# Assessment of an Introduction to Electrical Engineering Laboratory Course

**Dr. Gary H. Bernstein, University of Notre Dame**

Ph.D. in Electrical Engineering, Arizona State University, 1987. University of Notre Dame, 1988-present. Frank M. Freimann Professor of Electrical Engineering. Research in nanotechnology. Co-founded Indiana Integrated Circuits, LLC (www.indianaic.com).

**Dr. Kerry Meyers, University of Notre Dame**

Dr. Kerry Meyers holds a Ph.D. in Engineering Education (B.S. & M.S. Mechanical Engineering) and is specifically focused on programs that influence student's experience, affect retention rates, and the factors that determine the overall long term success of students entering an engineering program. She is the Assistant Dean for Student Development in the College of Engineering at the University of Notre Dame. She is committed to the betterment of the undergraduate curriculum and is still actively involved in the classroom, teaching students in the First-Year Engineering Program.

# Assessment of an Introduction-to-Electrical-Engineering Laboratory Course


## Abstract

A new Sophomore-level course, entitled "Introduction to Electrical Engineering Laboratory," was developed at a medium-sized, Midwestern, private institution. The course was taught for the first time in the Fall semester of 2015, and again in the Fall of 2016. It is a required course for students majoring in both electrical engineering and computer engineering. The second offering incorporated a pre- and post- course assessment of the content and student perceptions of their knowledge of the content areas. This two-credit course comprises one 50-minute lecture and one three-hour laboratory session per week. There are ten laboratory sessions incorporating nine separate topics of interest to engineers and scientists, with an emphasis on topics to be seen in later EE courses. The goals of the course are to a) foster an appreciation for the importance of electrical engineering at the level of modern civilization, b) have students understand simple circuits and be able to reason through electrical systems, c) introduce students to conceptually advanced material, such as frequency domain, in preparation for future courses, and d) develop a strong foundation in electronic lab bench skills. The results of the pre-and post-survey assessment found that students increased their knowledge and confidence in course material. There were no statistically significant differences between male and female students, lower and upper division students, nor engineering discipline.


## Introduction

A faculty committee was tasked to evaluate and improve the curriculum in the Department of Electrical Engineering at the University of Notre Dame. The committee identified the need for more context for the students' newly chosen field of study. In response to this, it was decided that the previous 4-credit "Introduction to Electrical Engineering" course, EE 20224, should be shifted from a substantially circuits course to a broad overview of topics in electrical engineering. In order to retain the total curriculum credits (at 128), the 4-credit 20224 course was split into two 2-credit courses, namely EE 20224, which continues to cover an introduction to electrical circuits, and the new EE 20225, "Introduction to Electrical Engineering Laboratory." The previous EE 20224 course included a weekly, 3-hour laboratory in which students programmed microcontrollers to demonstrate various circuit concepts. EE 20225 now incorporates the weekly laboratory activities. The total number of 50-minute lectures for the two courses remains at three with two devoted to EE 20224 and one to EE 20225. Prior to rolling out the first offering of the course, the Department of Electrical Engineering chose to spend funds of about $175k that had accrued for over a decade to upgrade 14 oscilloscopes to modern, 4-channel digital scopes with accessories. Also, several educational trainer tools were developed and introduced at each lab bench, as will be discussed below. The facility, which accommodates up to 24 students at 12 benches per session, was also physically expanded and provided with new lab benches. Although good arguments can be made for an "open laboratory[1]," we chose to have two to three graduate TAs per session closely supervising the students' activities in order to help them achieve success within the three-hour sessions. Our informal observation is that this minimizes frustration on the part of the students, and enhances learning and progress in the limited time available.

The new pair of courses was taught first in the Fall of 2015 and for the second time in the Fall of 2016. This paper discusses the results of the first two offerings of EE 20225, including an assessment of student learning and perceptions performed in the 2016 offering.

EE 20225 is a completely new course with over 250 pages of original reading materials that include nine original learning modules with laboratory activities spanning ten weekly 3-hour sessions. For each lab module, students read about 30 pages of topical materials, including the laboratory directions, submit a prelab assignment, attend the lab sessions, and submit a lab report that includes the notebook created during the lab, printouts of results, and answers to questions intended to help them think more deeply about what they are doing as they perform the activities. One full weekly module comprises a Friday morning lecture that covers the concepts and some lab issues, followed by the related 3-hour lab sessions held Monday to Thursday afternoons.

At the University of Notre Dame, all engineering students share a common First-Year of Engineering in which they are exposed to various engineering disciplines and choose a field of study that begins in the Fall of their third semester. The Intro to EE course is taken by those incoming, third-semester EEs as well as fifth-semester computer engineering (CPEG) students (from the Department of Computer Science and Engineering, which is distinct from Electrical Engineering). CPEG students take at least five courses in EE as part of their curriculum. These cadres of students are joined by several students from other departments who take it as an elective, which so-far has included Chemical Engineering, Mechanical Engineering and Physics. Each year there have been a few female students from our sister school, Saint Mary's College, which is adjacent to Notre Dame, who take this course in their fifth semester, and are counted amongst the EE students. A total of 52 students (26 EE) were enrolled in 2015 and 74 students (41 EE) took it in 2016. There was no single reason identified that could explain the significant increase in enrollment in the second year.

## Course Goals

According to Feisel and Rosa, undergraduate laboratory instruction often suffers from a lack of defined learning objectives, and they review thirteen objectives that resulted from a 2002 colloquy on undergraduate laboratory instruction[2-3]. Yadav et al. assert that problem-based learning (PBL) has advantages over deductive learning in which theory comes first before problem solving is initiated[5]. The authors claim that the pedagogical approach of deductive learning "…falls short because the knowledge is not grounded in context and not specific to the situation in which the task needs to take place[5]." We agree with this, but have designed our lab course to provide context to the activities without going so far as to require the advanced level of problem-solving skills needed for problem-based learning. Other researchers have recognized the need for beginning students to first learn to follow directions accurately[6], even before taking on more complicated activities. Montes et al. discuss the method of "Laboratory Practice Based on Questions[7]," which uses "Vee Mapping" of student-initiated questions and methods of applying theory to practice in the laboratory[8]. Although PBL has its successes[9], it has also been observed that PBL can sometimes result in less class material being presented as a trade-off for professional skills[5,10]. We based our course on the belief that the students to whom this course was directly geared (i.e., third-semester EEs) needed more information (or deductive learning) at this point in their education than some of the higher-level skills (e.g. communication and teamwork) that PBL or capstone courses emphasize.

From the outset, we defined several objectives that we felt were appropriate to the needs of our students, in particular at the start of their electrical engineering curriculum. The overarching objective, to expose students to a wider range of topics related to EE, underpins all of the activities, but several more were identified and incorporated into the design of the course. It turns out that the objectives of this course differ in a significant way, namely that it is designed to prepare students for their upcoming courses more so than directly for their intended careers. The emphasis in the readings is on both the relevance of EE as it pertains to technology that students can relate to, e.g., MP3 players, and to global problems, e.g., energy efficiency, as well as what will be taught in various courses that they will see in their next two or three semesters, and less on "what an electrical engineer does in her/his career."

The course goals are listed and discussed below:

1. *Expose students to a wide range of EE-related topics.* The choice of topics is necessarily limited by the constraints of a single semester, so it is not possible to discuss many of the areas of electrical engineering represented by the 39 societies of the IEEE. Rather, topics were chosen that were thought to shed light on everyday types of experiences, such as listening to digital music, understanding an electrical wall socket, looking up at high-voltage transmission lines, or choosing a "simple" lightbulb at the local hardware store.

2. *Place the field of electrical engineering into a global economic, political and environmental perspective*. Context is important for student motivation; current events, such as global climate change, energy efficiency, etc., may be strong motivators for some students who wish to be involved in a socially relevant field.

3. *Introduce concepts earlier in the curriculum.* Because of unavoidable time constraints in a typical engineering course, students may often be given only a cursory exposure to underlying concepts before the start of the associated mathematical rigor. This course introduces some advanced concepts and topics earlier in the curriculum, and allows students to spend more time reading and thinking about them, and experimenting with them in the lab. Examples include shape, frequency and phase of waveforms, duality of time and frequency domains, filters, Fourier spectra, sampling, aliasing, and more (see module topics below). As such, this course allows students to "play" with the concepts for an extended period before the later mathematical coursework is presented.

4. *Provide hands-on experience in lab-bench equipment use.* The oscilloscopes used in this course are Teledyne LeCroy Hdo4104, which offer 4 channels and powerful fast Fourier transform (FFT) capabilities, allowing the students to easily experience frequency-domain

concepts while performing their experiments in the time domain. We also provide inductive current probes in order to simplify the measurement of current wherever needed (as opposed to inserting an ammeter or using a shunt resistor). This course at times uses all four channels, plus X-Y mode and FFT capabilities in a single activity. Students save and print screen shots and append to their notebooks. Each week adds the need to explore more functions of the equipment, including the power supply, function generator, DMM, graphic equalizer, impedance analyzer, and current probe, so students continue throughout the semester to add new capabilities to their measurements skill set, and have provided feedback that they feel very prepared for follow-on electronics and other laboratory courses that use the same facility.

5. *Introduce some technical areas that may be overlooked in typical EE curricula.* Many subjects are not covered in a typical curriculum, with the assumption that students will surely pick up the material somehow. We feel that certain technical areas should be presented that might otherwise "slip through the cracks." For example, students appreciate knowing in considerable depth what exactly is a wall outlet and what exactly is the role of each of the three openings. We feel that such information helps them to gain practical knowledge early on, and feel more connected to the "real world." Such topics presented in the course include extended discussions of soldering, "common" and "ground" (especially the use of Earth ground), power lines, house wiring, breakers, ground fault interrupters, amplifiers, radios, solar cells, and batteries.

6. *Give students a sense of accomplishment and confidence at the outset of their studies.* By introducing the materials in Goal 5, as well as many areas that they experience in daily life, such as the power grid, radio transmission, digital music reproduction, solar cells and much more, and provide a deep experience into the use of the lab bench equipment, students gain a "can-do" attitude about their studies.

**Module Topics**

The topics covered in the course comprise nine modules, each devoted to a distinct topic, including nine lab activities in ten laboratory sessions. The module topics are:

M1. *Introduction to electrical components through soldering of an AM radio kit.* Being early in the semester, no circuit knowledge is assumed. An amplitude modulation (AM) radio kit (Elenco AM-780K), supplied to all of the students, is built during the lab. Each student builds his/her own radio. Students read about all of the common electrical components, from resistors to speakers, and learn to recognize them as they gain hands-on soldering experience. Students seem to take pride in a clean soldering job and a working radio. The radio is used in M5 as part of their bench-top radio station.

M2. *Introduction to the lab bench equipment.* The oscilloscope, digital multimeter (DMM), power supply, function generator and current probe are introduced. By this time in the semester (third week), students have learned about current and voltage dividers in EE 20224. Here, bread-boarding is introduced, and students build simple resistor networks as current and voltage dividers. They use DC and AC sources and measure voltages and currents using the DMM and oscilloscope. A variety of activities allows them to explore the basic functions of each of the core bench tools.

M3. *Power transmission.* Time-wise, this is the most intensive module of the semester. Out of necessity, we developed our own benchtop, low-voltage, 3-phase power supply whose amplitudes and phases can be adjusted. This course has students use the 3-phase supply, several transformers, and loads to model an entire power grid, with substations and even reactive loads, on their benches (Fig. 1). Students learn about amplitude and phase, 3-phase power transmission, house wiring, neutral wires, Earth ground, transformers, wye and delta circuits, and power factor by building up the entire system in small steps.

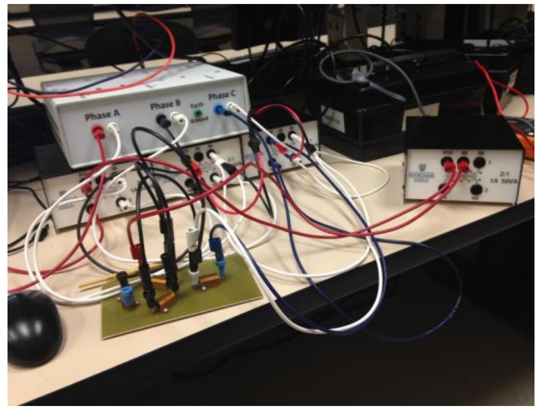


**Figure 1. Module 3, 3-phase power supply, transformers and load board.**

M4. *Introduction to time and frequency domains and filters.* Students build simple RC filters and investigate their frequency response. They investigate the frequency spectrum of sine, square and triangle waves. We introduce a graphic equalizer (JBL DBX 1231) as an easily configurable filter to modify the spectra for all of the waveforms and relate the shapes of the modified waveforms to their new spectra. The objective is to have them begin to think in the frequency domain and to understand the relationship between the shapes of the waveforms and their spectra.

M5. *Maxwell's equations, radio waves, and amplitude modulation.* Here we introduce electromagnetic waves, their spectra, antennas, modulation, and the frequency characteristics of amplitude modulation (AM). Students use the function generator with built-in AM functions to directly investigate the waveforms in both time and frequency domains to view the carrier and sidebands. First we generate a simple tone (sine wave), and then add music. Students provide their own music sources and listen to their own selections. We add an antenna directly to the output of the generator and broadcast the tones and music over a distance of about 20 cm to their radios. Students hear the music on their radios, and probe test points to view the modulated and de-modulated signals and their spectra.

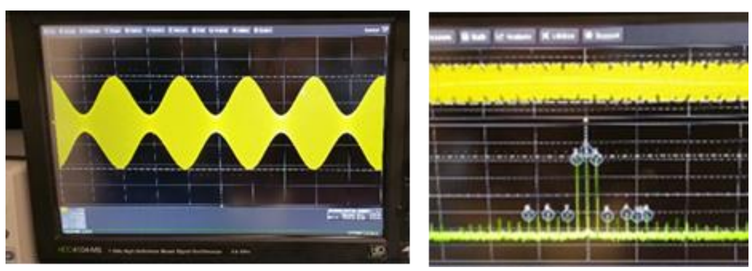

**Figure 2. Module 5, (left) scope trace of modulation of carrier by sine wave and (right) its associated frequency spectrum with carrier and sidebands**

M6. *Semiconductors including diodes, transistors, op-amps; BJT and op-amp amplifiers.* This is an introduction to semiconductors, energy bands, electrons and holes, doping, and devices, all at a very basic level. Diodes, transistors, op-amps and integrated circuits are introduced as examples of common semiconductor devices. Students become familiar with the diode I-V curve by viewing it on a dedicated curve tracer (Tektronix 571) and also using the X-Y mode of their oscilloscopes. They obtain more breadboard experience by building (with no design component) simple BJT and op-amp amplifiers, and measuring their cutoff frequencies. They view the spectrum of the outputs and look for harmonic distortion.

M7. *Energy efficiency, photometrics, lightbulbs, and solar cells.* This module is based on understanding the label on a box of lightbulbs, as might be found in a hardware store. Students learn the difference between radiometric and photometric units, including the units of lux and lumens. The notion of color temperature is introduced. The physical origins of light emission in incandescent (blackbody radiation), fluorescent (plasmas and phosphors) and light emitting diode (LED) (electron-hole recombination and photon emission) bulbs are taught. The solar spectrum is discussed and solar cells are introduced. Students perform tests on the four types of light bulbs (including halogen) and fill in an extensive table of characteristics. They use this data to compare the relative luminous efficacy of the various bulbs as advertised in the product packaging. Additional equipment required for this module are (Fig. 3) modified aluminum ventilation tubes (used as mini darkrooms), bulb holders, inexpensive lux meters, UV light meters, inexpensive power meters (Kill-a-Watt), and thermocouples. In the last part of the lab, students use the various bulbs to illuminate a solar cell and drive a small DC motor.

**Figure 3. Lightbulb experiment setup showing the improvised "light box," bulb fixtures, lux meter, UV meter, power meter, solar cells and DC motor.**

M8. *Analog-to-digital conversion (ADC), digital-to-analog conversion (DAC), sampling, Nyquist criterion, and music compression.* This module uses a custom-built board (Fig. 4) that allows a signal to be input to an 8-bit DAC followed by 8 DIP switches, and then passed to the input of an 8-bit DAC. The sampled signal is then passed through a graphic equalizer used as a reconstruction filter. Students can input arbitrary signals, observe the digital output of the DAC at the DIP switches, and then pass some number of bits, from 1 to 8, to the DAC to observe the quality of the output with more or fewer bits of resolution. An 8-bit data probe is used to observe how the digital bits change with the analog input. The clock rate is selectable, so students have a wide range of variables with which to observe how the time-domain output of the DAC changes with fewer bits of resolution and at different sampling rates. This allows a detailed study of aliasing, and the observation of the spectra as the output is aliased and the copies of the baseband signal overlaps. Students use the graphic equalizer as a filter at the output of the DAC to reconstruct their original signals. As usual for this course, students use their own music sources and programs to test how various sampling and reconstruction filters affect the quality of their music output.

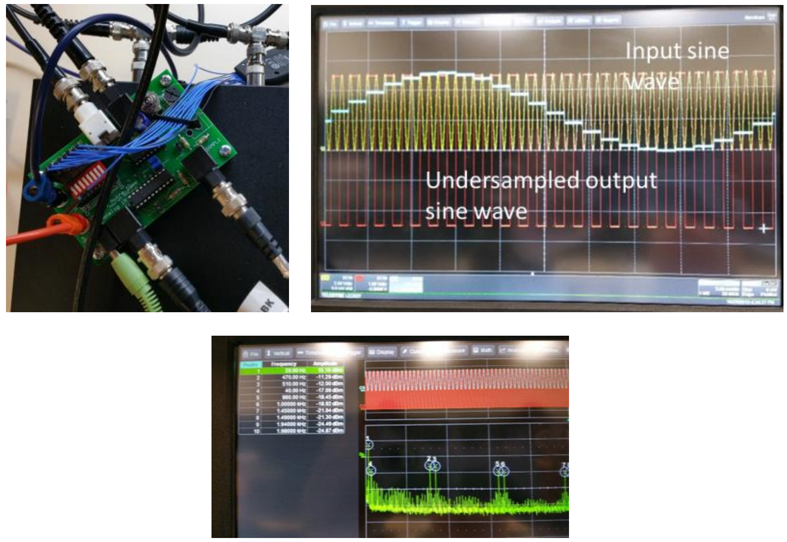


**Figure 4. Module 8, (top left), custom-built ADC/DAC demonstrator and (top right) screen shot of undersampled sine wave. Aliasing is clearly evident to the students. Students also interact with the spectrum of the sampled signal (bottom).**

M9. *Week two of ADC/DAC.* There is no "Module 9." Students are encouraged to devise their own tests and make their own observations. This week's class lecture is devoted to introducing a somewhat mathematical notion of delta functions, convolution, a few specific Fourier transforms, such as pulse trains and gates, and duality of the time and frequency domains. The end result is to understand some of the more-nuanced phenomena observed in the first week of the lab, in particular the sinc-function-shaped envelope of the spectrum shown in the bottom of Fig. 4.

M10. *Batteries and power supplies.* One of the most ubiquitous and yet overlooked (in an EE curriculum) technologies is the simple disposable battery. The reading material discusses the significance of batteries, the different types, how they are constructed, how they work electrochemically, and how important they are to modern technology. Trends in rechargeable battery technology are presented with respect to global issues that include electric vehicles and energy storage. This material is followed by a discussion of common DC power-supply circuits. The laboratory exercise uses a custom-built board based on a microcontroller that closes relay contacts for 100 msec so that students can safely short-circuit several different types of batteries, from button cells to D-cells and "transistor" batteries. Students observe the short-circuit current (which is remarkably high – over 15 amperes in some cases) and perform careful measurements to back out the internal resistance. They also build

**Figure 5. Module 10, showing custom board used for creating a quick short circuit to test internal resistance of a battery. Also visible here is the current probe used.**

several versions of DC power supplies using LEDs rather than conventional Si diodes so that they can observe the flashing (at low frequencies) when current flows in the forward direction of the diodes in their half- and full-wave rectifiers. Ripple factor is calculated for a variety of circuits and filter conditions.

## Research Questions

Mindful of the difficulties in designing new course/laboratory materials, the research questions were focused on evaluating whether or not the course met the needs of the students in the following areas and comparisons by gender, engineering discipline, and academic progress towards graduation:

- Did learning take place as result of the course experience?
  - Was the material new to the students?
  - Was there a difference in the number of correct responses pre vs. post?
- Were there significant differences in attitudes?
  - Did the course material represent areas that they already had confidence in?
  - Did students' confidence in the course material increase after taking the course?

## Methods

The course was assessed through a pre / post survey analysis in which students were asked a series of multiple choice questions based on course topics. The same questions were asked at the start of the semester (prior to the first laboratory session) and again at the end of the semester (after the last laboratory session). The questions are shown below in Table 1. Roughly half of the questions were confidence questions where students were asked how well they understood a certain topic (on a 7 point Likert scale). And there were also a series of content based multiple choice questions with 5 choices and an option for "do not know." Finally, there was a question about how students reacted to the course and a few demographic questions.

**Table 1. Summary of Pre / Post Survey Questions**

| Questions | Confidence Question | Response Type | Content Questions | Response Type |
|---|---|---|---|---|
| 2-3 | I feel very comfortable around basic electronic test equipment | 7 point Likert Scale | Which of the following statements is/are true? | Multiple Choice question (5 choices)<br><br>***Do not know*** is one answer choice for all questions |
| 4-5 | I am generally aware of the national power grid and understand how power comes to my home. | | The neutral wire in the home provides the following function | |
| 6-7 | I understand what time and frequency domain are and how they are relevant to engineering. | | An electrical filter does the following function: | |
| 8-9 | I have a good idea about how electromagnetic waves are transmitted and received in radio transmission. | | Music on an AM radio wave is transmitted by: | |
| 10-11 | I can distinguish between semiconductor devices and those not based on semiconductors. | | The following device is usually made from a semiconductor: | |
| 12-13 | I can explain some of the major issues in national energy policy. | | Which type of light bulb is the most efficient? | |
| 14-15 | I have a basic understanding of how music is recorded, processed and then played on an MP3 player. | | Aliasing is a phenomenon caused by: | |
| 16-17 | I understand how a battery works. | | Which of the following statements is true about power supplies: | |
| **Reaction to the course and demographic questions** | | | | |
| How do you feel about taking this course? | | | | |
| Gender | | | | |
| Graduation Year | | | | |
| Engineering Discipline | | | | |

The survey was administered on-line through Qualtrics and responses were anonymous. There were 58/80 (72.5%) responses for the pre-survey and 55/74 (74.3%) responses for the post-survey. The responses were analyzed to show the differences in the pre vs. post results in correct responses and number of students that said “do not know” to the content questions. Results were also analyzed to determine how student’s perception of their understanding changed (confidence questions). Results were analyzed for statistically significant differences in terms of pre vs. post survey responses, gender, by graduation year (sophomores vs. upper division students), and by engineering discipline (EE vs. all other engineering disciplines).

**Results**

Figure 6 compares the percentage of correct responses from students at the start of the semester vs. the end of the semester. At the end of the semester each question had 50%+ increase in the number of correct responses such that questions had 84% - 95% correct responses. The results were also considered by gender, graduation year (sophomore vs. upper division), and engineering discipline (EE vs. other disciplines) using unpaired ttests. There were no statistically significant differences by graduation year. There were no differences by gender or engineering discipline, except for Question 13: "Which type of light bulb is most efficient?," which women were less likely to answer correctly $t=2.54$ ($p<0.01$), and other engineering disciplines were also less likely to answer correctly $t=-2.13$ ($p<0.05$).

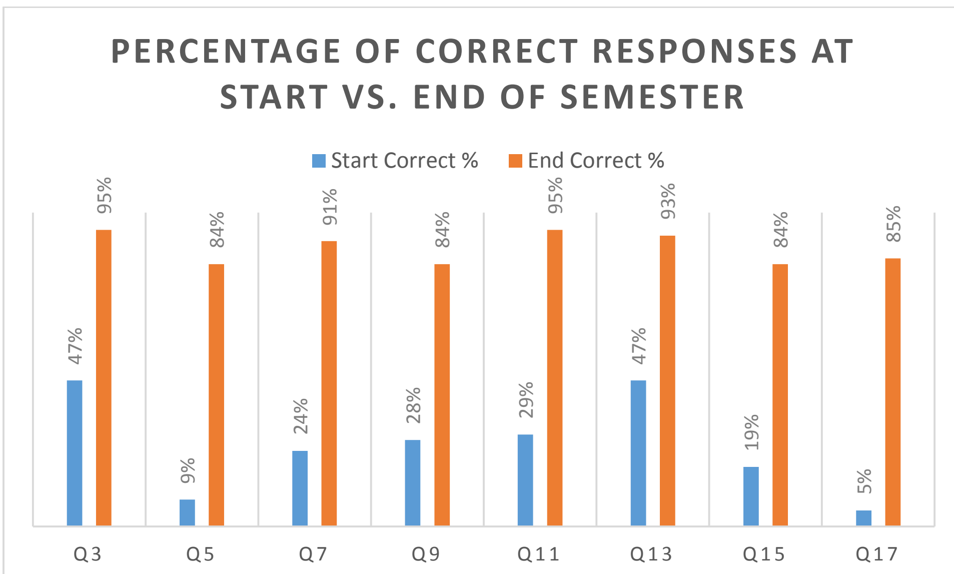


**Figure 6. Comparison of Correct Responses for Content Questions**

Figure 7 shows that the number of "Do Not Know" responses to the content questions decreased from as high as 83% at the start of the semester down to 7% or less at the end of the semester.

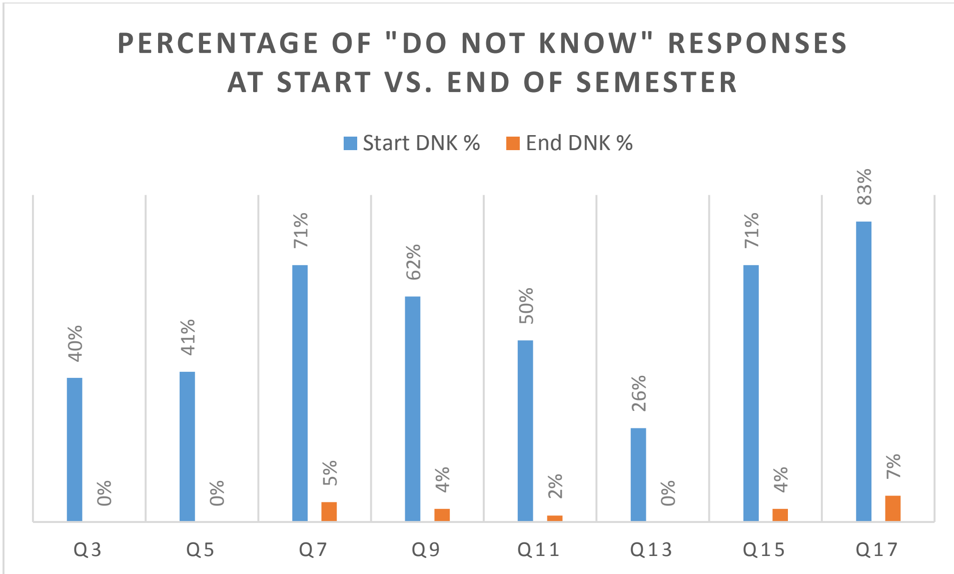


**Figure 7. Comparison of "Do Not Know" Response**

Table 2 shows the summary of the "Do Not Know" responses at the start vs. the end of the semester. The results of the ttests were statistically significant for each question; note that the values were 1's for "Do not Know" and 0's for another response (fewer "Do Not Know" responses at the end of the semester than at the start). There were no statistically significant differences by gender, graduation year, or engineering discipline.

**Table 2. Summary of "Do Not Know" Responses for Content Questions**

| Question # | start of semester mean | end of semester mean | ttest start vs. end |
|---|---|---|---|
| 3 | 0.40 | 0.00 | **6.01*** ** |
| 5 | 0.41 | 0.00 | **6.23*** ** |
| 7 | 0.70 | 0.05 | **9.57*** ** |
| 9 | 0.62 | 0.04 | **8.37*** ** |
| 11 | 0.50 | 0.02 | **6.92*** ** |
| 13 | 0.26 | 0.00 | **4.38*** ** |
| 15 | 0.71 | 0.04 | **10.15*** ** |
| 17 | 0.83 | 0.07 | **12.34*** ** |

where *** denotes p<0.001

Table 3 shows the mean response for students during the pre-survey at the start of the semester as compared to the mean response at the end of the semester. Every perception question had a statistically significant difference from pre to post survey; for questions 2-16, the mean response at the end of semester was higher than the mean response at the start of semester. The last question, 18, which asked how students felt about taking the course, had a slightly lower mean at the end of the semester. This shift could be perceived as a negative implication for the course, but rather the numbers were based on a Likert Scale where 5= Somewhat excited /interested, 6= Excited / interested, and 7=Very Excited / interested, which are positive responses from the students. The results were also considered for gender, engineering discipline (EE vs. others), and grade level (sophomore vs. others) and there were no statistically significant differences to report.

**Table 3. Summary of Perception Questions**

| Question # | Start of semester mean | End of semester mean | ttest start vs. end |
|---|---|---|---|
| 2 | 4.81 | 6.45 | **-8.02*** ** |
| 4 | 3.31 | 6.30 | **-13.7*** ** |
| 6 | 3.63 | 6.25 | **-9.8*** ** |
| 8 | 3.63 | 5.95 | **-9.99*** ** |
| 10 | 2.86 | 5.66 | **-10.01*** ** |
| 12 | 2.86 | 5.25 | **-8.87*** ** |
| 14 | 3.43 | 5.86 | **-9.05*** ** |
| 16 | 4.53 | 6.04 | **-6.83*** ** |
| 18 | 6.36 | 5.86 | **2.85** ** |

where ** denotes $p<0.01$, *** denotes $p<0.001$

**Revisiting the Research Questions**

Revisiting the previously outlined research questions by comparing overall student responses (pre vs. post), gender, engineering discipline (EE vs. others), and progress towards graduation (sophomores vs. upper division students).

- Did learning take place as result of the course experience? ***Yes***
    - Was the material new to the students? ***Yes***
      ***The pretest showed a very low percentage of students getting the correct answer, and a high number of students reporting "do not know."***
    - Was there a difference in the number of correct responses pre vs. post? ***Yes***
      ***The posttest showed a high percentage of students getting the correct answer, and a low percentage of students reporting "do not know."***
      ***The difference between the pre and posttest analysis was statistically significant for all content questions asked.***
      ***There were no statistically significant differences by engineering discipline (EE vs. others) or by progress towards graduation (sophomore vs. upper division).***
      ***There was one statistically significant difference in a content question about light bulbs by gender, but all others were the same.***
- Were there significant differences in attitudes? ***Yes***
    - Did the course material represent areas that they already had confidence in? ***No***

      ***The pretest showed a very low percentage of students indicating a high level of confidence in their understanding of content areas.***

- Did students’ confidence in the course material increase after taking the course?
  ***Yes***
  ***The posttest showed a high percentage of students indicating a high confidence in the content areas.***
  ***The difference between the pre and post test analysis were statistically significant for all confidence questions asked.***

  ***There were no statistically significant differences in confidence level reported by: engineering discipline (EE vs. others), progress towards graduation (sophomore vs. upper division), and gender.***

**Conclusions:**

The redesigned version of the Introduction to EE course was successful in increasing student understanding of course concepts as evidenced by the increase in correct responses and decrease in “do not know” responses. The redesigned course was also successful in increasing student confidence in course concepts as evidenced by the increases in perception questions. While, there is no data on the effectiveness of the original course, the positive attitude / interest of students is an indication that this model is effective. Further, the lack of difference in performance by male and female student is an indication that it appeals to both genders. Finally, the lack of difference in performance of sophomores / EE’s, and upper division / non-EE’s could be interpreted as an indication that the course material was at an appropriate level. Assessment of the course content will continue to be evaluated for potential areas for improvement.

**References:**


1. Palais, J.C. and Javurek, C.G. (1996). The Arizona State University electrical engineering undergraduate open laboratory. IEEE Transactions on Education, 39(2), pp. 257-264.
2. Feisel, L.D. and Rosa, A.J. (2005). The role of the laboratory in undergraduate engineering education. Journal of Engineering Education, 94(1), pp. 121-130.
3. Feisel, L.D. and Peterson, G.D., (2002, June). A colloquy on learning objectives for engineering education laboratories. In Proceedings of the 2002 American Society for Engineering Education Annual Conference & Exposition (pp. 16-19).
4. Peterson, G.D. and Feisel, L.D. (2002, August). e-Learning: The challenge for engineering education. In e-Technologies in Engineering Education, A United Engineering Foundation Conference, Davos, Switzerland, pp. 11–16 http://services.bepress.com/eci/etechnologies/.
5. Yadav, A., Subedi, D., Lundeberg, M.A. and Bunting, C.F. (2011). Problem-based Learning: Influence on Students' Learning in an Electrical Engineering Course. Journal of Engineering Education, 100(2), pp. 253-280.
6. Edward, N.S. (2002). The role of laboratory work in engineering education: student and staff perceptions. International Journal of Electrical Engineering Education, 39(1), pp. 11-19.
7. Montes, A.J.S., Castro, H.A.B. and Riveros, J.A.H. (2010). How to motivate students to work in the laboratory: A new approach for an electrical machines laboratory. IEEE Transactions on Education, 53(3), pp. 490-496.
8. http://www.nsta.org/publications/news/story.aspx?id=41136 ******Kerry: Please choose a citation form. See “Vee Mapping” in the document.********
9. Matthew, R.G.S. and Hughes, D.C. (1994). Getting at deep learning: A problem-based approach. Engineering Science & Education Journal, 3(5), pp.234-240.
10. Yadav, A., Shaver, G.M. and Meckl, P. (2010). Lessons learned: Implementing the case teaching method in a mechanical engineering course. Journal of Engineering Education, 99(1), pp.55-69.



**Acknowledgement:**

Bernstein is grateful to C. Manning for boundless enthusiasm and creativity in building the custom demonstrators and for organizing the lab sessions. Also, A. M. Kriman and P. Fay are gratefully acknowledged for helpful discussions and suggestions.