknowledged by students and have been valuable assets of the Intro to EE course. The hands-on lab curriculum of this course has shown to be a successful endeavor as well. Some of these hands-on activities can be adopted as tools to engage K-12 students to inspire them to study STEM majors. We will further elaborate such possibilities in Section III. Our experience of offering the Intro to EE course in winter 2015, 2016 (and 2017) validated that this pilot course has been successful in achieving its targeted goals and student learning outcomes. It may also be possible for other EE programs to adopt a similar introductory course in their EE curricula.

In the succeeding sections, we will present the general course content, its organization (textbook, homework, student performance evaluation mechanism, etc), the pedagogical objectives, and student learning outcomes. We will also elaborate the scope of the guest lectures, provide detailed information about the guest speakers and how we recruited them, and discuss the developed hands-on lab exercises and course projects, respectively. Assessment results in terms of student survey are provided in Section IV. Finally we conclude in Section V.

II Overview of the Intro to EE Course

The Intro to EE course in our program is offered to EE pre-majors as a freshmen course (with 2 credits) in the winter quarter (a ten-week span) of the freshmen year. This is the first EE course and is a required course for admission to the EE major. Currently the EE program in our institution offers two concentrations: the EE-Electronics track and the EE-Energy track. All prospective EE students need to take this intro class.

The intro class consists of a weekly fifty-minute lecture in conjunction with a weekly two-hour hands-on laboratory session. The only prerequisite (or

concurrent requirement) is a physics course that lays out basic elements of circuit theory such as current, voltage, and resistive circuits.

This Intro to EE course is not designed to introduce students with technical content as in traditional introductory courses. Instead, we focus on non-technical topics as stated in the course catalog: “General overview of the field of electrical engineering and the electrical engineering program curriculum. Introduction to common lab instruments and software tools through basic project design and testing”.

Specifically, the course objectives are as follows:

- providing an overview of the EE profession, careers, and the field in general;
- introducing the pre-major students to the EE curricula and have an understanding of various course sequences in the EE program;
- exposing students with essential EE lab instruments and common software tools; and
- inspiring students to study the EE major.

The desired students’ learning outcomes are summarized in Table 1 and tie to the ABET SOs.

Desired Learning Outcomes: Upon completion of this course, the student should be able to:	
1.	List possible career options in the field of Electrical Engineering
2.	Demonstrate an understanding of the electrical engineering program curriculum
3.	Demonstrate appropriate use of electrical engineering lab tools (instruments and software)
4.	Successfully design, construct, and program a simple MCU-based project
5.	Demonstrate the ability to work as a team

Table 1: Desired learning outcomes of the Intro to EE course

II.1 Information on Guest Speakers and their Presentation Scopes

As we noted in the preceding Section, the lectures are composed of a series of guest speaker presentations which focus on different aspects pertinent to the EE profession and the EE program curriculum. The guest speakers have been recruited with thoughtful consideration of their areas of expertise, career paths,

and roles in their profession. We have relied on the following sources to successfully recruit guest speakers:

- Members of the Industrial Advisory board (IAB) of the EE program in our institution. The IAB members are representatives from local industries, national research labs, and/or higher education institutions.
- Connections of faculty members of our EE program. Several speakers have been recommended by colleagues in the EE program.
- Alumni from our EE program. Our graduates have been well-placed among employers in a variety of professional roles. They are the best assets of our program. Per students' feedback, the Alumni's presentations have been rated as having the biggest impression on students.

Next, we provide a summary of the scope of guest talks, the areas of expertise of speakers, and typical lecture schedules for winter 2016/2017 offerings.

Week 1	Speaker: the instructor Topics: Course Overview and Syllabus, Intro to the field of EE
Week 2	Speaker: Joe Decuir (Area: wireless communication) IEEE Fellow, past IEEE NW region chair Topics: Career advice, career path, IEEE, and IEEE student branch
Week 3	Speaker: Todd Morton Professor and program director, EE program Topics: EE program overview and curriculum with Q/A session
Week 4	Speaker: Aaron Michelle (Area: analog and digital circuits) Alumni, Electrical Engineer, Wood Stone Corporation Topics: Career advice and projects completed
Week 5	Speaker: Kyle Williams (Area: Electronic display systems) Alumni, Engineer, Daktronics Inc. Topics: Career path, advice, and projects completed
Week 6	Speaker: Evan Anderson & Trevor Owen (Area: Hardware design and testing/software coding for communication applications) Alumni, Lead Engineer & engineer, Alpha Tech Inc. Topics: Career advice and project design and development
Week 7	Speakers: Jacie Unpingco, Victor Perez, & Dustin Sjoerdsma (Area: embedded systems, system testing) Alumni, Engineer, Paccar Tech Center. Topics: Career advice, project management, and teamwork
Week 8	Speaker: Gary Braaksma (Area: power systems and energy) Founder and owner, Braaksma Engineering Inc. Topics: Career path, advice, and power system projects completed
Week 9	Speaker: Dan Zumwalt (Area: software development) Alumni, Engineer, Microsoft. Topics: Career path and career preparation, projects completed
Week 10	Final exam review and course wrap-up

Table 2: Guest speaker information and scope of guest talks

As shown from Table 2, the speakers come from a broad background with a variety of areas of expertise, which showcases different aspects of the EE field.

II.2 Textbook, Homework, and Other Course Components

Although there is no formal lecturing on technical topics during the weekly lectures, we have selected a well-received textbook for students to study independently. The textbook introduces students to important aspects of studying an engineering major and provides valuable suggestions on how to be an effective learner. It is a good complement to the guest lectures and the hands-on lab activities.

The textbook information is given as follows:

Title: “Studying engineering (a road map to a rewarding career)”, 4th edition

Author: Raymond Landis

Publisher: Discovery Press

ISBN: 9780979348747

A weekly homework is assigned and the homework problems mostly come from the textbook content together with some questions related to guest presentations and lab topics. Below are a few examples of homework assignment:

- What type of learner you are (between sensing learners and intuitive learners)?
- The author discusses that learning is a reinforcement process. He also provides the five-item example (in a table) of the reinforcement process at its best on page 97. Have you also adopted such five-step approach when you took a WWU course? If not, which steps were you missed?
- Specify the steps involved in a general problem-solving methodology.

Given the various course components, student performance has been evaluated using the following mechanism as listed in Table 3.

Homework	12 %
Attendance	3%
Labs	35%
Project 1&2	5%+15%=20%
Final Exam	30%

Table 3: Course components and weight distribution for Intro to EE course

III Hands-on Laboratory Coursework

The weekly two-hour hands-on laboratory exercises and weeks-long course projects provide students opportunities to experience Electrical Engineering in an engaging manner. Specifically, there are five lab exercises and two course projects that students complete during the ten-week span. The developed laboratory coursework in this Intro to EE course has been aimed to familiarize students with common EE lab instrument and tools and to inspire students to pursue the EE major, in addition to achieving desired student learning outcomes #3, #4, and #5 as listed in Table 1.

The lab exercises and course projects focus on a variety of topics including software simulation using MatLab, circuit construction and testing, and microcontroller programming through real-life examples using the Arduino board and sensors. We have strived to achieve a balance between the broadness of the lab topics and the manageable challenge levels. We also have tailored the lab exercises such that most students should be able to finish the required lab tasks within the two-hour period given appropriate tutorial training.

Table 4 summarizes the lab coursework adopted in winter 2016/2017 offering. In Figure 1, we also provide several labs and course projects photos.

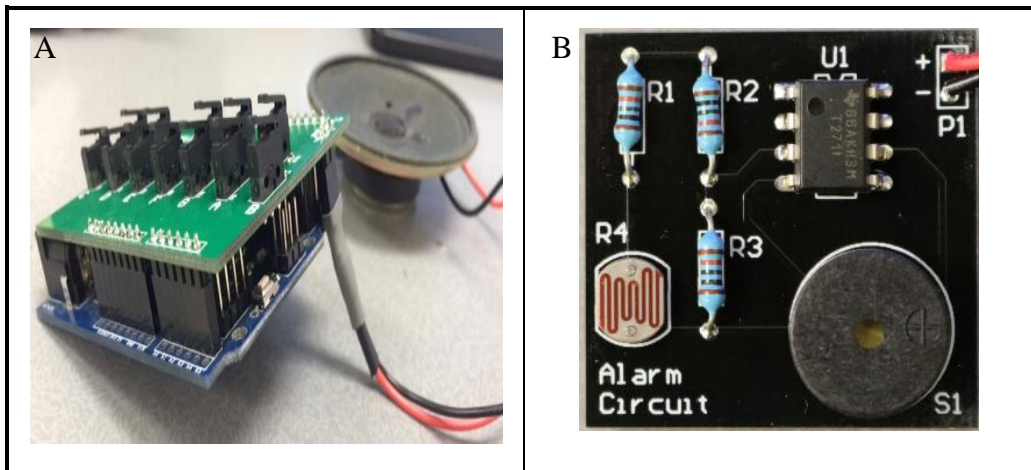
Lab 1: Scope: Software simulation	Tutorial: Matlab and Matlab GUI programming Lab topic: create a MatLab GUI to simulate digital piano keyboard
Lab 2: Scope: Circuit construction and testing	Tutorial: Introduction to common EE lab instruments and hands-on tools Tutorial: Breadboard prototyping and basic circuit components Lab topic: build a simple alarm circuit using light sensor, buzzer, and an op-amp
Lab 3: Scope: Arduino-based MCU application	Tutorial: Introduction to Microcontroller – Arduino basics I Lab topic: Arduino-based electronic piano
Project #1: Scope: Soldering PCB	Tutorial: Introduction to soldering Project #1 topic: “Soldering an alarm circuit onto a PCB” (two weeks to finish)
Lab 4: Scope: Arduino-based MCU application	Tutorial: Temperature sensor working with Arduino Lab topic: Arduino-based temperature monitor system
Lab 5: Scope:	Tutorial: Intro to Microcontroller – Arduino basics II (control motors and line tracking)

Arduino-based MCU application	Lab topic: Arduino-based motor control and line tracking
Project #2: Scope: Arduino-based MCU application	Project #2 topic: “Designing Arduino-based robot car” Alternative project #2 topic: “Designing Arduino-based solar tracking” (three weeks to finish)

Table 4: developed laboratory coursework for winter 2016/2017 offering

Among these laboratory activities, the 3-week long course project #2 offers students a greater learning experience. Students are required to work in a team of two or three members to design, build, and test either an autonomous track-tracing Arduino-based robot car or an autonomous Arduino-based light tracking system for a solar energy application. The students choose one of these two project #2 topics according to their interest of study (i.e, the EE-electronics concentration or the EE-energy concentration). Through completion of the course project #2, students practice the multi-step engineering design process and gain teamwork skills.

Some of these hands-on lab curricula can be adopted as tools to engage K-12 students and to inspire young students to pursue STEM degrees. For instance, labs 1, 2, 3, and the two course projects can be attractive to young students. Recently, the instructor of the Intro to EE course hosted two groups of 4th and 5th graders from local schools during an on-campus outreach event. The young visitors were very interested in the digital pianos (both MatLab simulation and the Arduino-based) and the light sensor-based alarm circuit. We foresee that the Arduino robot car and the Arduino light tracking system would bring fun exposures and generate interests to the young students as well.



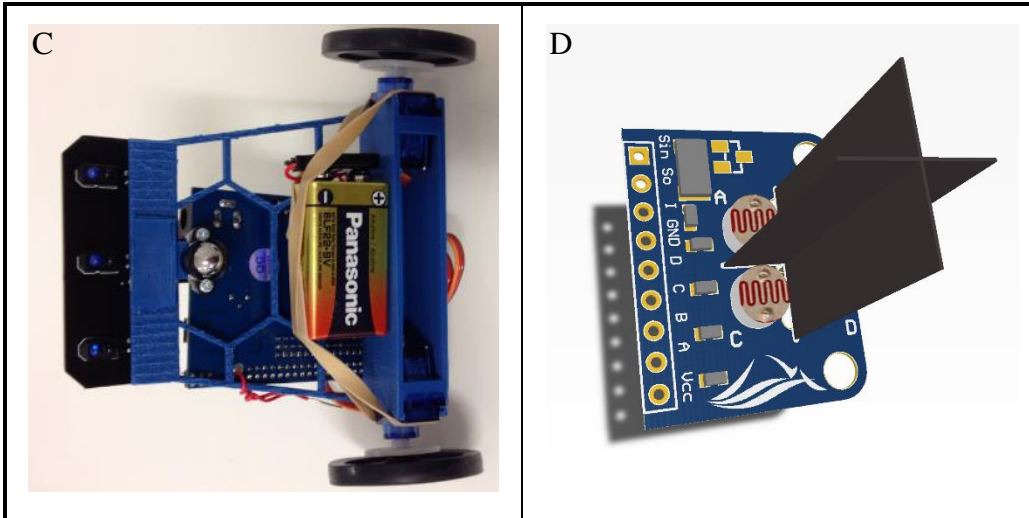


Figure 1: (A) Arduino electronic piano (B) Alarm circuit PCB (C) Arduino robot car (D) Solar tracker

IV: Assessment Results

To gauge the effectiveness of the developed pilot Intro to EE coursework, we have adopted the following assessment measures:

- Student feedback in the form of survey questionnaires were collected from students who took the intro class in winter 2016 and later were accepted to the EE program. The surveys were taken in fall 2016 while this group of students were enrolled in two other EE courses. As such, their feedback was based on the retrospect of this intro course. We consider such feedback may be more valuable and useful in assessing the effectiveness of the developed coursework compared to the feedback from the entire class which consists of students who took the class but did not apply for the major.

The student survey results are summarized in Table 5 with twenty student responses received. We noticed that several students did not answer some of the questions. The majority of students felt that the hands-on labs and course projects were engaging, the guest talks were helpful for students to know the EE profession, and the EE program overview talk was valuable. A majority of the students recognized that the lab coursework had inspired them or increased their motivation to pursue the EE major.

Such feedback confirms that this pilot intro to EE course has achieved the targeted pedagogical goals and desired student learning outcomes.

A few other observations have been made based on student feedback. Many of the students think highly of the Alumni's guest lectures. They also spoke very positively about the Arduino-based robot car project. Constructive suggestions were also provided by several students. For example, one student noted that it would be great if the EE program and curriculum talk could cover more in-depth discussions about what to be learned in each EE course. Another student suggested offering more explanations during lab tutorials if time permitted. Two students pointed out that they would like to work on more MatLab-based lab exercises.

We will consider incorporating these suggestions in our future offering of this course.

V. Conclusions

In this paper, we present a pilot introductory course offered to Electrical Engineering pre-major students. The intro class offers a combination of weekly guest lectures by industry professionals and a series of engaging hands-on laboratory activities. The guest talks are aimed at introducing students to different aspects of the EE profession, the EE field, and the EE curriculum. The developed hands-on lab exercises and course projects embrace software simulation, circuit construction and testing, and microcontroller applications. The assessment results demonstrate that, in addition to achieving the desired student learning outcomes, the intro class coursework also stimulates students' interests in studying the EE major. Moreover, some of the lab curriculum might be used as outreach tools to engage K-12 students in pursuing STEM majors.

Questions	Strongly Agree	agree	disagree	Strongly disagree	Additional comments
Were the hands-on lab exercises fun and engaging?	55% (11)	40% (8)	5% (1)	0%	
Did the hands-on lab exercises help you familiar with common EE lab instruments?	20% (4)	70% (14)	10% (2)	0%	
Did the hands-on labs stimulate or increase your motivation to study in EE major?	20% (4)	60% (12)	5% (1)	0%	

Was the project an engaging experience?	45% (9)	40% (8)	10% (2)	0%	“My team is older and did not treat it seriously” “I loved the creativity portion”
Do you feel the teamwork experience (through completing labs and the project) - is valuable? - help develop teamwork skills?	55% (11)	40% (8)	5% (1)	0%	
Were the guest lectures useful for you to know the EE profession (such as careers)?	35% (7)	45% (9)	15% (3)	0%	“Too early and too technical”
Did the “EE program overview talk” help you understand the EE curriculum and the program?	25% (5)	65% (13)	10% (2)	0%	“More in-depth about what we will learn in each class”

Table 5: Students’ survey results from students who took the intro class in winter 2016 and were accepted to the EE major.

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