Extended Abstract – Flipping and Integrating the First-Year Engineering Experience

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Abstract **- Due to a drop in the number 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. At the University of Cincinnati, three courses were introduced during the 2012-2013 school year to provide students with a hands-on experience with engineering and a link between engineering and the required mathematics and science courses. Following the successful introduction of these courses, efforts are currently underway to improve the experience for students in all first-year courses. A major effort is underway to provide additional connections between the newly introduced engineering courses. A data acquisition (DAQ) device is being introduced as a way to link the content of the courses, where students will write MATLAB® scripts in a course where computing is introduced as a problem-solving tool and will use them during hands-on experiences in an introductory engineering class. In addition, a flipped pedagogy is being implemented in the computing courses so that lecture time can be spent solving problems. Discussions are also 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.**

Index Terms – Data acquisition, Hands-on engineering, Integrated curriculum, MATLAB®

INTRODUCTION

Over the past several decades, there has been a drop in the number 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 the engineering disciplines and to retain them once they have chosen 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 purse 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, however, 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 (UC) 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 UC, work is progressing to implement a variety of educational reforms in order to enhance the first-year engineering experience for students.

CURRENT WORK

During the 2012-2013 academic year, a set of 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 was 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 computing as a tool for solving engineering problems, through the use of MATLAB®.

The Engineering Foundations course aims to introduce students to the types of activities engineers perform and provide information on the engineering degree programs available at UC. Students are introduced to several engineering disciplines through four hands-on experiments. The students work in small groups to complete the experiments, which consist of building and testing bridges, analyzing basic circuitry, investigating the basic laws of thermodynamics, and performing efficiency measurements of a fuel cell system.

In this course, students are also introduced to a number of soft skills, such as technical writing, presentation skills, engineering ethics, and the engineering design process. Technical writing is covered as the students are required to prepare laboratory reports for each of the four hands-on experiments. The presentation skills are emphasized through a group presentation requiring the students to research a given topic and 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. The other two courses, Engineering Models I and II, form a two-semester sequence. This pair 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. While some applications are shown, the majority of the time in Engineering Models I is spent developing the logical thinking and computing knowledge required to make full use of MATLAB®. 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 students. Here, students are introduced to such ideas as interpolation, curve-fitting, and numeric differentiation and integration, through applications areas such as data analysis, image processing, communications, position tracking, basic mechanics, and system modeling. This course again ends with a project requiring the students to work in groups to solve open-ended design problems.

FUTURE WORK

Following the successful introduction of these courses this past year, efforts are currently underway to improve and provide a more tightly integrated experience for students between all first-year courses. Currently, a major effort is underway to provide additional connections between the newly introduced engineering courses. A data acquisition (DAQ) device is being introduced as a way to link the content of the courses. In the Engineering Models courses, students will write MATLAB® scripts that utilize the DAQ device to collect and process data. This will help to provide context for the various computing concepts covered in the course. In addition, those scripts will then be used in the Engineering Foundations course to collect data on physical systems involved in the hands-on experiments, providing further context for how MATLAB® is used in practical engineering contexts.

For example, one of the experiments that students currently perform in the Engineering Foundations course is an analysis of a simple direct-current (DC) driven resistive-capacitive (RC) circuit. In this experiment, students connect a resistor and a capacitor in series to a voltage source, and measure the voltage on the capacitor over time. The purpose is to allow the students to compare the measured results to what theory says should happen. Since the experiment requires the students to take measurements over time, what often happens is that students break up the tasks among the group: one person uses a stopwatch to note when measurements should be taken, one person reads the voltage off of the digital multimeter, and a third person records the results. The students then take the collected data and enter it into either MATLAB® or Microsoft Excel® and plot the theoretical and measured data. What is often lost in the process is that the students are supposed to compare the theoretical and observed data and draw conclusions based on the results. Instead, students become so engrossed in the collection process that they fail to spend adequate time exploring these differences.

Since computers are excellent at collecting and analyzing large amounts of data, this experiment becomes an ideal candidate to introduce the DAQ device. Students can easily write a script that will take measurements of the voltage on the capacitor over time and plot these in real-time. The theoretical results can be plotted at the same time, making any differences between theoretical and observed values much more prominent. By offloading the menial task of data collection from the students to the computer, the students will be better able to focus on developing the analysis and critical thinking skills, which are the focus of the experiments.

Currently, two different DAQ devices are being evaluated for adoption. The first device under consideration, the Digilent Analog Discovery™, is very new to the market. It is intended to be used in introductory electronics courses, allowing for both analog and digital I/O and is easily interfaced with MATLAB® through the Data Acquisition Toolbox. The second device is the National Instruments NI myDAQ. It is similar to the Digilent device, but also includes a digital multimeter. The NI myDAQ is also easily interfaced with MATLAB® through the Data Acquisition Toolbox.

Additional reforms are also planned. In an effort to better prepare students to apply MATLAB® in problem solving situations, a flipped pedagogy is being implemented in the Engineering Models I and II courses. In a flipped pedagogy [9], traditional lecture content is assigned as homework, freeing the instructor to use the designated lecture time to focus on solving problems and addressing common misconceptions. For the Engineering Models I and II courses, videos are being created of the lecture material covered during the 2012-2013 school year. Students will then be required to watch these videos prior to lecture. Lecture time will be spent using the concepts covered in the videos to solve problems, helping students to develop the structured problem-solving skills often lacking among many first-year students.

Discussions are also 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

In summary, due to decreasing numbers of students graduating with degrees in engineering, much effort has been focused on both recruiting and retaining students in engineering. The College of Engineering and Applied Science at the University of Cincinnati is attempting to address this by providing students with an integrated first-year experience. This is being done by providing a set of first-year engineering courses tied closely to the mathematics and science courses taken by students during their first year and using more interactive pedagogical techniques. The ultimate goal is to develop a common first-year curriculum along with a common set of tools and requirements among all first-year courses to both attract students to engineering and provide them with the experiences necessary to retain them.

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