121st ASEE Annual Conference & Exposition
Indianapolis, IN
June 15-18, 2014
Paper ID #8753

First Year Engineering Courses Effect on Retention and Student Engagement

Dr. Gregory Warren Bucks, University of Cincinnati
Dr. Kathleen A. Ossman, University of Cincinnati

Dr. Kathleen Ossman is an Associate Professor in the School of Engineering Education in the College of Engineering and Applied Science at the University of Cincinnati. She teaches courses to freshmen engineering students that require the application of mathematics and physics to solving applied problems from a variety of engineering disciplines and utilize MATLAB for solving computationally intensive problems and analyzing data. She earned a BSEE and MSEE from Georgia Tech in 1982 and a Ph.D. from the University of Florida in 1986. She is a member of IEEE and ASEE.

Dr. Jeff Kastner, University of Cincinnati

Jeff Kastner is an Assistant Professor Educator in the Department of Engineering Education at the University of Cincinnati. He currently teaches the freshmen engineering courses to all engineering students at UC.

Dr. F James Boerio, University of Cincinnati

F. James Boerio is Professor of Materials Science and Head of the Department of Engineering Education in the College of Engineering and Applied Science (CEAS) at the University of Cincinnati. He has received numerous awards for his work in engineering education, including the CEAS Engineering Tribunal "Professor of the Quarter" for the Winter Quarter, 2003; Engineering Tribunal "Professor of the Year" for 2002-03; and the CEAS "Dean's Award for Educational Innovation" in 2001. Professor Boerio has authored approximately 225 papers; he received the award "Best Paper - Original Contribution," at the 152nd Meeting of the ACS Rubber Division in 1997.

Dr. Joni A Torsella, University of Cincinnati

©American Society for Engineering Education, 2014

First-Year Engineering Courses
Effect on Retention and Student Engagement

Abstract

Due to a drop in the percentage of students enrolling and persisting in engineering programs, there is currently a lack of qualified engineering graduates, which jeopardizes both the health of the U.S. economy and the security of the nation. This issue has led to the development and implementation of a variety of first-year engineering experiences designed to recruit more students to engineering and to retain them once they have chosen to pursue a degree in engineering. At the University of Cincinnati, three common courses were introduced during the 2012-2013 school year to provide first-year students with hands-on experiences in engineering and a link between engineering and the required mathematics and science courses.

This paper includes a description of the first-year courses and provides detailed information about the hands-on experiments and the computing assignments that link engineering applications to topics in math and science courses. Lessons learned during the first offerings of the courses and changes made to the courses in response to student and faculty feedback are also discussed. Retention data of the engineering students from freshmen to sophomore year is provided and shows a significant increase since the common courses were introduced.

Introduction

Over the past several decades, there has been a drop in the percentage of students enrolling and persisting in engineering programs.[1,2] This has led to a lack of qualified individuals to fulfill industrial demands within the United States.[3] A lack of qualified engineering graduates jeopardizes both the health of the U.S. economy and the security of the nation. Because of this, significant effort has been expended to recruit more students to pursue a degree in engineering.

One of the key reasons that students leave engineering after they have begun a degree program is the lack of engineering-related experiences in the first year.[4] Many students choose to pursue engineering because they enjoy the design and creation of new products and systems. However, once they arrive on campus and begin their coursework, they are faced with a significant number of required mathematics and science courses dealing predominately with abstract material and little engineering context. As a result, students end up believing that engineering courses will be similar to the mathematics and science courses and ultimately leave for other fields where applications can be seen much earlier in their academic career.[5]

Ironically, it is performance in these introductory courses, specifically calculus, which is one of the primary determinants of success in engineering.[6] Internal data collected by the Department of Engineering Education at the University of Cincinnati shows that students who receive a grade of C or lower in their first calculus class have virtually no chance of completing an engineering degree, whereas students who receive a C+ or better successfully complete a degree in engineering at a rate of approximately 75%.

This has led to the development and implementation of first-year engineering experiences, either through engineering specific courses or through integrated curricula, to provide context and support for the mathematics and science courses taken during the first year and to provide students with engineering-related experience.[7] Use of these strategies has been shown to improve retention of students in engineering fields.[8] At the University of Cincinnati work is progressing to implement a variety of educational reforms to enhance the first-year engineering experience for students.

University of Cincinnati switched from quarters to semesters in fall of 2013. The switch to semesters provided an opportunity to make changes to the first year curriculum which previously included no common engineering courses taken by all of the engineering students.
During the 2012-2013 academic year, three first-year engineering courses designed to provide students with a hands-on experience with engineering and with a link between engineering and the required mathematics and science courses were introduced. The three courses consist of an introduction to engineering course called Engineering Foundations and a two-course sequence called Engineering Models I and II, which introduces students to MATLAB® as a computing tool for solving engineering problems. All three courses are required for all engineering and engineering technology majors, are 2 credit hours, and meet once a week for lecture (55 minutes) and once a week for recitation (2 hours).

Engineering Foundations

The Engineering Foundations course aims to introduce students to the types of activities engineers perform and provides information on the engineering degree programs. Students are introduced to several engineering disciplines through four hands-on experiments. The students work in groups of three to complete the experiments, which consist of bridge-building and analysis under static and dynamic loads; analyzing basic circuitry, including RC circuits and resistors in series and parallel; investigating the basic laws of thermodynamics through the use of Peltier devices as heat pumps and heat engines; and using solar cells to convert light into electrical energy and using fuel cells to generate electrical energy from the reaction of hydrogen and oxygen. Each of the experiments lasts for two weeks.

In Engineering Foundations, students are also introduced to a number of professional skills, such as technical writing, communication, engineering ethics, and the engineering design process. Technical writing is covered by requiring the students to prepare laboratory reports for each of the four hands-on experiments. Communication is emphasized through a group presentation that requires the students to research one of the fourteen Grand Challenges[9] identified by the National Academy of Engineers and to present their findings to the class. Ethics is covered during a lecture that uses practical examples and role playing to emphasize the challenges in making ethical decisions in an engineering context.

Engineering Models I and II

The other two courses, Engineering Models I and II, form a two-semester sequence. This sequence of courses serves two purposes: to introduce students to the computer as a tool for solving engineering problems and to provide context and applications for the mathematics and science material covered in other introductory STEM courses. In the Engineering Models I course, students are introduced to the computation package MATLAB® and shown how it can be used as a tool when solving engineering problems. The course begins with plotting various functions including exponentials, sinusoids, and damped sinusoidal functions. The emphasis is on how these functions can be used to model certain physical processes such as a charging or discharging a capacitor, chemical reaction rates, and damped harmonic motion. Interpolation and curve fitting are introduced and used to extract parameters of a physical process. The next several weeks are spent developing the logical thinking and computing knowledge required to make full use of MATLAB®. Even though the emphasis is on programming skills, the recitation assignments and labs are closely tied to math, science, and engineering applications. For example, students use loops to program iterative algorithms based on the Newtown-Raphson algorithm or Taylor Series to determine square roots and cube roots of numbers and the sine or cosine of angles, respectively. One of the array application labs involves searching through a genome sequence to identify start and end codons for genes. The course culminates with an end-of-semester group project requiring the students to use MATLAB® to develop a solution to an open-ended design problem.

In the Engineering Models II course, the attention turns from developing computing proficiency to using MATLAB® in engineering applications and providing context to the other STEM courses required of the first-year engineering students. Here, students are introduced to statistics and data analysis, numeric differentiation and integration, applications of differentiation and integration, communications, basic mechanics, and system modeling. The course again ends with a project requiring the students to work in groups to design a graphical user interface (GUI) that serves as a teaching tool for some topic that they learned in calculus, chemistry, physics, or a discipline specific engineering course.

First Year Results

There was a significant improvement in retention of first-year students in the 2012-2013 academic year when the three common courses were implemented and required for all incoming freshmen. Retention data for the last twelve years is summarized in Table 1.

Table 1: Retention Rates from Freshman to Sophmore Year

Year	**2002 2003**	**2003 2004**	**2004 2005**	**2005 2006**	**2006 2007**	**2007 2008**	**2008 2009**	**2009 2010**	**2010 2011**	**2011 2012**	**2012 2013**
Retention Rate	76%	73%	68%	70%	75%	75%	73%	70%	76%	73%	85%

There are several factors that could account for the significant increase in retention: the introduction of the three common first-year engineering courses, an increase by one point in the minimum ACT score required for admission to the College of Engineering and Applied Sciences (CEAS), and the changes in the calculus sequence with semester conversion. For the calculus sequence, depending on the math placement score, students may take a standard Calculus I course (4 credit hours) or a Pre-Calculus/Calculus I course (5 credit hours) that begins with a review of algebra and trigonometry.

The survey results from the first offering of the courses indicated the following:

- Students preferred the open-ended portions of the Models and Foundations classes and appreciated the connections to mathematics and science concepts.
- The team projects at the end of Models I and Models II were cited most often as the favorite topic in these courses. Students enjoyed the freedom to be creative and design their own "product".
- Some of the students commented that they did not see how computer programming would help them in their chosen engineering discipline. Civil engineering students and construction management students, in particular, have trouble seeing the benefit of Models I and Models II since the focus was strictly on software.
- The students enjoyed the experiments in Engineering Foundations and it didn't seem to matter whether the experiment was in any way related to their chosen engineering discipline.
- There was a disconnection between Engineering Foundations and the Models I and II courses. Engineering Foundations was perceived as a "hands on" experimental course; whereas, Models I and II were programming classes. The courses were not connected in any way even though Foundations and Models I both run in the fall semester.
- There were significant differences in how Models I and II were taught by the various instructors. Some instructors provided demonstrations in MATLAB® during lecture while others simply read from the power-point slides. Students indicated that actually working with MATLAB® during lecture would have helped prepare them better for recitation and homework assignments.

Changes Implemented in Second Year

We learned in the first year that students really enjoyed the "hands on" experiments in Foundations regardless of their chosen engineering discipline. However, some students, notably the civil engineering students and construction management students, did not see the value of the software courses. In response to this feedback, new experiments using a data acquisition device (DAQ) were developed for all three courses to enable students to visualize how a software program can be used both to control hardware and monitor a physical system by acquiring sensor data. This year, we have been experimenting with two different hardware platforms: the Digilent Analog Discovery Kit and the National Instruments MyDAQ.

In Engineering Foundations, the MyDAQ was used to collect voltage measurements across a capacitor in an RC series circuit as the capacitor charged and discharged. The measurements were read directly into MATLAB® where the measurement data was easily graphed. The MyDAQ was also used as part of an experiment exploring solar cells in order to determine the maximum power output based on the load resistance. The only change to these experiments between the first and second year was using the MyDAQ to collect data rather than having students manually collect the data.

In Models I and II, none of the experiments in the first year involved hardware so new experiments were developed. One of the experiments in Models I involved using the Digilent

Analog Discovery Kit to interface MATLAB® with a circuit as shown in Figure 1. Students wrote a MATLAB® script to create an automatic night light that would become brighter as the room got darker. They used the Digilent to take voltage measurements across the 10 kΩ resistor in series with the photocell to determine the level of ambient light and to adjust the light level of the LED by applying a voltage calculated in the MATLAB® script.

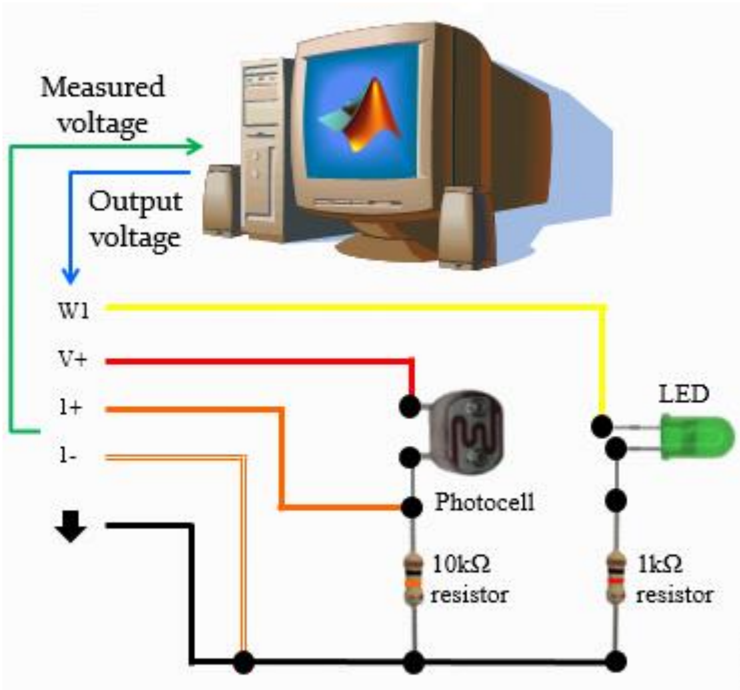

Figure 1: Schematic of a DAQ Experiment in Models I

In the end-of-course survey for Models I this year, students were asked what topics they enjoyed most. The night light experiment was cited most often. A sample of some of the comments:

- I enjoyed the night light code the most. It was a code that was using all that we had learned and was a fun hands on experience that shows how MatLab applies to real world uses.
- I enjoyed the Night Light lab because you could physically see what your programming had done.
- I enjoyed making the night light that adjusts to the surrounding light. It was cool to see how an engineer might approach the coding of that night light.
- I really enjoyed programming for the automatic nightlight. It was interesting to see the ins and outs of how programming works in concert with actual hardware. This made the class seem very useful and less theoretical like other core classes would seem (like chem or calc).

In Models II, students will be implementing and testing real-time differentiation and real-time integration algorithms by taking measurements from a series RC circuit using the Digilent DAQ and reading those measurements into MATLAB®.

In Engineering Foundations, an additional experiment was introduced at the conclusion of the four original hands-on experiments. This summative experiment required students to combine elements from several of the prior experiments in an open-ended design experience. Example projects included the design of a solar powered cooler and a fuel cell powered vehicle. In an end-of-semester survey, the students responded very positively to the addition of this experiment. They liked the open-ended nature of the experiment, as well as the ability to select a topic that was of interest to them.

The team project for Models I was tied to the oral presentation in Engineering Foundations. In Foundations, teams of students did research on one of the fourteen Grand Challenges identified by the National Academy of Engineers then presented their findings in recitation. In Models I, teams of students were directed to a website[10] developed by the UN to find data related to their Grand Challenge. Students imported the data into MATLAB® and then wrote scripts to analyze and present the data.

Student responses to the team project on the end of course survey were for the most part positive, even from students that indicated that the project was somewhat difficult. Students enjoyed the connection to Foundations, appreciated the opportunity to apply what they learned through the course, and the freedom to create their own script and choose what to present. The negative responses to the project were either because the team didn't work well together, the project seemed ill-defined, losing a work-day in recitation due to a weather cancellation, or wishing the project was designing a game as it was in fall 2012.

Selected student comments on the team project:

- The team project made us think more outside of the box while trying to create our script as we did not have a specific outline to follow. It was also very interesting finding and comparing the different values and percentages between each country we used. It was not too easy but also not too hard to complete and I think it was a good way to end the semester.
- The team project was a good way of applying the lessons that we learned through matlab to our final presentation, as well as a good way of cooperating with a team. Through the project, our group was able to use our individual strengths in the course to create a great presentation that was intriguing to us.
- The team project was a lot more difficult than I had originally anticipated. However, I like that it challenged me. Although it was a little difficult, it was at the right level of difficulty because the point was to build a code from scratch. However, it was pretty difficult trying to incorporate four people into working on one code. I think having three to a group would be more efficient *(Author's Note: Most teams had 3 members*).
- The team project is a cool concept because it ties in with what we were doing in engineering foundations, but i thought that a lot of it was really vague and hard to understand what we were actually supposed to be doing in the beginning. After we got the script going a lot of it was problem solving and just fixing the general programming issues then adding more to it and making it more complex. It is a good end of the year exercise for putting everything together.

- I liked how it was connected with foundations, but this allowed more of an analytical approach to the topic rather then focusing just on the social and engineering concepts.
- The overall demands needed to complete the project were simple, however, they did display the concepts learned at exactly the right level. I liked how it integrated into a similar topic setup to that of the Engineering Foundations course, but provided a different take on what to do with each topic. The freedom in displaying/depicting the topic is also great, and the requirements are very clear. Overall, I definitely like the team project.
- Coding with a group is difficult because coordinating the different parts requires a lot of supervision and unity in thought. When I am coding a program I do try to outline in beforehand but it changes almost 100% of the time as I am working on it. It's not that I don't trust my group members to do their part, it's just that I find it more practical, especially for an assignment this simple, to do it yourself. It will take some extra time but I can move at a more fluid pace.
- I did not enjoy the group project at all. My team mates slacked off and would not put the time in during recitation to get it done. It was very difficult to get stuff done because I seemed to be the only one who cared. Also there was not very much information on our topic which increased its difficulty. I did not enjoy the group aspect of the project.

In order to address the differences in how various sections of Models I and II were taught and provide an active learning environment for students during lecture, an inverted classroom was implemented this past fall. The effectiveness of the inverted classroom is actually a topic for another paper, but Table 2 shows a significant drop in the D-F-W rate in Models I between fall 2012 and fall 2013 in spite of a large increase in enrollment and a one point drop in the minimum ACT score required for admission to CEAS for the 2013-2014 school year.

Table 2: D-F-W Rates in Engineering Models I

	Models I: Fall 2012 (Traditional Lecture)					Models I: Fall 2013 (Inverted Classroom)				
	Students Enrolled	**D**	**F**	**W**	**Total**	**Students Enrolled**	**D**	**F**	**W**	**Total**
CEAS	816	3.3%	4.3%	4.5%	12.1%	1029	2.7%	3.5%	2.9%	9.1%
Non-CEAS	174	8.6%	10.9%	14.9%	34.5%	123	3.3%	7.3%	17.1%	27.6%

Future Work

Now that we have gained some experience with the data acquisition devices, more experiments will be developed for Models I and II. Similar efforts will be made in the Engineering Foundations class by incorporating the DAQ device into several of the other experiments and streamlining its use in the current experiments. In addition, based on the feedback received from the students on the new open-ended final experiment, effort will be made to increase the open-endedness of the other four experiments. More options will also be developed for the final hands-on experiment in order to allow students more choices and the opportunity to select an option more closely tied to their major.

The retention data will continue to be monitored between freshman and sophomore years and will also be evaluated as these students progress through their programs to the senior year.

Co-op is required for all of our students and Professional Practice has an extensive survey that employers fill out at the end of each student's co-op term. The freshmen from 2012-2013 are completing their first co-op terms this year. Ideally, the three first-year courses are better preparing our students for co-op by exposing them to open-ended problems, hands-on activities, and communication skills. Data from the co-op employer surveys will be analyzed to compare performance in the first co-op term of the students who took the common first-year courses to the students that did not.

Discussions are ongoing between faculty in Engineering, Mathematics, Physics, and Chemistry to develop a common set of practices within all first-year STEM courses. The first step is the development of a common report structure so that students are exposed to a single set of guidelines. Future plans involve the adoption of common technology platforms and matching schedules so that topic delivery is more cohesive.

Conclusion

The results from student surveys and the retention data show that reaching out to first-year engineering students by giving them engineering problems to solve can have a positive impact on their first-year experience. In addition, students enjoyed the opportunity to work on open-ended projects that allowed them to be creative. Incorporating the data acquisition devices in the courses had a positive effect in helping students visualize how a software program could be written and used to control and/or monitor hardware.

Acknowledgment

This work was supported, in part, through a MathWorks grant from the Curriculum Development Program in spring 2013. The grant supported the purchase of the Digilent Analog Discovery Kits, the National Instruments MyDAQs, and the electronic components used in the hardware experiments.

Bibliography

1. Besterfield-Sacre, M., Atman, C. J., Shuman, L.J., " Characteristics of freshman engineering students: Models for determining student attrition in engineering," *Journal of Engineering Education*, 86, 2, 1997, 139-149.
2. Grose, T. K., "The 10,000 challenge," *ASEE Prism*, 2012, 32-35.

3. Johnson, M. J., Sheppard, S. D., "Students entering and exiting the engineering pipeline-identifying key decision points and trends," *Frontiers in Education*, 2002.
4. Olds, B. M., Miller, R. L., "The effect of a first-year integrated engineering curriculum on graduation rates and student satisfaction: A longitudinal study," *Journal of Engineering Education*, 93, 1, 2004, 23-36.
5. Bernold, L., Spurlin, J. E., Anson, C, M, "Understanding our students: A longitudinal-study of success and failure in engineering with implications for increased retention," *Journal of Engineering Education*, 96, 3, 2007, 263-274.
6. Klingbeil, N., Rattan, K., Raymer, M., Reynolds, D., Mercer, R., et al, "The WSU model for engineering mathematics education: A multiyear assessment and expansion to collaborating institutions," *ASEE Annual Conference and Exposition*, 2008.
7. Froyd, J. Ohland, M. W., "Integrated engineering curricula," *Journal of Engineering Education*, 94, 1, 2005, 147-164.
8. Pendergrass, N. A., Kowalczyk, R. E., Dowd, J. P., Laoulache, R. N., Nelles, W., et al, "Improving first-year engineering education," *Frontiers in Education*, 1999.
9. http://www.engineeringchallenges.org/cms/8996.aspx
10. http://data.un.org/Explorer.aspx