
AC 2011-1758: FRONTIERS OF ELECTRICAL AND COMPUTER ENGINEERING: AN INTRODUCTORY FIRST YEAR COURSE

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Introduction

Several motivations exist for exploration of new approaches to the introduction of first year students to Electrical and Computer Engineering. One clear motivation is the decline in ECE enrollments and degrees over the recent past. In the United States, BS degrees in EE, Computer Engineering, and ECE declined from 21,038 in 2004 to 15,447 in 2009¹. Another aspect is the broad conclusion that a new, more engaging and motivational approach is needed for the first year experience of all college students, and particularly for engineering students.

Various forms of introductory courses, both credit and noncredit, have been in existence for many years, with varying degrees of success. More broadly, the crucial importance of the first year of the college experience has become well recognized, and many engineering programs have introduced new first-year programs and courses. Formats, content, and credit vary widely. Two distinct approaches to first course design can be categorized as either (1) an “overview, seminar-type, low or no credit experience” vs (2) an “immersive, full-credit first course in the technical material of the discipline.” The goals of the two types of courses differ to some extent, and both can be successful but a literature review seems to suggest that experiences of type 1 have met with less success than those of type 2.

Substantial success at Carnegie Mellon University is reported for a carefully designed first course of type 2 for Mechanical Engineering students². At WPI an introductory ECE course of this type is in place in the students’ second semester, and in the students’ first term an intense, immersive, full-credit experience titled “Great Problems Seminars” is offered to all incoming students regardless of major³. Against this background, it was desired to also provide a less intense experience of type 1 in the fall semester for students who may fall into either of two categories: (1) those who are certain of ECE as their major and want to get started immediately, and (2) those who are uncertain and would like to learn more about the major and the profession. The assumption that many students have little understanding of the engineering profession is reinforced by a survey that showed that approximately 30% of the entering students had no family member or acquaintance who was an engineer⁴. For minority students, the same survey determined that almost 50% had no experience with a family member or acquaintance who was an engineer.

Learning Outcomes

The ECE Department faculty has developed learning outcomes for all undergraduate courses. These serve as the bases for development of the catalog descriptions and the detailed courses syllabi. Following are the learning outcomes for the course described here:

1. Familiarity with the physical aspects of passive and active electronic components;
2. Understanding of circuit construction details, together with some understanding of the basics of circuit design and analysis;
3. Ability to relate a schematic diagram to a physical circuit;
4. Understanding of the relation of basic academic content (physics, math, etc.) to the professional activities of electrical and computer engineers;
5. Understanding of the range of career opportunities with a BS degree in Electrical and Computer Engineering (or in EE or Computer Engineering);
6. Understanding of what electrical and computer engineers actually do in their professional lives.

The level of achievement of these outcomes will be discussed later in the paper.

Course Format and Content

This course carries 1.5 semester credits, meets once per week, and includes weekly written assignments that are graded. Experience at WPI and elsewhere has shown that experiences of this type are more successful if they carry some credit and contain activities that are graded. There are no exams in the course. Students register for this activity in addition to their regular first year courses so it is important to maintain a reasonable expectation for out-of-class time, consistent with academic legitimacy. Each weekly meeting welcomes a guest presenter, approximately half of whom come from outside the institution.

Examples of the twelve speakers in the immediate past term include: an antenna/RF engineer from a major defense contractor whose avocation lies in residential photovoltaic systems; an analog design engineer who led the design of a helium ion microscope; a communications engineer who has risen in management as he has participated in the internet revolution with one of the major telecommunications corporations, a patent attorney with a BS degree in ECE, and an entrepreneur who started his company in his dormitory room. The presentations range from the moderately technical (such as the science and engineering involved in the generation and focusing of helium ions) to the rather philosophical (such as the social impacts of the growing ubiquity and intensity of interpersonal connectivity).

The presentation topics are listed in Appendix A. In addition, three optional laboratory sessions are held on Saturday mornings. In these labs students construct simple electronic devices such as AM radios and heart rate monitors.

Assignments

All assignments are in the form of short (one-half to four-page) essays. The intent of these assignments is multi-fold:

- To introduce students to important examples of electrical and computer engineering,
- To enhance skills in learning about new topics in efficient ways,
- To stimulate creative and critical thinking,
- To provide practice in technical writing.

The topics for all of the assignments are provided in Appendix B. These assignments are quite different from traditional ECE homework and students generally respond well to them.

Following is a quotation from one response to the lecture on the design of a helium ion microscope: “This week’s speaker really got me excited about Electrical and Computer Engineering. Prior to the presentation I was unsure of what field I want to study, but now I am almost certain I am going to be an ECE major. The concept of designing a helium microscope that can almost see individual atoms is simply incredible to me. I hope to be able to do the kind of micro-engineering the presenter had to do in order to create that machine.”

Each weekly assignment consists of two parts. Part one asks the students to comment on that week’s presentation in one of three ways:

- 1) *Why I would or would not be interested in pursuing this type of work in my career,*
- 2) *What I found that was surprising or totally new to me in the topic discussed,*
- 3) *In addition to what the speaker discussed, I investigated further and discovered some more information about this topic. (This information could be technical or could address the career or other aspects of the topic. Cite your sources.)*

The second part of each assignment varies widely from week to week in addressing the goal of introducing students to the breadth of career possibilities resulting from an ECE education. For example, following is the first week’s assignment:

This assignment is designed to start you thinking about technology, society, applications and being an entrepreneur. The Global Positioning System (GPS) has become ubiquitous and integral to daily life. This would not have been dreamed of by its original developers. You may own several GPS devices for use in hiking, finding directions while driving, and 911 calls from your cellphone. The GPS system is a wonderful example of Electrical and Computer Engineering in practice. The GPS device that you can carry around includes the following basic elements:

- *A high performance radio receiver operating near 1 GHz and the associated antenna.*
- *A high speed digital signal processor to do the calculations necessary to determine position.*

- A data base stored in digital memory that might include every road, city, and major landmark in the United States.
- A visual display system and user interface.
- Possibly a voice response and recognition system.

In addition there is a very sophisticated “back end” of the system including orbiting satellites and ground stations that supplies the signals.

Below are a few links to various technical aspects of the GPS system

- http://en.wikipedia.org/wiki/Global_positioning_system
- http://en.wikipedia.org/wiki/Introduction_to_the_Global_Positioning_System
- <http://www.af.mil/information/factsheets/factsheet.asp?id=119> (the US Air Force oversees the GPS system)
- <http://www.gpspassion.com/> (a GPS enthusiast’s site)
- <https://buy.garmin.com/shop/shop.do?cID=157> (GPS modules to incorporate into full systems)

1) The GPS system costs many billions of dollars. Briefly explain how you are able to buy a GPS device for less than \$100 (perhaps for as little as \$10) and what this “low cost of entry” has meant in technical, entrepreneurial, and economic terms.

2) Does GPS have any limitations and if so, how might they be overcome?

2) If you were to start an innovative, entrepreneurial company that uses the GPS system, what application would you provide? The application may make use of either a complete system such as a Garmin Nuvi, or a bare GPS chip or board (a so-called OEM device) that the designer must integrate into a complete system.

Don’t just duplicate the common GPS devices such as car navigation systems, but don’t worry too much about whether someone may already have come up with your idea. Your application could require a completely new electronics design, or it could just be an application that makes use of an existing GPS system (like the iPhone apps).

Include the following in your report:

- A marketing writeup that would “sell” your device to the consumer.
- A brief “business plan” that would explain to your investors how you are going to make money with this device.
- A technical description of the device including any appropriate diagrams and explanations.

All of the above can be quite brief and much less detailed than would be required in the real world.

Limit your response to no more than 4 pages plus the cover sheet.

Laboratories

Three lab sessions have been held on Saturday mornings. At each session an electronic kit was constructed. The functions are:

- AM radio
- LED strobe light
- Heart rate monitor

The first two kits were purchased commercially while the second had been designed in-house (originally for a summer electronics camp for high school students). All of the circuits were constructed on printed circuit boards. The kits were provided free of charge, and students kept their circuit. Each lab session began with an informal lecture on the circuit to be constructed – being careful to avoid jargon and circuit theory concepts other than what would be addressed in high school physics. Test instruments including the oscilloscope were demonstrated and each electronic component was shown and explained. Lessons in soldering were conducted.

These labs have been very well received by students. It is vitally important to have substantial one-on-one help available to assure positive outcomes. A student to instructor ratio of approximately four to one was maintained in order to provide the needed assistance for the first lab. With this level of assistance all the students were able to leave each of the three labs with working circuits. One of the laboratories was held on parents' weekend, and the parents enjoyed the opportunity to experience some of their student's ECE education.

The labs are not required and are not included in the formal course scheduling process. Hence some students have conflicts and are unable to participate. Several students have expressed disappointment at this situation, and we will attempt to move 1 or 2 labs from Saturday morning to a weekday evening to provide options for students.

Lecture Capture

The guest lectures were recorded and made available via a lecture capture system. This commercial system is almost completely automated and makes use of a wireless microphone on the presenter, a video camera for a view of the presenter, and a connection to the classroom computer to capture displayed material. The system is managed remotely, and captured lectures are posted on the course management system within a few hours of the end of class. Figure 1 shows an image from this system. Students commented very positively on this feature, which would be even more valuable in a course where exams are based on lecture material. The primary limitations are that images of blackboard materials are not captured, and student comments are seldom audible.

Course Results

Achievement of the course outcomes varied considerably from outcome to outcome. The first three outcomes were achieved only for those students (approximately half the class) who performed the optional labs. In the future a requirement to complete at least one of the three labs will be added, if scheduling permits. The content of the weekly assignments indicated that hearing about the diverse professional experiences of the speakers provided substantial insight into the value of the mathematics and science material that the students are studying. The

sessions by the design engineer on the helium-microscope and the PhD candidate were particularly informative in this regard. The course was quite successful in addressing outcomes five and six. Upon entry many students possessed almost no idea of what electrical and computer engineers actually do, and students with some past experience generally only had seen one example of such an engineer (often a family member) and so had a very one-dimensional view.

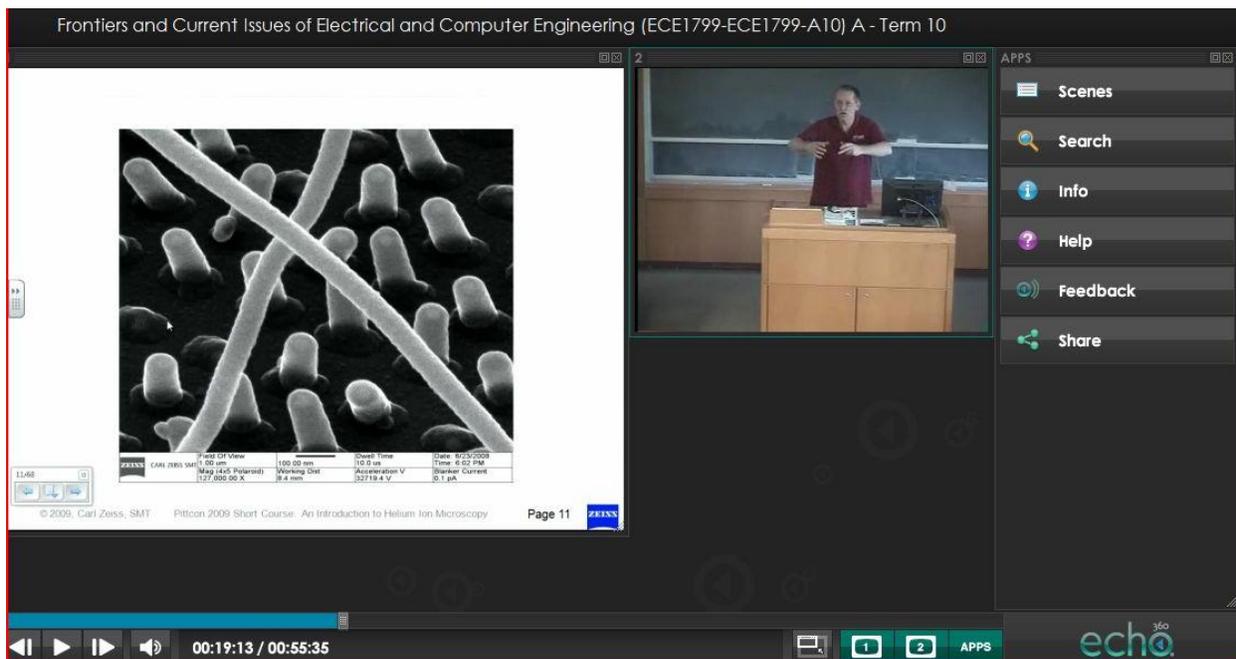


Figure 1. Illustration from the lecture capture system that includes a view of the instructor, the material displayed on the computer, and the audio.

Student perception of the workload appears to vary substantially. Some students commented on the heavy workload for only half the credit of a normal class. From the author's point of view, the workload is quite modest, expecting class attendance only one hour per week and the writing of two to four pages in essay format most weeks, together with the necessary background research needed to inform the writing. For some students this is a new experience, for whom the background research and writing is quite time consuming.

A selection of relevant comments from the student essays is included in Appendix C.

Longitudinal Data

This course has been offered in five successive years (to a total of 158 students) so the first cohort of students completed their fourth year in academic year 2009-2010. That cohort included 21 students and as of the beginning of the 2010-2011 academic year, nineteen of those students had in fact graduated.

In each of the offerings of the course, the percentage of enrollees who were ECE majors ranged from 50 to 70 percent. It was our hope to have a larger percentage of students who had not already chosen the ECE major, but as shown by student comments, the course has proved valuable to those students also. The disciplines of Computer Science, Robotics Engineering, and Mechanical Engineering are the most common majors outside of ECE, but a broad range of the majors at the institution are represented.

One hundred fifteen students enrolled in the course in the first four offerings, and as of the time of writing this paper 76 are majoring (or have graduated) in ECE. With regard to one specific goal of the course, twenty-nine of those students changed their major *into* ECE and 18 changed *out* of ECE. From that particular point of view, the course has been successful. For those who changed their majors to one that is outside of ECE, no particular trend is evident. Ten different majors are represented, both inside and outside engineering.

Conclusions and Future Plans

Evidence from the student assignments and course evaluations as well as from subsequent success in progress toward graduation demonstrates the value of the course. It is important to note that the range of previous experience with, and knowledge of, ECE varies greatly among students. The median level of knowledge is rather low, but some students arrive with substantial knowledge and sophistication, and course materials must engage and challenge them without intimidating the larger group of students who arrive with little knowledge of ECE as a discipline or a career. The ECE faculty are pleased with the success of the course and plan to continue offering it.

References

1. Engineering College Profiles, 2009, ASEE.
2. Susan A. Ambrose, Cristina H. Amon, "Design of a First-Year Mechanical Engineering Course at Carnegie Mellon University, *Journal of Engineering Education*, April 1997, pp 173-181.
3. B.J. Savilonis, D. Spanagel, K. Wobbe. Engaging Students with Great Problems. Proceedings of the 2010 ASEE Annual Conference, Louisville, KY (June, 2010).
4. Mary R. Anderson-Rowland, "A First Year Engineering Student Survey to Assist Recruitment and Retention," Proceedings of FIE 1996, Salt Lake City, pp 372-376.

Appendix A, Guest Lectures

Following are the topics of the guest lectures:

- Technology and Economics of photovoltaic power,
- Electronics design for the helium ion microscope,
- The evolution of the networking and telecommunications industries,
- Indoor tracking for emergency responders,

- Life after your BS degree – graduate school,
- Night vision goggles and the defense industry,
- Chip design at Intel corporation,
- Starting your own company,
- Patent law,
- Neuro-prosthetics and other biomedical devices,
- Making a difference in the world (introduction to the university's global program),
- Data security and privacy,
- Cold fusion – is it really cold?

Appendix B, Assignments

Following are the topics of the second part of the weekly assignments:

- Learn about the GPS system, explain some of its characteristics, and develop a product idea that makes use of the GPS system.
- Introduction to alternative electric energy sources in comparison to conventional sources.
- Assignment to envision their intended major and describe the role that each major academic aspect (science, mathematics, engineering, humanities, social science) of their upcoming education will play, as well as their post-BS career path.
- Consider the speed of light, and the context in which it is a fundamental constant (with the resulting relativistic effects), as well as the fact that the speed varies substantially in transmission through materials other than a vacuum.
- “True Grit” - read two papers addressing perseverance (one on the life of Steinmetz) and relate this to your own experience to date and your thoughts for your future career.
- Define and explain “Moore’s Law.” Comment on whether it is in fact a “law.” Propose a similar law in some other technical area.
- Briefly report on the history of radio and describe the many different technological directions in which radio (or something that performs a similar function) is heading.
- What is meant by the phrase, “The World is Flat?” From a list of corporations, determine in which nation each is headquartered. Comment on whether globalization is viewed differently in China than in the U.S.
- Explain why modern technology is greatly complicating the issues of privacy and information security. Explain why work on data security and privacy would be a part of Electrical and Computer Engineering.
- Over the career of the course instructor, the computer and communications revolution has dominated technology and much of society. Identify one technological area that you believe will be of major significance over your career, and explain why it will be a “Big Thing.”

- Explain what the National Academy of Engineering is. Compare and contrast two lists: the greatest engineering achievements of the twentieth century, and the NAE's "Grand Challenges" for the twenty-first century.
- For the last assignment, explain how you are different now than when you entered college and began the course. Comment on the major points that you take away.

Appendix C, Selected Excerpts from Assignments

The following quotations from the final assignment are indicative of the impact of the course on students:

I am surprised at how much I've changed since my first day at WPI. Electrical and computer engineering is a very broad topic that will continue to grow as time passes. I came to WPI with the intention of studying ECE, now it's not even an option to me.... This course has helped me to decide that computer science is for me.

Before I came to WPI, I have always conceived engineering and research as the same type of work, which is all about staying in the lab all day long and working with all sorts of scientific puzzles. After I came to WPI where I heard more and more about what engineering truly is about, I began to realize and understand the aspects of engineering that have never occurred to me. Especially after this course which lasted throughout two terms, I was amazed at the significance of social and humane sides of engineering that never impressed me so much. It just became increasingly apparent to me that it is not just a saying to place socioeconomic concerns into the design of an electronic product and it is not just the marketing strategy that makes a product stand out in the real world.

Over all I feel more confident in my decision of ECE as a major. I wish I had not procrastinated doing all of the assignments until the last week of the term.

Entering this course I was a pretty clueless freshman who had no idea what ECE, CS, or any other courses here entailed. After this course and my others here I can safely say I now understand what a major in each would require. After this term I feel like I know what I want to do with my future, and that is pursue a CS major.

The past semester of my freshman year I've changed a lot since high school and I've learned some of the necessary skills to thrive in college. My work ethic has improved greatly and it shows in my grades. The most important thing I discovered was that doing homework not only raised my grade but was also a good aid for reviewing the class material. My classes such as ECE1799 are very different from the high school classes I had become accustomed to. They challenge me to think and form my own ideas unlike my previous classes where it was more memorization and testing.

I came into this class sure that I was going to pursue a degree in electrical engineering and that this class would just be a good introduction to the world of electrical engineering. It proved to be more than that because of its focus on my education, such as the presentation on

the global projects program, and its focus on my future, such as the presentation given about starting up a business. This class surprised me because it had me thinking about what possibilities existed in my field and what I would do during my four years of college and after graduation.