AC 2012-4786: WHY SHOULD THEY CARE? MEETING THE CHALLENGES OF TEACHING NON-ENGINEERS TO ENGINEER

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Why Should They Care? Meeting the Challenges of Teaching Non-Engineers to Engineer

Abstract

Students must be prepared for today's globally-interconnected, technology-reliant world, so it is absolutely vital that they possess sound technological skills when they graduate. For students immediately entering the United States military upon graduation, this need is paramount. At the U.S. Air Force Academy, students are required to take several core engineering courses, regardless of their major, to graduate with a Bachelor of Science degree. An earlier ASEE paper [1] explored the basic pedagogy developed by the Air Force Academy's Department of Electrical and Computer Engineering to overcome the inherent challenges of teaching non-engineers "to engineer." This paper explores the measure of success for those efforts based on tangible feedback and assessment data. Furthermore, the paper specifically addresses a monumental challenge beyond educating the students: motivating them to care about their learning. Various approaches are discussed and solutions graded on their success or failure. A representative syllabus is included at the end of this paper.

Introduction

History is rife with famous examples illustrating the technological nearsightedness of even our most technologically-savvy leaders. "Flight by machines heavier than air is unpractical [sic] and insignificant, if not utterly impossible" – Simon Newcomb, 18 months before the Wright Brothers flew at Kitty Hawk, NC. "There is not the slightest indication that nuclear energy will ever be obtainable. It would mean the atom would have to be shattered at will." – Albert Einstein, 1932. "The world potential market for copying machines is 5000 at most." – IBM to Xerox founders in 1959. "We will never make a 32 bit operating system" – Bill Gates. Despite these non-prophetical, almost heretical, failed assertions, our society continually finds a way to achieve the technologically impossible. Future leaders must be technologically proficient to succeed in such a society. Thus, by extension, non-engineers must understand basic engineering principles before entering a marketplace steeped in globalization and interconnected at the speed of electrons.

The feedback and assessment data presented in this paper depict a measure of success in teaching non-engineers "to engineer." "To engineer" is not used in this paper in the formal sense that we generally view engineering activity. These students will not be designing a new communications system or a jet engine. However, they will be expected to apply the engineering method when faced with evaluating proposed systems, contracting for development and production, and approving outcomes.

All students at the U. S. Air Force Academy must take several core engineering courses to graduate with a Bachelor of Science degree. The Department of Electrical and Computer Engineering offers one of these courses, The Principles of Air Force Electronic Systems. Overall, many students see value in the course, but either dislike learning about technology or become discouraged due to subpar analytical abilities. We strive to instill and hone traditional engineering skills such as problem solving, detailed technical work, and critical thinking. Yet, beyond classroom technical performance, a recurring crack exists in the execution of this course. Like any 12-step recovery program, we first recognize that we have a motivation problem.

On the first day of class, students are generally polled, "If this class was optional, would you take it?" The taciturn response is not surprising, and it is coupled with fear and hesitation. Initially, non-engineering students do not understand why they must learn engineering concepts, especially if it is unrelated to their major. Why should they care? For many students, the course is just another box to be checked for graduation; yet for all students, the lessons learned in the class will benefit them in their military careers and beyond. Convincing them of this necessity is a struggle. Many students will have military jobs that will be unrelated to their major. Yet, students that possess a fundamental understanding of how electronic systems work will be better decision-makers in our technologically advanced military. This understanding will combat ignorance of devices that most people, both civilian and military, depend on daily in today's modern society.

Within this contextual framework, our course was developed and has morphed with the audience in mind. (A syllabus is attached to this paper.) From 2004-2007, the course was assessed to be one of the lowest rated courses at the Air Force Academy in terms of both relevancy and student enjoyment. Great strides have been made in improving the course in order to make it more learning-focused. Feedback and assessment data from the past two years confirm that a focus on concepts before details is imperative. The key elements—keeping readings, demonstrations and formative assessments simple and to the point; highlighting relationships among concepts; providing relevant examples; providing alternate explanations of mathematical methods—are in place and results show promise. Our instructors meet these tough critics through enthusiastic motivation, a clear focus on concepts before details, relation of concepts to relevant Air Force missions when possible, and reinforcement to enable long term memory. However, the process of teaching engineering to a non-engineer remains a challenge. The ultimate goal is for students to retain the knowledge they gain in the course, relate the information to things they will see and use every day while in the military, and recognize that they really do understand the basics.

This paper addresses these key issues by reporting on successes over the past 2-3 years of teaching non-engineers to engineer and addressing a fundamental, recurring problem from semester-to-semester: motivation. After introducing the topic, the paper provides some background for contextual understanding. The background addresses the sophistication in technology for today's Air Force, and it briefly summarizes the ASEE 2010 paper, which addressed the initiation of our course [1]. Next, the paper discusses assessment methodology used to collect the tangible feedback and assessment data in order to score the measure of success of our efforts. The results point to an issue with student motivation, which leads to a section addressing motivational challenges in the classroom as we prepare students for their future. Finally, the conclusions offer some key nuggets for the thoughts presented in this paper.

Background

"The mission of the United States Air Force is to *fly*, *fight*, and *win*… in air, space and cyberspace" [2]. To accomplish this mission, the Air Force focuses on three core competencies: Developing Airman, Technology-to-Warfighting, and Integrating Operation. Obviously, to fly, we need aircraft equipped with electronic equipment. To operate in space, we rely heavily on technology to provide autonomous operations to perform a variety of missions. To communicate with these satellites, we rely on radio communication. Lastly, cyberspace wouldn't exist without technology. Technology gives the Air Force the advantage on and off the battlefield. For these reasons, it is just as important for future Air Force leaders to understand the basic principles of Air Force electronic systems, as it is for them to learn about the basics of biology. The more knowledgeable these leaders become, the more informed decision-maker will they be.

So, how do we create a course that incorporates the basic principles of Air Force electronic systems and target students who are mathematically challenged, not interested in topics outside their major, or have a tough time grasping analytical concepts? The previous paper addressed the challenges of teaching basic engineering principles, while incorporating decision-making, the crux of any Air Force officer's responsibility. Six unifying themes were introduced, and a current lesson breakdown is offered in Appendix A:

- Aircraft electrical systems
- Power distribution systems
- Unmanned aircraft systems
- Global Positioning System (GPS)
- Radar
- Electronic warfare

The innovative method of presenting basic principles was "the packaging" of them into these themes. Through these themes, instructors strive to link basic principles to topics that the students may deem relevant. Furthermore, that paper addressed the complexity and relevance of the previously used text, specifically asserting that it was:

- Difficult to read and understand
- Not aligned with what was actually being taught
- Not sufficiently targeted to non-engineers

The resultant changes based on these underlying concepts have been incorporated and slightly modified over the last two years. (See the attached syllabus.) The themes have been linked and segregated into three separate blocks of instruction:

1. Power distribution systems
   Basic circuit analysis, power generation/transmission/conversion/distribution
2. Signal conditioning/processing and Cyberspace
   Transducers, instrumentation, operational amplifiers, frequency domain, filters, analog-to-digital and digital-to-analog conversion, multiplexing, cyberspace
3. Communication, Navigation and Radar
   Modulation, demodulation, antennas, wireless communications, radar, GPS, electronic warfare

At the end of each block, an exam is given, and two or three lessons are reserved for projects. A project is the culmination of the previous block, tying all principles together into an overarching scenario. Students must work in teams to solve analytical problems, identify viable options, and then step through a decision-making process in order to recommend the best option.

Assessment Methodology

This section defines the methodology used to collect the tangible feedback and assessment data reported in the Results section. The first assessment discussed is generated by the Dean of Faculty (DF) for all academic courses at the Air Force Academy. The DF Course Feedback is directly linked to the course's learning goals. The learning goals of the engineering course offered to non-engineers state that:

Cadets shall:

- Demonstrate knowledge of basic electronic functions used in electronic systems
- Understand and apply fundamentals of electrical and computer engineering (ECE) to real-world operational scenarios and technical challenges
- Frame complex scenarios using the engineering method to logically solve problems
- Evaluate competing designs using ECE principles and integrated knowledge from other disciplines in a team environment to select and advocate a system-level solution

Generally, the graded assessments were the determining factors for meeting these objectives; however, whether the course contributed to life long learning or was a progression of knowledge to learn and brain dump later is difficult to measure. For years, the Academy has requisitioned and collected feedback from their students at midterm and at the end of each semester to help determine the effectiveness of the course. The feedback includes instructor ratings, course rating, grades, etc. The following course-related questions were asked for the DF Course Feedback ratings:

1. Overall, my **instructor** is:
   1-Very Poor, **2**-Poor, **3**-Fair, **4**-Good, **5**-Very Good, **6**-Excellent
2. Overall, the **course** is:
   1-Very Poor, **2**-Poor, **3**-Fair, **4**-Good, **5**-Very Good, **6**-Excellent
3. On average, for every **hour** I spent in this class, I spent about **___** outside of class completing work in this course (including studying, reading, writing, doing homework or lab work, etc.).
   1-1/2 hour or less, **2**-More than 1/2 hour, but less than one hour, **3**-More than one hour, but less than two hours, **4**-More than two hours, but less than three hours, **5**-More than three hours
4. The course **activities** (e.g., assigned readings, lectures, discussions, labs, projects, etc.) were effective in helping me accomplish the learning goals of this course.
   1-Strongly Disagree, **2**-Disagree, **3**-Slightly Disagree, **4**-Slightly Agree, **5**-Agree, **6**-Strongly Agree
5. In this course, the **graded** events (e.g., exams, papers, projects, etc.) provided the opportunity for me to demonstrate my accomplishment of the course learning goals.
   1-Strongly Disagree, **2**-Disagree, **3**-Slightly Disagree, **4**-Slightly Agree, **5**-Agree, **6**-Strongly Agree

We collected and reviewed the average ratings from Spring 2009 to Fall 2011. Depending on the semester, a range of 49-302 students provided inputs. The ratings from these semesters provided some insight to the health of the course and whether the course director (faculty responsible for the course) and instructors were meeting their course goals. However, the detailed feedback needed to provide more fidelity in determining success of course improvement was missing.

Starting Summer 2011, a second assessment, a more tailored feedback system, was established to more fully assess the accomplishment of the course's previously defined objectives. At the end of the Summer semester, 100% of ECE 315 students responded to the End-of-Course (EOC) survey; 56% of the students from Fall 2011 did so. The questions listed below are a sample of this survey.

1. The reading… (select all that apply)
    a. Was difficult to read and understand
    b. Was not aligned with what was actually being taught
    c. Was obviously targeted toward non-engineers
    d. Written in a way where very technical reading was easy to understand
    e. Was neither easy to read or confusing
    f. I didn't read
2. I liked…
    a. Project #3's structure because I liked working in a team
    b. Project #1 and #2's structure because I like to get credit for my own work
3. All projects were…
    a. ...useful because they tied in the course material with decision making, which is more in line with what we will experience in the Air Force
    b. ...senseless. I didn't learn anything
6. Knowing what I know now about the course, I ...
    a. Am glad I took the course
    b. Can see the utility, but just don't like learning about technology
    c. Thought it was a waste of time
7. I am ______________ scared of Electrical and Computer Engineering than I was on Lesson 1.
    a. More
    b. Less
    c. I was never scared
9. T/F. I believe learning about my major is more important than having a broad learning experience.
10. T/F. The core classes at USAFA will help make me a better decision maker as an Air Force officer.

Although an ideal feedback rate of 100% was not achieved in Fall 2011, a significant number of students did provide input to both the DF Course Feedback and the EOC Survey. These numbers were important to gain a representative student perspective of the course.

Results

The results of the DF Course Feedback (Spring 2009 – Fall 2011) and the ECE 315 EOC Survey (Summer and Fall 2011) provide interesting and insightful results. The DF Course Feedback results are summarized in Table 1.

Table 1. DF Course Feedback Ratings.

	Total # of students	Feedback rate	1 - Instructor	2 - Course	3 - Hours	4 - Activities	5 - Grades
Spring 2009	50	98%	5.36	4.78	2.18	4.88	4.98
Fall 2009	289	42%	5.15	4.65	2.24	5.05	5.00
Spring 2010	421	71%	4.79	4.13	2.39	4.60	4.43
Fall 2010	309	56%	5.10	4.45	2.29	4.83	4.58
Spring 2011	427	56%	5.37	4.66	2.30	4.95	4.90
Fall 2011	333	77%	4.71	4.04	2.23	4.63	4.46

For the course as a whole, the feedback from the students improved steadily from Spring 2010 through Spring 2011. However, Fall 2011 shows a dramatic decrease in overall student opinion of the course. Upon initial inspection, it is tempting to conclude that the instructor had a direct effect on this outcome since the instructor average is the lowest in three years. Due to retirements, separations, and military moves , the instructors for the engineering course vary from semester to semester. Further analysis revealed that the instructor rating is independent of the decline in course rating. Three instructors were evaluated over the past five semesters; their personal ratings show the same trend as the average instructor ratings shown in Table 1. Since the course went through only minor changes from Spring 2011 to Fall 2011, we ask, "Why the decline?"

Further exploration shows a high correlation between the student's grades from the course and their overall satisfaction/opinion of the course. From Spring 2011 to Fall 2011, the percentage of A's and B's given dropped by 10 percentage points, which would account for the course rating drop. Figure 1 provides the grade distribution over the past three years, while Figure 2 compares the percentage of A's and B's per semester to the corresponding DF Course Rating from Table 1.

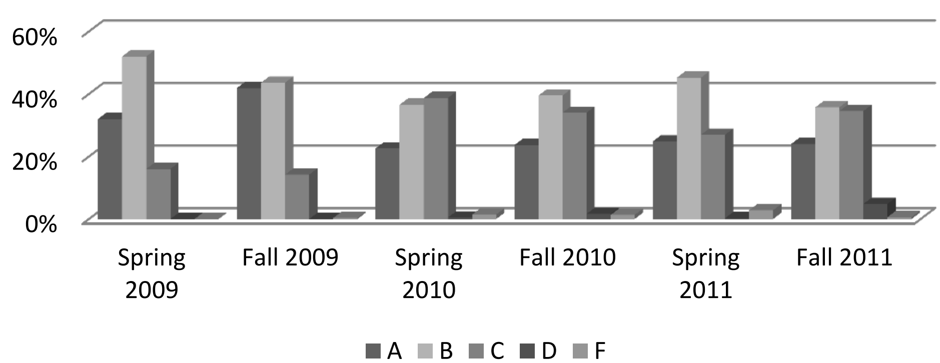

Figure 1. Earned Grade Distribution from Spring 2009 to Fall 2011.

The EOC Survey was developed because of the high correlation and the overall generality of the DF Course Feedback shown in Figure 2. It is intended to gauge possible issues with the course and provide the feedback needed to assess the course changes described in AC 2010-758 [1]. The specific areas discussed, as a follow-on to AC 2010-758, were the readings, decision-making, and relevancy.

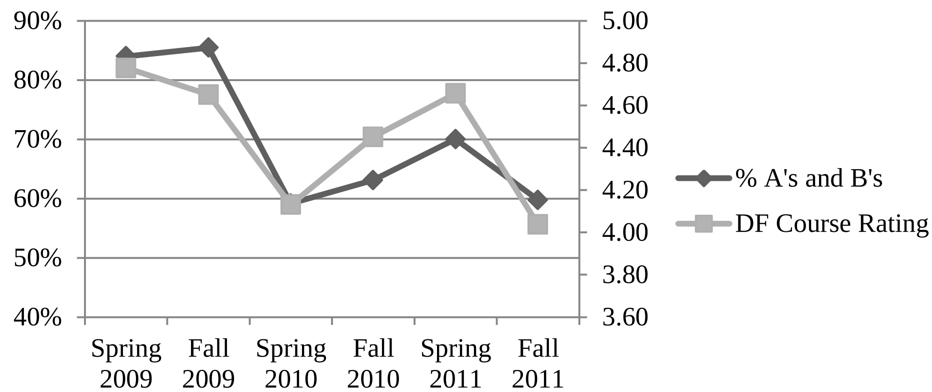

Figure 2. Comparison of Above Average Grades and DF Course Rating.

At the end of Summer 2011, 25 students (100%) completed the first EOC Survey. At the end of Fall 2011, 333 students were asked to take the Survey. A total of 187 students responded. The course material and format from Summer to Fall remained the same, but the student experience was slightly different. Those who took the class in the Summer did not have to split their time between many courses—their primary responsibility for three weeks was ECE 315. Students who took it in the Fall had to juggle five to seven classes over the four month-semester.

In 2009, major course changes were made with the goal of showing relevancy to electronic principles and establishing relationships between these principles through team-focused projects, while providing the opportunity to enhance decision-making skills. This overarching goal is met first with the readings—all lectures are based on the readings. The text was written by experienced Air Force officers, members of the Department Faculty, and strongly relates Air Force material to engineering principles. The readings are tailored to provide interest and relevancy to a non-engineer. They link basic electronic principles to devices and structures that the average American commonly touches, sees, or uses.

Many students in this course are considered "read-write" learners; for them the readings are crucial. The first question in the EOC Survey was to establish the general opinion of the faculty-written text (see Fig. 3). The results show that the changes to the faculty-written text were a success. About 86% of those who read thought the reading was understandable or easy, while 19% did not read the text. Furthermore, 97% of students felt the text was aligned with material covered in the lectures. This was a great start.

The second major change was the introduction of meaningful projects. A project was the pinnacle of each of the three blocks and impetus to illustrate the decision-making process, a fundamental goal of the course. The second question in the survey asked the students their opinions of the projects so we could gain insight into the project's usefulness.

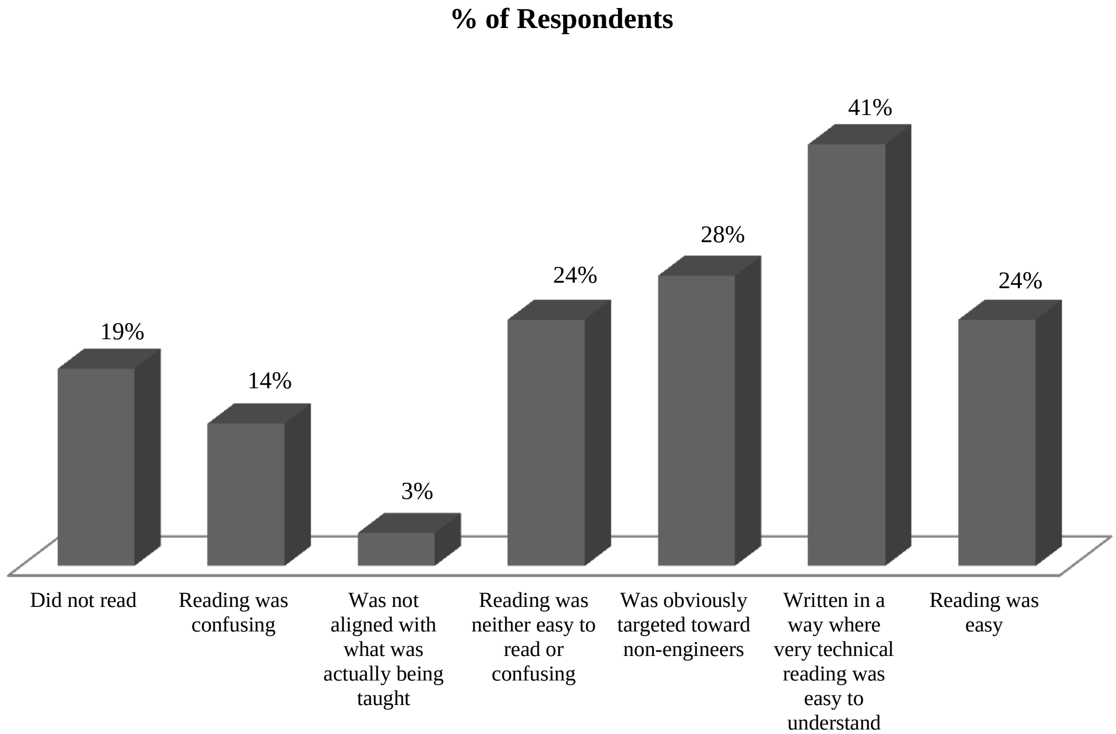

Figure 3. Reading Survey Results, Fall 2011. (Multiple responses were accepted)

There are three projects that correspond to the three blocks of instruction. Each project has an Air Force operational scenario where students have to analyze possible combinations of components, then categorize them into viable and unviable options. Once they have eliminated unviable options, the remaining selections, which must meet all threshold requirements, are entered into a decision matrix. Different measures of merit are selected and weighted based on the team's determination of their importance. The output of this matrix points to the team's recommended solution/option for the project. Their work is presented in a slideshow, which is a common method of communication used in Air Force. Of those surveyed over both semesters, the majority of students believed that the projects were useful (see Figure 4).

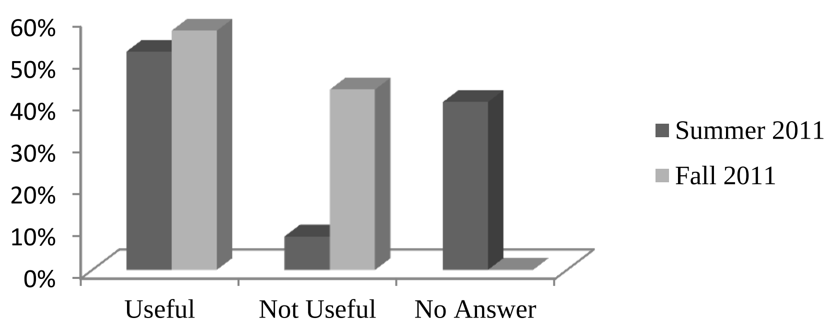

Figure 4. Feedback on Projects.

This was great news, but there was an underlying issue that instructors began to notice over the semesters. Many students who seemed to struggle with the material performed well on the projects. The reason was often that an academically-strong team member conducted the mathematical analysis for the project, so the team grade dispersed among the members was not representative of a below-average team member's work. This realization led to a slow transformation to projects containing both team and individual portions. In Summer 2011, one of the three projects was modified. The change was wildly unpopular with the students! However, the project grades were more in line with each individual's effort and performance. For Fall 2011, another project was modified, leaving just one that was a total team effort. Not surprisingly, the changes were significantly more unpopular (see Figure 5)! But why?

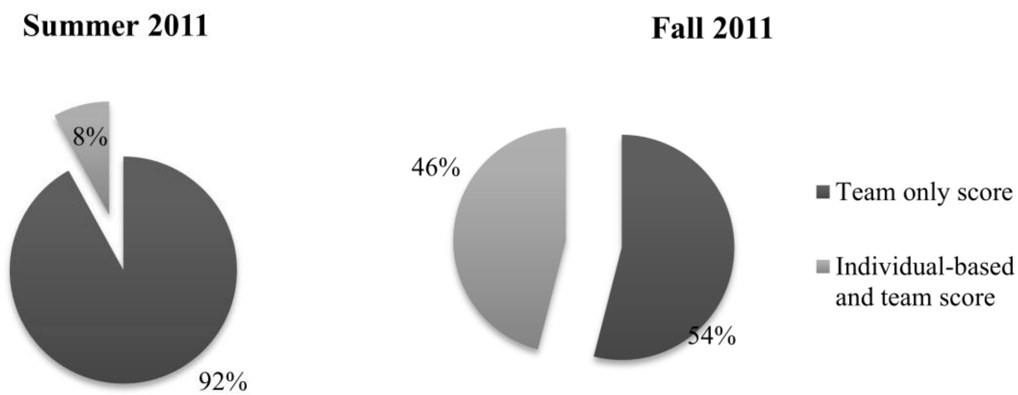

Figure 5. Project Preference.

On further analysis, we found a negative correlation between incoming GPA and whether the students preferred more of a team or an individual approach to projects. About 92% of the Summer students, who had an incoming GPA of 2.39, favored a more team approach. Only 54% of the students who replied to the EOC Survey in the Fall favored the team approach; they had an incoming GPA of 2.84. Obviously, the concept of team is very important in Air Force culture. It is the crux of mission accomplishment. In an academic environment, however, many students just want to complete the class and look at many classes as boxes to be checked. The total team approach generally provided a good grade with less work. This is somewhat understandable due to the life experience of most students.

Finally, the big question for this survey is whether the students found the course to be valuable. Figure 6 shows that approximately 79% of the respondents thought the course was useful, although some of them did not enjoy the material. Is this good or bad? Does it matter if students don't like what they are learning? Will it mean that they will more likely retain the information if the find it valuable? And, if it does, how do we motivate them to care about learning?

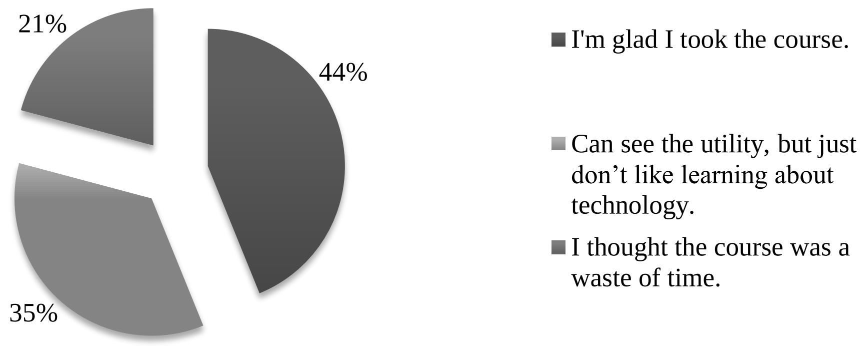

Figure 6. Course Reflection, Fall 2011.

Motivational Challenges

"Electrical Engineering?" "Electronic Systems?" "We have to take an engineering course? But, I'm an English major." "Why should I care about engineering?" These are common reactions from students on Lesson 1 of this 40-lesson course. Indeed, these are valid questions. So during Lesson 1, each instructor is challenged to convince these students that this course is relevant. Then, during every succeeding lesson, they continue to motivate the students to learn and to be interested, not just regurgitate information. Unless a student is motivated to learn the material, the information presented is unlikely to be committed to long-term memory, which is the real indicator that learning has occurred. Attitudes and prejudices need to be addressed early.

One thought is that maybe these non-engineering majors are intimidated by an engineering class. Students understand that there is a prerequisite Physics class, and there will be math involved. To debunk or link this idea to the core of the motivational problem, we asked the students how "scared" they were after taking the course. Figure 7 shows the result. The good news is that after taking ECE 315, almost 48% of these students are less scared of Electrical Engineering. Does this mean they learned? Not necessarily. It could just mean that they thought that the math or concepts were not as difficult as they envisioned before the course began. However, this news does, at least, loosely imply that the instructors have motivated the students.

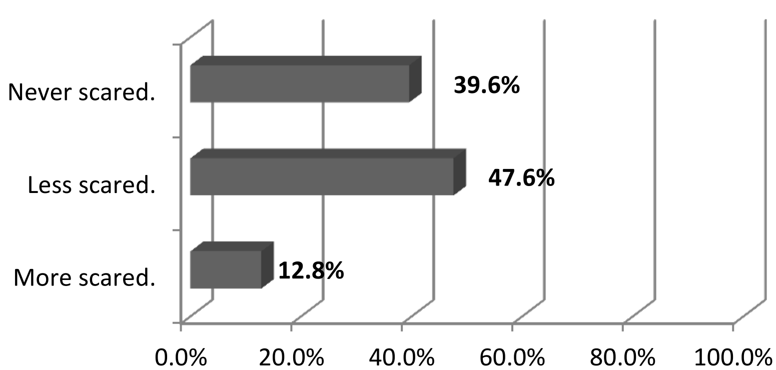

Figure 7. Fear of Electrical Engineering after taking ECE 315, Fall 2011.

Unfortunately, the motivation factor seems to be section dependent. Depending on the instructor, the time of day, and the students assigned, the motivation challenges in each section vary significantly. At the course level, this issue is only mildly manageable. It is the instructor's responsibility to assess and react based on that section's unique personality. For example, in some sections, going to the board during class to work out problems as a team is enjoyed, while others abhor it and would prefer to carry their work away with them after class. The instructor has to read the class, then modify the lesson plan to better fit the learning style of the section.

To address this issue at the course level, the instructor had many tools at his/her diposal to make the class more interesting and to actively engage the student. These include demonstrations that are visual and/or auditory, items to pass around class, analogies, stories demonstrating relevancy, and clicker sets that allow the student to provide anonymous feedback for close-ended questions.

During the DF Course Survey, students are provided the opportunity to make comments. Some of the more common comments refer to the use of clickers, labs, and demonstrations. “More clickers.” “Continue clicker slides.” “Demonstrations make the class interesting!” “More real world scenarios.” These tools really seem to connect with the visual and kinesthetic learners.

Analogies, examples, show-and-tell and demonstrations are used extensively in the course. For example, to introduce circuit protection, a simple circuit is drawn on the board, consisting of a 5-volt battery and a 1-Ω resistor. The students are asked to calculate current. Next, a 1-Ω resistor is actually connected to a 5-volt power source. The student sees the resistor burn and emit a puff of smoke. The concept of device current ratings is linked with that puff of smoke. From here, circuit breakers and fuses are passed around the room, while the instructor tells about house circuit-breaker panels and fuses found on electrical equipment and the detrimental results of their exclusion. This is one example of many demonstrations introduced in the course within the past five years to spark interest in technology.

The clickers have only recently been incorporated in the classroom, but with great success. PowerPoint is used to display multiple choice questions and the student is asked to select the correct answer. After all students have complied, the class statistics are automatically provided (i.e., the percentage of the class that selected each answer). This tool allows students to provide feedback during class while providing the instructor with immediate results on the class’s understanding. Based on these results, the instructor can change the lesson plan to tailor it to the students’ understanding. If the students are not grasping a certain concept, the instructor can spend more time on it. If they are, the instructor can save valuable classroom time and move on to the next topic. The students respond positively to these clickers and seem to enjoy the opportunity to interact in class without judgment.

Another huge factor in the student enjoyment of the course is the enthusiasm of the instructor. Instructors who are perceived as highly enthusiastic tend to receive the highest DF Course ratings. Enthusiastic instructors are generally entertaining. If a class is entertaining to the students, they will want to attend, listen, and learn, which is the overarching goal of Air Force’s learning-focused environment. Note that enthusiasm, as mentioned, is more aligned with being passionate about the information in the lecture rather than being an energetic presence. So, based on this perspective, the instructors are a key ingredient in motivating the students to learn.

The lecture is not the only avenue to success, however. Peer instruction has proven to be a useful classroom tool to further enhance the learning environment. Harvard professor Eric Mazur exclusively uses peer instructor to teach Physics [3]. Instead of lecturing, he acts as a "coach" in the classroom. He starts by submitting a question to the students. After the majority of the students realize that they got the answer wrong, Mazur encourages the students to talk amongst themselves to resolve the issue. Upon a repoll, the majority of the students answer the question correctly. Currently, this method is integrated into the lectures using clickers, but is not exclusively used.

Conclusion

The modification to the Principles of Air Force Electronic Systems (ECE 315) at the U. S. Air Force Academy was successful. Upon completion of the course, the overwhelming majority of non-engineering students feel that the reading was understandable, the projects were useful, and the overall course was valuable. Furthermore, the majority don't feel intimidated about engineering, and are glad they took the course. This is all great news, but the course still has an issue with individual motivation. Even if these students are taking the course because it is required and not optional, can they be convinced to attempt to learn as opposed to regurgitate? We assert that if the student is properly motivated to learn on Lesson 1 and are then presented with an interesting class that engages their senses and challenges them, they will not only learn, but they will hopefully retain the information to make a difference in their future career as an Air Force officer, and decision-maker.

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Appendix A – ECE 315 Syllabus (Spring 2012)

Lesson	Topic	Demonstrations	Comments
1	Course overview; Basics of ECE	Meter, source, resistor	
2	Circuit analysis I (Kirchhoff, power)	Resistors minilab	D-C only
3	Circuit analysis II; Protection	Overload (smoke!)	Series, parallel, dividers
4	Signals; A-C circuit analysis	Sine waves, scope, tones	Resistive only, RMS, power, efficiency
5	Lab 1		D-C circuit analysis: series, parallel, four resistors, voltage, current, resistance
6	Power generation	Simple motor demo	Fuels, efficiency
7	Power Transmission	Two coils and core	Transformer, voltage levels
8	AC/DC conversion		Select "wall wart", decision matrix
9	Power distribution	Aircraft diagrams	Bus concept, protection
10	**Exam #1**		
11	Engineering method		Define, collect, solve, analyze, etc.
12 13	Project Time, apply engineering method		Design of power distribution system, given power needs at various points and available power-system components
14	Instrumentation	Microphone to scope	Transducers, op-amps
15	Instrumentation implementations		Signal conditioning, gain, bias
16	Filters (LP, HP, BP)	Spectrum of musical note	Bandwidth vs. thruput
17	Analog-to-digital conversion	Fan & strobe, video	Sampling, resolution, aliasing
18	Analog-to-digital conversion		
19	Digital-to-analog conversion		Quantization error
20	Digital signal channels	Internet speed test	Parallel-serial, TDM, switching
21	Cyberspace	Video	
22	**Exam #2**		
23 24	Project time, apply engineering method		Design satellite monitoring comm system with multiple digital channels and TDM, component selection, select "best"
25	Modulation		Types, benefits, drawbacks
26	Amplitude modulation	Modulation worksheet	Under and over, bandwidth
27	Demodulation	Demo using o-scope	Envelope, synchronous
28	Lab 2		Set up AM modulator and demodulator and observe on scope signals at input, after modulation, and at output
29	Antennas	Radio demo, show & tell	Types, wavelength, frequency
30	Wireless communications	RF bands, fiber optics	Uses of frequency bands, line-of-sight
31	FRIIS equation		Range, signal-to-noise
32	Radar		Range, reflection, detection range
33	Radar	Application videos	Range resolution, velocity
34	GPS	Trilateralization	Satellites, coding, position
35	**Exam #3**		
36 37	Project time, apply engineering method		Select radar and comm system components and determine "best" system based on various constraints
38	Project brief		
39	Electronic warfare	Audio jamming demo	Jamming, countermeasures
40	Electronic warfare		
	Final examination		