AC 2009-1830: INCREASING THE ENROLLMENT, RETENTION, AND SATISFACTION OF FIRST-YEAR STUDENTS IN ELECTRICAL ENGINEERING, COMPUTER ENGINEERING, AND COMPUTER SCIENCE

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Increasing the Enrollment, Retention, and Satisfaction of First-Year Students in Electrical Engineering, Computer Engineering, and Computer Science

ABSTRACT

In this paper we describe the design and implementation of a novel first-year course for undergraduate students interested in electrical engineering (EE), computer engineering (CE), and computer science (CS). Our primary goal is to realize significant improvements in several student outcomes, including: increased enrollment, retention, and satisfaction for all students—with even greater impact for students from under-represented groups. Our work is motivated, in part, by the recent downward trend in undergraduate enrollment in these areas: in the United States, from Fall 2001 to Fall 2007, enrollment declined 29.7% in EE/CE bachelor’s degree programs and it declined 18.8% in CS bachelor’s degree programs.

This new, first-year course is focused on exciting, discovery-based, hands-on projects that address real-world, contemporary problems in EE/CE/CS. Students work in teams to solve these technically diverse problems and they interact with several faculty experts as they develop their solutions. Connections to how these problems and their solutions benefit society are emphasized; we expect societal impact is particularly important to the women students. As the students develop their solutions to these problems, they discover fundamental underlying concepts, problem-solving strategies, and trade-offs that arise in real EE/CE/CS problems. For example, a project in the signal processing area has students use Matlab to program and evaluate rate-based arrhythmia detection algorithms for patients with implanted cardioverter defibrillators. Through their work, the students discover the impact of computational complexity on the real-time constraint that is critical to the device’s ability to save lives.

This new course was launched in the 2007-2008 academic year; 330 students enrolled in the new course and 97.9% of them completed it. For the new course, the downward trend in total enrollment for the old version of this course was arrested; moreover, women’s enrollment increased 80% (from 15 to 27). Student retention in the course increased from 94.7% in the old course to 97.9% in the new course; this higher retention rate for the new course is statistically significant. Student retention in the EE/CE/CS majors increased from 37.8% for the old course to 45.2% for the new course—with women’s retention improving dramatically from 28.1% to 64.3%; these differences are also statistically significant. An affective questionnaire administered to students at the beginning and ending of the new course showed improvement on critical issues like: satisfaction with the EE/CE/CS major choice; confidence in becoming a successful EE/CE/CS engineer; and, importance of EE/CE/CS work to society. Interestingly, these improvements were even larger for the women students. At the end of the spring semester, 100% of the women intended to major in EE/CE/CS compared to only 80.9% at the beginning of the course. Men’s major intention also increased over the semester from 89.0% to 94.5%.
INTRODUCTION

In this paper we describe the design and implementation of a novel first-year course for undergraduate students interested in electrical engineering (EE), computer engineering (CE), and computer science (CS). Our primary goal is to realize significant improvements in several student outcomes, including: increased enrollment, retention, and satisfaction for all students—with even greater impact for students from under-represented groups. Our work is motivated, in part, by the recent downward trend in undergraduate enrollment in these areas: in the United States (US), from Fall 2001 to Fall 2007, enrollment declined 29.7% in EE/CE bachelor’s degree (BS) programs and it declined 18.8% in CS bachelor’s degree programs\(^1\). For our university, Virginia Tech, the corresponding figures for the same time period are: 29.3% enrollment decline in EE/CE bachelor’s degree programs and a 75.4% decline in the CS bachelor’s degree program\(^2\). The percentage of BS degrees awarded to women in these fields in the US has also fallen over the past few years, dropping to 12.4% for EE, 9.2% for CE, and 12.0% for CS in 2006-2007\(^1\). Our university suffers from a severe under-representation of women in these fields; our BS degrees awarded to women over the past few years are substantially lower than the eroding US statistics. On average, the percentage of BS degrees awarded to women in EE at our university is 34% lower than the corresponding US figure—our CE degrees awarded are 63% lower and our CS degrees awarded are 51% lower than the corresponding US figures\(^2\).

In our first year required courses for students intending to major in EE/CE/CS, we witnessed a precipitous decline in enrollment. We focused our attention on identifying the underlying reasons and discovered an inadequate and uninspiring approach to our first year engineering education. The primary problems are grouped into the following two categories.

First, in our introductory courses there was a dearth of examples of what electrical and computer engineers/scientists do and how their work helps people. Students are enthusiastic to learn about real, contemporary problems and how engineers solve them to benefit society—this societal impact aspect is particularly important to women students. Unfortunately, our first year courses were a hodgepodge of topics and tools with no introduction to contemporary, meaningful problems and how to solve them. On the occasion when a problem was introduced, it tended to be inane and trivial—with an emphasis on having “fun.” However, toy problems do not induce nearly as much fun or satisfaction as the sense of accomplishment derived from solving a real engineering problem. Consequently, it is unsurprising that our first year students gained no significant knowledge or understanding of important concepts; instead, their enthusiasm and interest—and ultimately their enrollment—in our EE/CE/CS majors waned\(^3\).

Second, our first year courses suffered from a collection of problems that we refer to as “poor teaching”\(^4\). The instructors had limited and/or outdated education and experience in the EE/CE/CS fields; their expertise in relevant pedagogical issues was also inadequate. Students are eager to interact with faculty who possess expertise, enthusiasm, and a sincere desire to engage students in meaningful work. Unfortunately, students in our first year courses experienced a variety of problems including: prohibited teamwork (in some cases) and unguided teamwork (in others); incomplete and erroneous information; lack of timely, accurate feedback; vague, opaque course policies, schedule, and learning goals; convoluted assessment tools; and, an instructional approach based on a punitive attitude toward students and their learning.
NEW FIRST YEAR COURSE

Overview
The new course represents a complete redesign of an existing/old first year course required of all undergraduate students who apply for admission to the EE/CE/CS majors. It is a 2-credit course that includes a 1-hour lecture and 2-hour lab every week. Most students enroll in the course during the “on-track” spring semester (approximately 280-300 students); an additional 60-70 students enroll in the course during the fall semester. A lead course instructor and several guest faculty experts present a range of technical projects that address contemporary, real-world engineering problems whose solutions help people. Students work in teams to design and implement their own solutions to these problems.

Meticulous organization, advanced planning and faculty teamwork are critical to both the effectiveness and enjoyment levels of this class—for students and faculty. Eight faculty develop projects in technically diverse areas; without their participation, this course can not exist. They possess the expertise that allows hard problems to be made tractable for first year students and they engender student enthusiasm that is profoundly absent in introductory courses. Four faculty present individual projects; each project requires two weeks. The remaining four faculty collaborate on a four-part multidisciplinary project that requires five weeks. Two weeks at the beginning of the course include introductions to: the projects, effective teamwork, and a warm-up technical project that introduces the students to Matlab through an investigation of audio clipping (why it occurs, its impact on audio signals, and how to mitigate it).

Because our faculty maintain a heavy load of teaching, research, and service commitments, a sustainable model that recognizes their participation in this extra teaching effort is essential. Each faculty member received two weeks of summer salary in order to develop her/his project. Many faculty expended additional time on their project’s development and also enlisted help from their graduate and undergraduate student researchers. Each faculty member participates in the course for the two weeks of her/his project: presenting introductory and summary lectures and interacting with students in the hands-on lab sections. For each semester that a faculty member participates in the course, she/he receives a 1/3 course buyout credit; after 3 semesters, the faculty member earns a “one free course buyout” credit. The faculty and the participating departments find this to be a worthwhile, sustainable arrangement.

In addition to coordinating the technical projects, the lead course instructor design, adapt and employ several pedagogical practices in the new course to further promote student learning, success, and satisfaction. Effective student teamwork is fostered through significant, early guidance on: identifying team roles and responsibilities; establishing a team identity and protocol; motivating reasons for the use of teams; and, effective team strategies for problem-solving. The lead instructor continues to monitor and guide the teams throughout the course. All project faculty are taught two active learning techniques for their lectures: a think-pair-share for the introductory lecture; and, a closure-writing-pair for the summary lecture. Faculty encourage (and assist) students to enhance their understanding by making connections across the projects on the concepts they discover, the problem-solving strategies they employ, and the trade-offs they encounter. The lead instructor makes the assessment tools and policies transparent to students; moreover, students receive helpful, accurate, timely feedback on their exams, project
reports, and oral presentations. All faculty promulgate an incremental theory of intelligence; they convey to the students that their questions and ideas are interesting and that every student is able to succeed—and have to fun doing it!

**Signal Processing Project**

**Arrhythmia Detection Algorithms for Implantable Cardioverter Defibrillators**

The normal heartbeat cycle, called a sinus rhythm, is described by the “PQRST” wave model shown in Figure 1. A cardiac arrhythmia is an irregular heartbeat caused by disordered electrical activity that disrupts the normal contract-relax cycle and results in rapid, unsynchronized, uncoordinated contractions, see Figure 1. When this occurs, little or no blood is pumped from the heart; the person can faint, suffer chest pains, and even sudden death may occur. The heart can be converted back to a normal rhythm with a substantial electrical shock (called a “therapy”). For people at high risk, an implanted electronic device called an implantable cardioverter defibrillator (ICD), pictured in Figure 1, administers the therapy. In this project, the student teams design a Matlab program to implement a simple ICD arrhythmia detection algorithm and compare it to a more complicated algorithm that is given to them. They evaluate their algorithms using real electrocardiograms (ECGs). Through their comparisons, the students discover the impact of algorithm computational complexity on the real-time constraint that is critical to the ICD’s ability to save lives.

![Diagram](image1.png)

**Figure 1**: Top: A normal (sinus) heart rhythm is described by the “PQRST” wave model; an arrhythmia occurs when abnormal electrical activity upsets the heart’s normal contract-relax cycle. Bottom: Implantable cardioverter defibrillators (ICDs) let patients at high risk lead safe, active lives.
Computer Software Project
Simulating the Motion of the Bacterium *E. coli*
In this project students use computer simulations to study the remarkable movement of the bacterium *Escherichia coli*, commonly known as *E. coli*. A better understanding of *E. coli* is important due to its use in bioengineering applications (e.g. to synthesize proteins at an industrial scale) and its ability to threaten public health through food safety (e.g. to prevent infections of the O157:H7 strain). An image of *E. coli* is shown in Figure 2. Its filaments are called flagella and they are responsible for the movement of the bacteria: when the flagella rotate one direction, they form an organized bundle that pushes the cell forward; when the flagella rotate the opposite direction, the bundle is no longer organized and the result is an erratic cell motion. The first type of motion is called a “run” and the second type a “tumble.” In this project, the student teams use a Matlab computer simulation of the “run and tumble” motion of *E. coli* to determine the optimum time it should spend in each of its two motion states in order to find food as quickly as possible. The students must develop an approach for addressing the randomness of their data in order to derive statistically meaningful results. An example of one student team’s 1D results is illustrated in Figure 2: the time spent in the tumble state is fixed and the mean time to find food as a function of the time spent in the run state is computed. Through their analysis, the students discover how increasing the number of simulation runs decreases the error in their results.

![Image of E. coli](image1)

*Figure 2:* Left: Picture of *E. Coli*; arrow pointing to flagella. Right: Data from one student team’s project showing the computed mean time to find food as a function of the time spent in the "running" state. The error bars show the estimate of the stochastic error.

Computer Hardware Project
Safer, Smarter Vehicles
Over 40,000 deaths result from traffic accidents every year in the United States. Vehicles use a variety of embedded computer processors to perform safety features—like anti-lock brakes—that are critical to driver and passenger safety. Some vehicles employ so many computers that they eliminate the driver altogether! Fully autonomous vehicles offer many advantages including the ability to traverse territory too dangerous or remote for humans. In this project, the student teams develop control logic for the embedded microprocessor that controls an autonomous vehicle.
(Figure 3) as it performs various sensing and navigation tasks. For each task the students develop the closed-loop control logic for the state tables stored in memory on the vehicle’s embedded processor so that, based on the input from the infrared vision sensors, the commands sent to the vehicle’s left and right wheel motors result in successful completion of the task. The students solve four navigation problems that range from simply driving the car forward and stopping on a black line, to the more complicated task of completing a maze (see Figure 3). Two additional tasks help students discover how the infrared sensors and motors work. Through their completion of these autonomous vehicle tasks, students discover the trade-off between vehicle speed and the ability to maintain the vehicle safely on the course at all times.

![Microcontroller Logic Diagram](image)

**Figure 3:** Top: Closed-loop control model for the autonomous vehicle. Bottom left: A student team discusses their state table control logic for the maze navigation task. Right: The autonomous vehicle.

### Biomedical Imaging Project
### Detecting Tumors with Tomography

Tomographic imaging creates three-dimensional images of the internal structure of opaque objects, like the human body, from the object’s exterior. These images allow, for example, a doctor to explore a patient’s pancreas for tumors without resorting to surgery. In many tomographic imaging systems—for example, X-Ray CT illustrated in Figure 4a—the measurements are projections that are produced by sending electromagnetic waves at particular wavelengths through the object. This collection of projections (called a sinogram) is used to form the tomographic image through a process called reconstruction. The number and quality of the projections, as well as the reconstruction algorithm parameters, impact the quality of the reconstructed images—and consequently, the ability to detect small tumors. In this project, the student teams use Matlab to generate tumor phantoms, acquire projections, filter noise, and reconstruct images. They employ the filtered backprojection algorithm to reconstruct images and compare the impact of averaging, filter choice, and number of projections on important measures like error and contrast-to-noise ratio. The students also investigate the impact of filter and
algorithm parameters on the quality of the reconstructed images to determine which of two images contains a tumor (Figure 4b). Through their comparisons, students discover how image quality can be improved so that tumors can be detected.

**Figure 4:** (a) Image reconstructed from a collection of 3D X-ray CT projections. (b) One student team’s best reconstructed image—and correct tumor location—from the noisy sinogram that corresponded to the image with the tumor.

**Multidisciplinary Project: Microelectronics, Sensors, Communications and Networking**

**Wireless Sensor Networks for Monitoring Civil Infrastructure**

The development of large, distributed networks of wireless sensor nodes to gather information about the physical world and report that information to decision makers who may be remotely located is an engineering challenge that generates tremendous interest. Unlike the other projects in this course, this project demonstrates how four technical areas of electrical engineering, computer engineering, and computer science integrate to solve an important real-world problem: the creation of a wireless sensor network to monitor the structural soundness of a bridge. The project’s four modules include: (1) electronic circuits for sensor readout and data conversion; (2) sensor devices; (3) radio frequency (RF) wireless communications; and, (4) wireless networking. The project’s bridge monitoring application was motivated, in part, by the collapse of the I-35W Mississippi River bridge in Minneapolis, Minnesota on August 1, 2007. Continuous monitoring of the bridge (as was suggested in a 2001 study of the I-35W bridge by the civil engineering department of the University of Minnesota) could have been accomplished via a wireless sensor network of the type studied in this project and might have predicted the bridge’s imminent collapse in time to close the bridge, avoiding injuries and loss of life.

In this project, the student teams spend one week on each of the four modules. In the first module, students build an electronic readout circuit for the sensor; it is implemented on a protoboard (Figure 5a) with a “mystery” resistor in place of the sensor to be introduced in the second module. Through their experiments, the students discover how the circuit measures the desired resistance and converts it to the digital domain. In the second module, students incorporate a piezoresistive sensor (a sensor that converts mechanical stress/strain into electrical resistance) attached to a “bridge beam” into their circuit from the first module. As students deflect the bridge beam (simulated in the lab by a plastic ruler) to the right or left, the attached
strain gauge converts the resulting tensile or compressive stress into resistance (Figure 5b). Through their analyses, the students determine the sensor’s gauge factor and establish relationships between beam deflection, strain, and voltage.

In the third module, all of the student teams work together and use wireless communications to move data between their sensor nodes. Each student team added a ZigBee transceiver (Figure 5c) to its protoboard (with the circuit and sensor) and evaluated the performance of two different medium access control (MAC) techniques: Aloha and carrier-sense multiple access (CSMA). As the transmitting and receiving conditions vary (i.e. MAC protocol, transmission rate, sensor node location, etc), the students discover the wireless communications factors critical to insuring that the data measured at each sensor node is received by the decision/gateway node. Finally, the students integrate all of the lessons learned in the first three modules to implement a wireless sensor network to determine the structural integrity of a bridge. In this fourth and final module, the teams take their circuit/sensor/transceiver/laptop nodes and stretch themselves along a long corridor to simulate a wireless sensor network distributed on a bridge span. For several scenarios, each team knows only its assigned beam deflection amount; after transmission, each team must determine the other teams’ strain levels from the received digital voltage values and identify where the bridge is operating at unsafe strain levels.

Table 1 depicts an overview of the primary concepts that students discover through their solutions to the hands-on projects. All of these concepts play fundamental roles in contemporary EE/CE/CS problems and their solutions.

<table>
<thead>
<tr>
<th>Project</th>
<th>Concepts Discovered</th>
</tr>
</thead>
<tbody>
<tr>
<td>Signal Processing</td>
<td>• Derivative of a digital signal</td>
</tr>
<tr>
<td></td>
<td>• Thresholding</td>
</tr>
<tr>
<td></td>
<td>• Algorithms to detect/classify signals</td>
</tr>
<tr>
<td>Computer Software</td>
<td>• Simulation models of biological systems</td>
</tr>
<tr>
<td></td>
<td>• Characterizing stochastic behavior</td>
</tr>
</tbody>
</table>
Brownian motion

- Embedded microprocessor systems
- Closed-loop control:
  - Sensors (input)
  - Control logic
  - Environment
  - Actuators (output)

Biomedical Imaging
- Tomography for internal imaging
- Thresholding
- Removing noise with digital filters

Wireless Sensor Networks
- Analog-to-digital data conversion
- Sense mechanical movement and convert it to electrical data
- Transmit data efficiently through a wireless medium
- Establish a wireless sensor network and transmit/receive data between the sensor nodes

Table 1: Summary of EE/CE/CS concepts that students discover through their work on the projects.

RESULTS

Course Enrollment
Course enrollment is defined as the number of students enrolled in the course at the beginning of the second week of the semester. For the new course, the downward trend in total enrollment for the old course was arrested. Women’s enrollment increased 60%: from 15 in Spring 2007 (old course) to 24 in Spring 2008 (new course). Enrollment figures indicate that 27 women (up 80% over the old course) and 267 men (up 4.3%) have enrolled in the new course in Spring 2009.

Course Retention
Course retention is defined as the percentage of students who enrolled in the course that subsequently received a grade at the end of the semester. Student retention in the course increased from 94.7% in the old course to 97.9% in the new course; this higher retention rate for the new course is statistically significant (note: details regarding all tests for statistical significance are included in the appendix). Furthermore, Table 2 reveals that course retention in the new course increased for every student group: women, men, and all six race/ethnicity categories. In several cases, retention increased to 100%.

<table>
<thead>
<tr>
<th></th>
<th>Old Course</th>
<th>New Course</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Students</td>
<td>94.7%</td>
<td>97.9%</td>
</tr>
<tr>
<td>Women</td>
<td>89.7%</td>
<td>100%</td>
</tr>
<tr>
<td>Men</td>
<td>95.1%</td>
<td>97.7%</td>
</tr>
</tbody>
</table>
African American 94.4% 94.7%  
Asian or Pacific Islander 94.2% 95.7%  
Hispanic or Latino 89.7% 100%  
Non-Resident Foreign Alien 89.0% 100%  
Unknown 93.8% 100%  
White, non-Hispanic 95.9% 98.1%  

Table 2: Student retention in old course vs. new course: total, by gender, and by race/ethnicity. Note: race/ethnicity is self-reported by the students; no students reported American Indian/Alaskan Native.

Retention in the EE/CE/CS Majors

Retention in the EE/CE/CS majors is defined as the percentage of students whose major was either EE, CE or CS in the semester following the one in which they took the course (note: these are restricted majors, so that students not only request admittance, but must also meet the academic performance criteria). Student retention in the EE/CE/CS majors increased from 37.8% for the old course to 45.2% for the new course; this difference is statistically significant. Figure 6 shows that increased retention into the majors occurred for women and men—with women’s retention improving dramatically from 28.1% to 64.3%; this difference is statistically significant.

![Figure 6: Retention in the EE/CE/CS majors in the subsequent semester for the old course vs. new course: total, and by gender. Here, “Old Course” is a combination of data from one old course in a fall semester and one old course in a spring semester; similarly for the “New Course.”]

To what extent can these improved results be attributed to the new course? Perhaps the improvement is due, instead, to the students in the new course—perhaps they began the course with better knowledge and skills than the students in the old course. In order to evaluate how similar these two student cohorts—old and new course cohorts—were at the beginning of the course, mean high school GPA and mean start-of-semester GPA were examined. In the old
course cohort, 354 students had a mean high school GPA of 3.78 and a mean start-of-semester GPA of 2.99. In the new course cohort, 330 students had a mean high school GPA of 3.80 and a mean start-of-semester GPA of 2.96.

**Awarded Grades and Time/Effort Required**
The final course grade distribution awarded in the new course was nearly identical to the distribution awarded in the old course. Students reported that the “time and effort required” by this course—as compared to their other courses—increased for the new course. This difference in the distribution of “time and effort required” between the old and new courses is statistically significant. In the old course, 22.7% of students reported that the course required “more than average time and effort” whereas in the new course, this figure increased to 55.1% of students.

**Questionnaire**
A student questionnaire was administered at the beginning of the course and again at the end. Five of the statements were as follows:
1. I am (or intend to be) an ECE/CS major.
2. I am satisfied with ECE/CS as my major choice.
3. I am confident that I can become a successful ECE/CS engineer.
4. I am capable of solving ECE/CS engineering problems.
5. It is important to me that I am good at ECE/CS engineering.
Each statement had the following five response options: strongly agree, agree, neutral, disagree, or strongly disagree.

Table 3 depicts the women and men students’ agreement/strong-agreement with these statements at the beginning and ending of the new course in Spring 2008. At the beginning of the course, an overwhelming majority (> 80%) of women and men students agreed/strongly-agreed with the major choice, satisfaction, and importance to self statements. Although an overwhelming majority of men agreed/strongly-agreed with the confidence and capability statements, women indicated less agreement with these statements at the beginning of the course.

<table>
<thead>
<tr>
<th>Student Questionnaire in New Course</th>
<th>Women</th>
<th>Men</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Beginning</td>
<td>Ending</td>
</tr>
<tr>
<td>EE/CE/CS as Major Choice</td>
<td>80.9%</td>
<td>100%</td>
</tr>
<tr>
<td>Satisfied with Major Choice</td>
<td>85.7%</td>
<td>100%</td>
</tr>
<tr>
<td>Confident can Become Successful</td>
<td>76.2%</td>
<td>88.9%</td>
</tr>
<tr>
<td>Capable of Solving Problems</td>
<td>61.9%</td>
<td>88.9%</td>
</tr>
<tr>
<td>Importance to Self</td>
<td>95.2%</td>
<td>100%</td>
</tr>
</tbody>
</table>

**Table 3:** Students’ responses to a questionnaire administered at the beginning and ending of the new course, by gender. Percentages reflect students who responded strongly agree and agree; other response choices included: neutral, disagree and strongly disagree.
Table 3 also shows how these responses changed at the end of the new course. Women’s agreement/strong-agreement increased (sometimes dramatically) for all statements—with 100% of women agreeing/strongly-agreeing with the major choice, satisfaction, and importance to self statements. Men’s agreement/strong-agreement also increased for all but one statement—and the increases occurred for several statements that had little room for improvement over the beginning responses. Men’s agreement level declined for the importance to self statement; this is difficult to understand in light of men’s increased agreement with major choice and satisfaction.

Correlations between all students’ responses to the statements were tested in the beginning and ending questionnaires. The correlation coefficients are on a scale from -1 to +1 where 0 indicates no correlation and +1 means positive, perfect correlation. The larger the correlation coefficient, the greater the association between a pair of statements—with values greater than 0.5 indicating a strong association. At the beginning of the new course, pairwise comparisons revealed strong associations between two statement pairs: major choice and satisfaction; and, satisfaction and confident. In other words, at the beginning of the semester, students who tended to be satisfied with their ECE/CS major choice also tended to be confident that they could become successful ECE/CS engineers. At the end of the new course, these associations strengthened and new associations were formed. Figure 7 indicates nine strong associations at the end of the course with satisfaction, confident and importance to self each having four strong associations.

DISCUSSION

Engineering faculty teach their classes with virtually no oversight; in a typical semester, no other faculty, staff or manager knows, for example: if the official course syllabus is followed; how many class meetings are cancelled, rescheduled, or taught by someone else; the accuracy of the course content; if learning objectives and grading policies are conveyed to the students; or, the value of the pedagogical approaches being used. We are left to wonder: how good is our
engineering education? ABET visits for a couple of days every seven years during the accreditation process—and a few faculty colleagues visit one class every five years during the tenure and promotion process. Students fill out an end-of-semester evaluation form for a class and some department heads evaluate their faculty’s teaching by looking at the “overall” rating on this form.

Common wisdom deems it reasonable to speculate that the quality of engineering teaching lies along a spectrum from abysmally poor to relatively good to unexpectedly excellent. Suppose a faculty member knows he needs to improve his teaching: how does he go about it? Although many faculty are subject matter experts, their understanding of relevant educational research and teaching methods tends to be inadequate. Perhaps the faculty member’s university has a teaching center that offers seminars—but the quality is variable and the few tangible “take-aways” that he implemented in his engineering class didn’t go very well. Furthermore, the faculty member only has a limited amount of time to devote to improving his teaching: he already works 55 hours per week on his research, teaching, and service.

Moreover, what about the students who encounter and are frustrated by poor teaching in their undergraduate engineering courses? They often lack the experience and understanding needed to formulate their concerns as well as an official venue in which to voice them. Only 48% of students who matriculate into undergraduate engineering programs in the US go on to graduate with engineering BS degrees. In addition to this retention-to-degree problem, undergraduate engineering also suffers from an enrollment problem. In 2004, only 96,978 students enrolled in first year, full time undergraduate engineering programs in the US; this figure is only 3.5% of the number of public high school graduates in 2003-2004. Seymour and Hewitt collected a vast amount of data that revealed that the primary concern expressed by all students (men and women, stayers and leavers) in undergraduate science, technology, engineering and mathematics (STEM) programs was poor teaching by STEM faculty.

Our new course realized significant increases in student enrollment, course retention, and retention into the EE/CE/CS majors; moreover, it positively impacted students’ beliefs and forged new connections between these beliefs and the students’ choice to study EE/CE/CS. The students interacted with eight faculty experts on the solutions of meaningful, contemporary technical problems. The faculty rose to the creative challenge of designing problems that were tractable for first year students; moreover, the faculty reported several benefits: they enjoyed talking with the first year students who exhibited tremendous energy, inquisitiveness, and appreciation; they embraced the new pedagogical techniques; and, they found the “buyout credit” a manageable way include this extra teaching load into their busy schedules.

Excellent introductory engineering courses and teaching can be realized; in our case, it requires: a faculty member who organizes and leads the faculty team, projects, pedagogical approaches, and course; the faculty team and their projects; a sustainable model that rewards faculty participation; initial funding for project development; and, wise managers who support the faculty in their efforts. Perhaps more courses like ours will result in more than 3.5% of our high school graduates entering engineering.
APPENDIX
For the statistically significant outcomes indicated in the Results section, the following table lists the specific tests that were used and the resulting p-values.

<table>
<thead>
<tr>
<th>Result</th>
<th>Statistical Test</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>New course has a significantly higher course retention rate than the old course</td>
<td>Chi-square</td>
<td>0.0142</td>
</tr>
<tr>
<td>New course has a significantly higher retention into the EE/CE/CS majors than the old course</td>
<td>Fisher’s exact</td>
<td>0.0265</td>
</tr>
<tr>
<td>New course has a significantly higher women’s retention into the EE/CE/CS majors than the old course</td>
<td>Fisher’s exact</td>
<td>0.0051</td>
</tr>
<tr>
<td>New course “time-and-effort required” increased significantly over the old course</td>
<td>Chi-square</td>
<td>0.0001</td>
</tr>
<tr>
<td>Questionnaire correlations</td>
<td>Kendall tau and Spearman’s rho</td>
<td>All correlation values were significant at the 0.01 level</td>
</tr>
</tbody>
</table>

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REFERENCES