EFFECTIVELY TEACHING MAJORS AND NON-MAJORS IN HANDS-ON ELECTRICAL ENGINEERING TECHNOLOGY COURSES

Aurenice M. Oliveira, Michigan Technological University, oliveira@mtu.edu

Abstract

Modern technologies are remarkably interdisciplinary and often require knowledge of several fields. In particular, the accelerated technology development in electrical engineering with most of the industrial systems integrated with electronic solutions results in an increasing correlation among different disciplines. The goal of higher education institutions is to prepare highly-qualified graduates who will contribute to the industry with the latest technologies in their fields. Most of the instructors, however, face the challenge of teaching both non-majors and majors, sometimes even in the same classroom. The aim of this article is to discuss the main challenges and to share teaching methods that the author has used to encourage active learning and engagement among major and non-major students in an Electrical Engineering Technology program. The author addresses the use of technology for teaching, the use of lecture time effectively, the importance of well-designed laboratory experiments, and use of simulation tools. Assessment tools have indicated that the teaching methods used have been successful in meeting the teaching goals.

Keywords: engineering education, non-majors, active learning, electrical engineering technology.

Background

In recent years both universities expectations and student expectations of faculty have increased, not only a professor is expected to teach effectively, but also to manage other responsibilities such as maintaining certain levels of research and other scholarly activities. Teaching freshman and sophomore engineering students is crucial because it is during this initial period that students are more likely to change majors or drop out of college [1, 2]. Many studies stress the importance of first-year college experience, and indicate the first-year GPA as the best predictor of attrition. The adoption of an active learning format whereby student participation is highly encouraged has the strongest impact on students' academic performance and their attitudes towards engineering profession [3]. Despite of the fact that many students may have been academically prepared and motivated to study engineering, 50% of students who enter engineering programs as freshman do not earn an engineering degree [1, 2]. The gap between engineers needed annually and the number of graduates available to fill positions is still wide [4, 5]. Instructors are confronted by the task of conveying a general knowledge base to non-majors while simultaneously laying the foundation for continued study by majors. Teaching electrical engineering (EE) and electrical engineering technology (EET) hands-on courses to non-majors has been recognized by a number of universities as challenging. In particular, the hands-on nature of EET courses can make them even more intimidating, especially for non-EET majors required to use relatively complex instruments and techniques.

The aim of this article is to discuss the main challenges and to share teaching methods that the author has used to encourage active learning and engagement among major and non-major students in an EET program in a medium-size institution in the Midwestern United States. The courses taught by the author give undergraduates their first and, for many students, their last formal exposure to some understanding of electrical engineering. The author addresses the use of technology for teaching, the use of lecture time effectively, the importance of well-designed laboratory experiments, and use of simulation tools. The suggestions provided in this paper, while confirming principles and practices described in the literature, provides new insights and ideas. So far, these methods can be considered successful due to the positive and encouraging feedback provided by the students. Assessments of courses taught following the author's guidelines were performed to evaluate the teaching effectiveness, and they indicate that the teaching methods have been successful in meeting the teaching goals.

Introductory courses in electrical engineering not always have been adequate to satisfy the goals of providing a foundation for EE majors, while providing some EE knowledge and tools needed for other majors to support their field of study [6]. A study conducted in [7] showed that more than 75% of students surveyed at that institution faced problems with both the topics and the teaching methods in EE service courses. In addition, the traditional approach failed to make the connection between the students' field and the course, to motivate students, and to encourage lifelong learning necessary to keep pace with the accelerated development in today's technologies. The hands-on nature of EET courses can make them even more intimidating, especially for non-EET majors required to use relatively complex instruments and techniques. A change in motivation is perhaps the key factor in students' decision to earn an engineering or engineering technology degree. Positive experiences in introductory electronics courses, for instance, can influence both EE major and non-major students in their career path and in some cases even influence them to change majors. These courses can greatly influence whether a mechanical engineering student will pursue further studies in robotics, or control mechanisms, much needed in the automobile industry and any other automated industry. Thus, a challenge for individual faculty and engineering departments collectively is to find ways to build on these positive experiences and enable students to acquire some knowledge in electronics related fields. However, there is no general agreement on how best to serve diverse student audiences in any discipline and, in some cases, no formal consensus about desired learning outcomes [8].

Several institutions have recognized the problems in service courses and have tried to address them by requiring two EE service courses for non-majors. Technology programs have faced similar issues. As described in [7], the problems with the two-semester approach include: (1) the extra course is usually structured to meet the needs of mechanical engineering only; (2) increase in the number of required courses rather than optimizing existing one; (3) the increase in credit usually only accommodates ME majors not serving as option to other non-EE students. Particularly, at the two institutions that the author taught service courses, instructors still continue to face many challenges, even after implementing changes in the design of these courses. They continue to struggle with the task of imparting knowledge to students who often have little interest in the material, and who are very impatient. They also are often faced with the decision of covering only the most basic information on most topics in the syllabus or focus on communicating a comprehensive understanding of a subset of topics. At the same time they struggle to teach substantive knowledge and build critical skills. These challenges are faced not only by instructors of EE classes for non-majors but also by other instructors across disciplines [9].

Effectively teaching engineering technology majors and non-majors

In this section the author summarize the teaching methods she used for effective teaching EET major and non-EET major in the same class. These guiding principles are based on the author's teaching experiences in two Midwest institutions. The author teaching philosophy for grading, homework assignments, and exams are not discussed in detail since the author believes that they should be tailored in a case by case basis.

The traditional order to teach EE is that one must learn about semiconductor junctions before common emitter amplifiers. According to Wolaver et al. [10], instruction should follow an order that starts with the broad uses and system components and only then delves further down into details. This methodology is known as "outside-in" or "top-down" approach and is widely applicable and is practiced in many fields, especially by engineers. The advantages of the outside-in approach, includes the motivation to students. Students, especially non-majors, want to appreciate why they are putting effort into learning a specific material that at first doesn't appear related to their majors. They need a better answer than, "Because you will need it later." The author has follow an approach consistent to the top-down approach, where the application is briefly discussed first and the teaching of the basic principles follows. For instance, to tailor a given topic to Computer Network & System Administration students, the author talks about the need for different cables to carry out binary data at different data rates before talking about specific characteristics of transmission media. Moreover, the author regularly checks with students about her lecture style, the pace of the class, and the interest level in the material.

Special attention need to be paid when choosing appropriate course content, its learning objectives, and the corresponding levels of learning. A comprehensive study must be done in order to identify topics suitable for the diverse fields. Collaboration between non-EET faculty, industry and individuals in different engineering fields is crucial to develop a strong and relevant curriculum. At the author's current institution, meetings among faculty and Industrial Advisory Board members are frequently conducted to help design a relevant curriculum with the goal of provide students with content that is up to date and relevant to their field of study. A combination of lectures, laboratory experiments, and course management software is used.

Discuss real-world applications that are straightforward extensions of fundamental ideas. Examples should establish a clear relationship between EET and non-EET disciplines, and be aligned with the focus of technology degrees, which is on hands-on oriented learning with little emphasis in math analysis. Show students why electrical engineering is relevant to their careers, and involve them in lecture demonstrations. Emphasize "transferable skills" and their relevance to future careers: robotics, information system management. The use of examples relating electronics to their field, for instance, a mapping correlating the electrical circuit of an automobile and an electrical circuit diagram helps students to make a connection between the classroom and their major in the case of Mechanical Engineering students, or the need for electrical cables with different proprieties to carry out binary data at different data rates for the case of Computer Network & System Administration students. Students in electronics courses only master a small fraction of the material with which they are presented. Therefore, focus on fundamental concepts and keep the math simple.

The author also actively pursues the engagement of the students in the classroom by frequently asking them questions and stimulating them to ask questions. The author creates an email list for every class, and also uses course management software resources for discussions. The author encourages students to send questions via email. She then sends the answer to selected student questions to a list of all the students attending the course without identifying who submitted the question. To further motivate students, three key questions that should be answered in every lecture: Why, What, and How. Students must understand: “Why” do we need to study a specific topic? “What” is the relationship between this specific topic and other topics covered in that class or even in other classes? “How” do we reach a given result or derivation? Properly addressing these questions and other related questions is crucial to keep students attention and maximize their learning experience. The author also motivates students to study for my courses on a weekly basis through the application of frequent quizzes, consistently assigning a reasonable load of homework, and carefully designed exams.

Using course management software, textbook, and teaching materials

The author makes extensive use of electronic media and course management software such as Canvas®, Blackboard®, Desire-2-Learn®, WebCT®, which are provided by most universities in the U.S. In addition, she gives preference to adopt textbooks with companion websites and e-books, which are cheaper and more convenient for students to carry in their laptops or digital notepads/tablets. The author has noticed that both majors and non-majors take advantage of these resources; however, they are particularly more relevant for non-majors, as they have the tendency to use these resources more often than EET majors. It is important to note that for some courses it is difficult to find a book well-tailored to technology students, and with companion laboratory manual. In these cases, the author has developed her own teaching materials for class and lab experiments. The author also has implemented an online only submission procedure for all class and lab assignments, with exception of exams. The graded assignments with detailed rubrics are uploaded back on Canvas to students to keep a soft copy for their records. This system is also a valuable asset for ABET paperless documentation. The author also implemented final exams using course management software with the goal of collecting additional statistics for ABET course assessment. This online mechanism allows her to save all the exam information as opposed to paper exam, which would require scanning of every single exam and manual processing of statistics such as number of questions per topic, topics with highest or lowest scores, among others.

To support classroom activities, the author has extensively used course management tools. Canvas®, for instance, is an extremely helpful teaching tool that can be used to complement classroom instruction in a variety of ways, such as:

- To develop and apply online exams and quizzes;
- To post lecture presentations;
- To post homework assignments;
- To post graded assignments with detailed rubrics;
- To post solutions of homework, exams, and quizzes;

- To obtain statistics of online taken exams and quizzes, such as statistics of each problem, class average, and class standard deviation;
- To provide any class related document;
- To post grades online. Canvas is an excellent tool to post grades as the university are making more strict the students privacy policies, in which the grades can only been seen by each individual students.
- Email a specific student or a group of students, since Canvas contains the email address of all the students registered for the class.

Classroom presentation, instructional resources, and timely feedback
For college level courses in general, the lecture is still the primary method of instruction. The author's experience in the classroom has leaded her to explore a number of classroom presentation methods to help engage students on a number of different levels.
The author uses a balanced combination of electronic media and traditional lecture on the whiteboard, in which I often demonstrate how to apply the theory to solve practical problems. This is a way to help each student develop problem solving skills. To support classroom activities, the author has extensively used course management software. The author also uses i-Clickers for classroom short quizzes to review material taught on previous lectures. The example problems are pre-designed and made available online. Students have the tendency to lose concentration just by looking at slides upon slides in the classroom, incorporating breaks into the monotony of slides is very important in getting students to be more engaged and thereby more willing and able to learn the material. Furthermore, the exclusive use of PowerPoint (PP) during lecture makes students more tempted to skip lecture, in particular if the instructor makes the PP presentations available to students afterwards [11].

The author makes available to students the PP presentations, and a set of lecture notes with summary of main topics discussed in class and exercises with answers (not solutions) in the last page of each note sheet. The author encourages students to work on these problems prior and while the material is being covered in class. This set of problems must be solved prior to homework assignments as an additional way for students to learn the material. The author also solves selected problems in the classroom, stimulating students to interact with the author on the right path to the solution. The incorporation of examples into the lectures, in combination with PP presentations has the goal of better motivate students by establishing a connection between EET and non-EET disciplines.

Nowadays, students are more and more technology savvy and technology demanding. The traditional textbooks sometimes are only opened by the students in the assigned homework sections. This behavior is particularly the case for non-EE major students, who wish to spend the least amount of time for an electrical engineering class. With that in mind, the author prefers to assign e-books and textbooks that have a companion website where students can have access to online chapter summary, multiple choice and true or false problems, fill in the blank sentences on the chapter material, and exercises based on software tools such as MultiSim®, Cadence Design Systems' PSpice®, and National Instrument's LabVIEW®. Cadence Design Systems' PSpice files were developed to assist in circuit analysis. National Instrument's LabVIEW files were developed to introduce rapids methods of computer-aided special-purpose instrumentation and control systems. MultiSim is a schematic capture, simulation, and programmable logic tool used by college and university students in their course of study of electronics and electrical engineering. MultiSim is widely regarded as an excellent tool for classroom and laboratory learning.

While it is important for any class, frequent feedback is particularly important for non-majors. Timely and adequate feedback is important is various forms, such as in class discussions, written comments, graded homework, quizzes, and exams. Depending on the number of students per class, this task may be very time consuming from the instructor stand point. The author has been applying mid-term instruction evaluation as a way to collect feedback from students while there are still several weeks before the end of the semester to make appropriate changes. Again, course management software can help with this process, were electronic feedback can be made, and exams can be graded automatically. In addition, Canvas makes available the statistics for any exam taken through Canvas. The students can access the class average for each particular problem of an exam and for the entire exam so that he or she can know exactly how they stand with respect to the class average. The author has noticed that frequent feedback have a positive impact on class performance for most of the students, and the students show more satisfaction with their course experience. In addition, the evaluations applied to an EET classes offered to non-majors should focus on conceptual knowledge, core skills, and applications related to their major.

Lab Experiments and simple simulations

It is a common understanding that the laboratory must serve as a learning resource center in which the students not only perform formal lab assignments, but also have the opportunity to use the equipment and computers to strengthen their understanding of the concepts presented in the lecture section [6]. We can't stress enough the value of hands-on learning. The laboratory adds realism and solidity to the large number of topics that are covered in an EE course for non-majors. Students usually enjoy laboratory work, especially as it can be related to some of their own major interests. Therefore, it is imperative to choose experiments that provide students with real life applications that are challenging but achievable, and most importantly that the lab experiments are tightly couple with lecture. We also receive input from our Industrial Advisory Board for experiments that would be beneficial for our students in their professional careers. Therefore, undergraduate laboratories require constant updating and development of new and innovative experiments each semester, which requires a fairly large amount of time on the instructors' side. The majority of books don't offer a companion lab manual suitable for a technology courses. For instance, books in data communication don't offer a companion lab manual suitable for a technology course in data communication, rather the majority of the experiments are focused on networking in data communication. In addition to well-chosen experiments, students' data should be checked before they leave the lab to make sure that the data is at least acceptable to complete the lab assignment, this policy is particularly important for non-EE majors taking possibly their only EE lab session.

It is also of great use to have a computer on each bench that can be used for instrument control and data acquisition, data processing and plotting, and circuit simulation. The author encourages students to simulate simple circuits using software such as Electronics Workbench Multisim® by assigning them simulated lab homework prior to the hand-on lab experiment. The simulations provide a link between the theory learned in class and the actual lab experiment. Computer-based lab experiments speed up student progress in hands-on experiments and make the learning experience in the lab more efficient. However, careful attention should be paid to avoid the use of simulation as a substitute for thinking, as can be the case for some students. Students are also stimulated to make circuit analysis of the lab experiment prior to the lab section; in addition, students should choose a different partner for each lab section. By working with a different partner for each lab section, the students will be forced to change their role instead of constantly doing the same type of task, such as only taking notes or only taking measurements. Students have reported in their instruction evaluation form that the laboratory experiments were valuable elements of their learning process, through meaningful hands-on experience gained in the laboratory.

The author frequently re-designs laboratory experiments and laboratory manuals, updates and develops new teaching materials. The author also has developed and built laboratory experiments kits for classes. For instance, for a data communication class she built her own lab kits for experiments in digital modulation (total of 20 kits), and serial communications (total of 24 kits). These kits help students to focus of the input, output, and main concepts as opposed to spending time to build circuit boards. The author also frequently develops hybrid lab experiments based on simulations, traditional circuitry and basic instruments, and Emona ETT 101 modules, which allows for a relatively low-cost and flexible data communications laboratory experience.

Example of Lab experiments:
We include below a few examples of hybrid lab experiments based on simulations, traditional circuitry and basic instruments, and Emona ETT 101 modules, which allows for a relatively low-cost and flexible *data communications laboratory* experience. Most of the lab experiments presented below was developed by the author.
Experiment 1: Frequency-domain analysis using Virtual Multisim® Lab
Concepts: Spectral content of popular waveforms such as: sinusoid, triangle wave, and square wave, in addition to harmonics energy, frequency span, and amplitude range in dB.
Objectives: Students become familiar with the use of Electronics Workbench Multisim (EWB) in analyzing complex waveforms in frequency domain, and the operation of virtual EWB oscilloscope, Spectrum Analyzer, Function Generator, and virtual components.

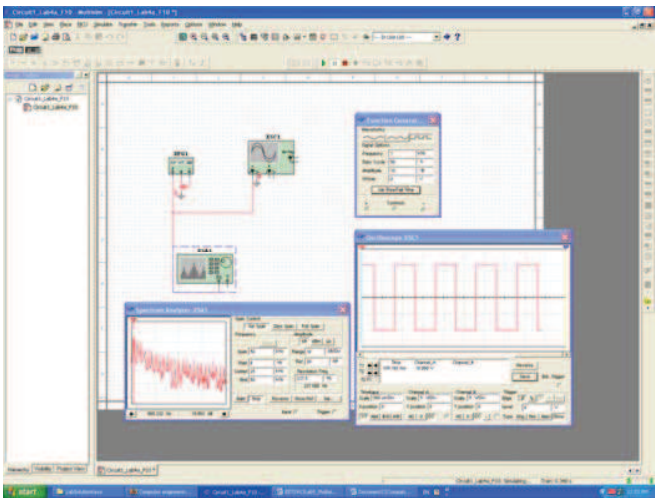
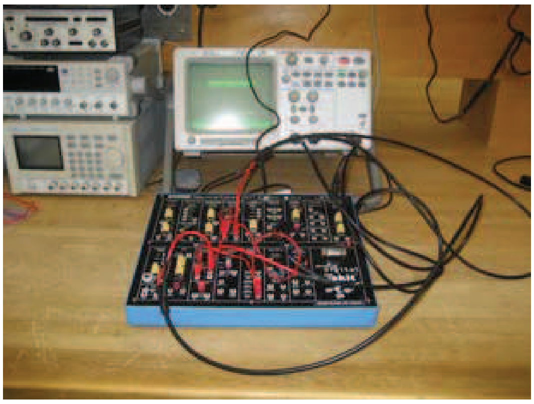


Fig. 1 – Experiment 1 equipment setup using Virtual Multisim Lab.

Experiment 2: Digital Modulation/demodulation ASK using EMONA® ETT-101
Concepts: Amplitude Shift Keying (ASK) modulation and demodulation, digital signal modeling, ASK generation (using switching mode), sequence generation, envelope detection, noise effects, bit error rate (BER), and carrier frequency.
Objectives: Students become familiar with modulation and demodulation of digital signals onto a radio frequency (RF) carrier, and importance of appropriately choosing carrier frequency. In addition, students add noise to the system, which introduces bit errors in the data transmission, and then perform simple BER analysis in the demodulated/detected signal. The use of traditional measurement equipment such as the scope in combination with the Emona ETT-101 substantiates to the student that the platform is functioning.



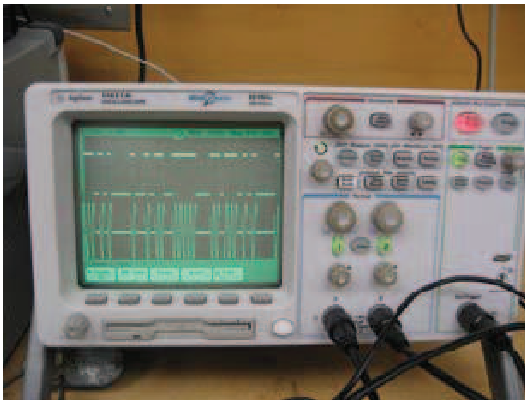
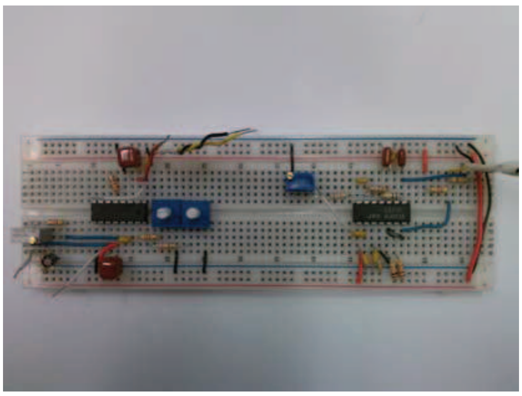


Fig. 2 a (left): Emona® Telecoms-Trainer ETT-101 experimental platform connected to an oscilloscope. Fig. 2b (right): Input and output of ASK modulator using EMONA platform [12].

Experiment 3: Digital Modulation/demodulation BFSK using "home-made kit"
Concepts: Binary Frequency Shift Keying (BFSK) modulation and demodulation, digital signal modeling, sequence generator, filtering/envelope detector, and carrier frequencies.
Objectives: Students become familiar with another form of modulation of digital signals onto an RF carrier. Students also learn that the general principles of FSK are used in more advanced data encoding techniques.



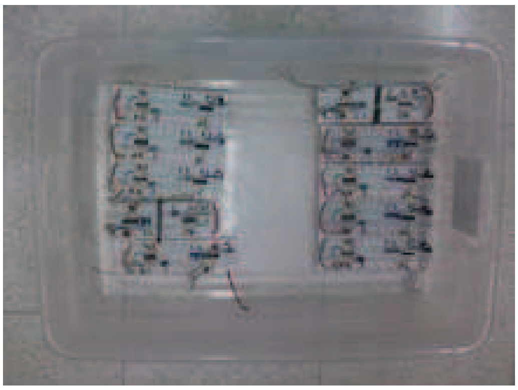


Fig. 3 a (left): Kit with both BFSK modulator and demodulator circuits. Fig. 3b (right): Box with the set of 10 kits.

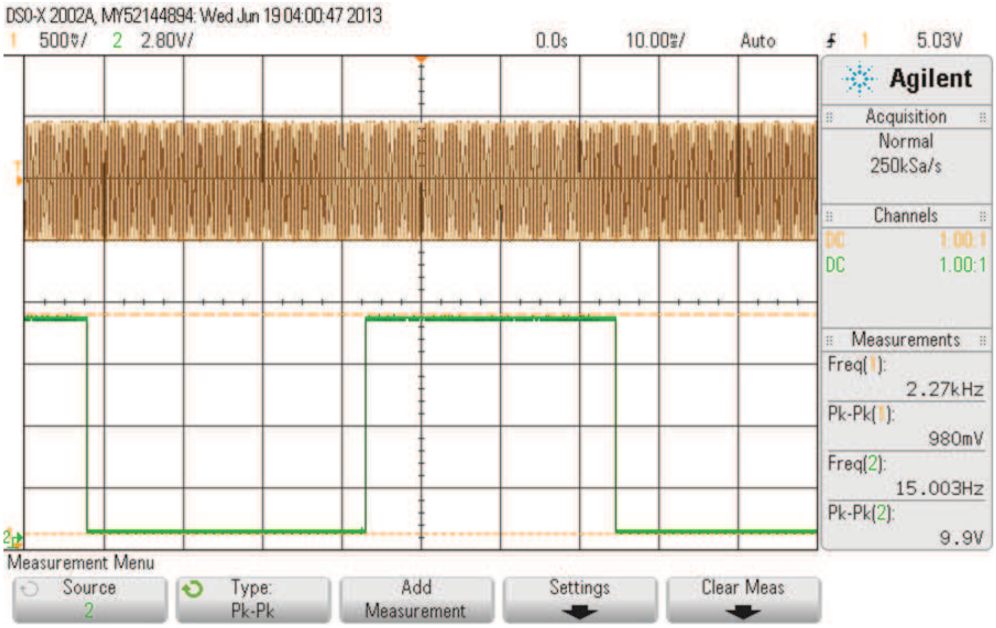


Fig. 4: Input (orange) and output (green) of the BFSK demodulator kit.

Assessment

The courses taught following the author's guidelines are always assessed to evaluate the teaching effectiveness, and they indicate that the teaching methods are successful in improving the students learning outcomes for the courses. The success indicators are based in direct and indirect quantitative measures such as exams, written lab reports, student surveys, and instructor/students meetings. To measure the adequacy of the teaching methods, students are also given a midterm survey in the beginning of the second half of the semester. This survey is independent of the traditional course evaluations, and is used to solicit students' response to overall course performance and any recommendation that they may have. Informal meetings between the students and the instructor are also conducted. At the end of the semester, the university instruction evaluation surveys are also used as a tool for assessment. The author presents here examples of assessment data for one of the course taught following the guidelines presented in this paper.

Question	**Rating - Fall 2011** (33 students)	**Rating- Fall 2010** (49 students)	**Rating-Fall 2009** (42 students)
1) The pace of this course is consistent with my ability to learn the material.	3.78 (95%)	3.91 (98%)	3.24 (81%)
2) The instructor is well prepared, and is able to communicate the course material clearly.	3.60 (90%)	3.40 (85%)	3.21 (80%)
3) The instructor's grading policies are fair.	3.74 (94%)	3.67 (92%)	3.24 (81%)
4) Have the labs be useful in helping you understanding the material better	3.57 (89%)	3.35 (84%)	2.83 (71%)
5) Would you take another course with this instructor	3.58 (90%)	3.24 (81%)	2.86 (72%)

Table 1: Example of midterm instruction and learning evaluation for a data communication course. Score 4 and %.

In Table 1, the author shows the survey questions and students' responses for the student rating of instruction and learning for the midterm class evaluation for a course in data communications. The rating used for the questions in table 1 was: (4) strong agree, (3) agree, (2) disagree, (1) strong disagree. In addition to the questions/ratings listed in Table 1, we also asked the students "What grade do you think you deserve in the course so far. This should be based on what you think you have learned, not the actual grade you have received." This additional question was not included in the evaluation for Fall 2009 that is why it is not shown in Table 2.

Positive comments of students for the data communication course include, "*the laboratory experiments were exciting and a valuable element of their learning process, through meaningful hands-on experience gained in the laboratory*". "*The use of Canvas and i-clicker review quizzes, and classroom examples were helpful to understand the material.*" Some of the students' answers to an additional question in the survey: What about this class is helping you to learn? *"Instructor working in class problems on the board"*, *"The i-clicker questions to review material that we covered in previous lectures"*, *"PowerPoint slides of notes posted on Blackboard"*, *"The material in class is similar to what we practice in the lab."*

Letter Grade (%)	Fall 2011	Fall 2010
A (90-100)	30.4%	17.6%
AB (85-89)	47.8%	47.1%
B (80-84)	17.4%	20.6%
BC (75-79)	0.0%	11.8%
C (70-74)	0.0%	2.9%

Table 2: Student answers to grade based on learning for a data communication course. Note: In Fall 2011, one student (4.3%) answered "CD (60-64)".

	Fall 2009 (42 Students)	Fall 2010 (49 Students)	Fall 2011(33 Students)
Exam 1	Av. = 77.2, Sd=16.55	Av. = 83.7, Sd=13.24	Av. = 85.8, Sd= 18.12
Exam 2	Av. = 78.1, Sd=12.63	Av. = 65.3, Sd=21.20	Av. = 85.1, Sd= 11.63
Final Exam/project	Av. = 74.5, Sd=15.66	Av. = 79.8, Sd=18.94	Av. = 80.6, Sd=12.38
Final Grade	Av. = 77.9, Sd=13.95	Av. = 78.4, Sd=12.56	Av. = 81.7, Sd=9.09

Table 3: Comparing grades for Fall 2009, Fall 2010, and Fall 2011 for a data communication course.

The results shown in Table 3 clearly indicate significant improvement in the students' grades with an increase in the class average and a reduction in the standard deviation. The author attributes the grade improvement as the result of several factors:

- The instructor has also continuously updated the lab descriptions and developed new lab experiments;
- In addition, instructor has changed the sequence that part of the material is covered in the lectures in order to tightly couple weekly lab activities with lectures;
- Instructor has given more assignments, frequent review quizzes using I-Clickers, has given more problems solving sections, provided solutions to all assignments in a timely fashion, and provided faster feedback for students. Instructor has also correlated more the material covered in the class with practical application examples.

Final Remarks

Teaching hands-on courses in EET to non-majors presents many challenges and requires a substantial time investment. The methods described here tried to promote an active learning environment, with higher perception and immediate application. While the author fells that the suggestions presented in this paper show promise to a successful non-EET major experience in an EET class and can help improve retention rate, performance, and make the idea of interdisciplinary engineering more appealing to a wider, diverse group of students, each instructor must work within the context of his or her own institutions. Assessment data indicated that the teaching methods used have proved to be efficient tools in responding successfully to the challenge of teaching EET classes to non-EET majors. The author strives for continuing improvement. In order to continue the teaching methods improvement cycle, direct and indirect assessment statistics will be constantly considered and used as feedback for courses modifications.

References

1. L. Fleming, K. Engerman and D. Williams, presented at the 2006 ASEE Annual Conference & Exposition Proceedings, 2006.
2. P. Burton, presented at the 2007 ASEE Annual Conference & Exposition Proceedings, 2007.
3. J. Tezcan, J. Nicklow, J.Mathias, L. Gupta and R. Kowalchuk, presented at the 2008 ASEE Annual Conference & Exposition Proceedings, 2008.
4. S. Bacon, The Kansas City Star (2008).
5. U.S. Department of Labor, Bureau of Labor Statistics.
6. J. Hatfield, D. Scott and D. Szmyd, presented at the ASEE- IEEE Frontier in Education Conference Proceedings, 1995.
7. S. A. Zekavat, C. Sandu, G. Archer and K. Hungwe, presented at the 2004 American Society of Engineering Education Annual Conference, Salt Lake City, 2004.
8. R. Thorne, Physics Colloquium, Cornell University (2007).
9. K. Ainuson and S. Ulbig, PS: Political Science and Politics **41** (3), 620-622 (2008).
10. D. Wolaver and W. Roadstrum, presented at the ASEE-IEEE Frontier in Education Conference Proceedings, 1983.
11. D. Kim, presented at the ASEE Annual Conference & Exposition Proceedings, 2007.
12. ETT101, E. Instruments, Sydney, Australia.