The Missing Link: Providing an Integrated First-Year Engineering Experience

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Over the past several decades, there has been a substantial drop in the numbers of students both 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 the health of the U.S. economy and the security of the nation, as the majority of defense contracts require that those striving to complete the work are U.S. citizens. Because of this, significant effort has been expended to both 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 creating new things. However, once they arrive on campus and begin their coursework, they are faced with a slew of mathematics and science courses dealing predominately with abstract material and largely void of context. As a result, students become disenchanted with engineering and leave for other fields[5].

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

This has ultimately led to the development and implementation of first-year engineering experiences, either through engineering specific courses or through integrated curriculum, in an attempt to both 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 provide an integrated first-year engineering experience for students. The first step in this process has been the introduction of a set of first-year engineering courses designed to provide students with both a hands-on experience with engineering and a link between engineering and the mathematics and science courses required.

The first course, Engineering Foundations, aims to introduce students to the types of activities engineers perform and provide information on some of the engineering program options available at UC. Students are introduced to several engineering disciplines through four hands-on experiments. The students work in groups of two or three to complete activities, such as building and testing bridges, analyzing basic circuitry, and taking performance measurements of

a fuel cell system. Students are also introduced to 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. Presentation skills are emphasized through a group presentation that requires the students to research a given topic and then present their findings to other students in their class. Ethics is covered during a lecture that uses practical examples and role playing to emphasize the challenges in making ethical decisions. Finally, the design process is highlighted in a paper tower building contest.

The second course is a two-semester sequence called Engineering Models I and II. This pair of courses introduces students to the computer as a tool for completing engineering work and provides additional instruction and context for the mathematics and science material covered in other STEM courses. In the 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. As an example, at the beginning of Models I, students are shown how to plot data sets. This skill is then employed in the Engineering Foundations class to graphically represent the data collected during two of the experiments, allowing the students to compare theoretical and experimental results and providing additional context for the Models I material. The majority of the time in this first course, however, 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 Models II course, the attention shifts from developing computing proficiency to using MATLAB® in engineering applications and to relating these applications to the other STEM courses required of first-year students. Here, students are introduced to such ideas as interpolation, curve-fitting, and numeric differentiation and integration, through applications areas like data analysis, image processing, 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.

With the success of these courses this past year, efforts are currently underway to improve and provide a more tightly integrated experience for students between all the first-year courses. Currently, a major effort is underway to provide additional connections between the Engineering Foundations and Engineering Models courses. As the use of MATLAB® in engineering applications is the primary focus of the Engineering Models courses and the Engineering Foundations course focuses on engineering applications, a data acquisition (DAQ) device is being introduced as a way to marry the content of the two courses. In the Engineering Models course, students will write MATLAB® scripts that utilize the DAQ device to collect and process data. Those scripts will then be used in the Engineering Foundations course to collect data on the physical systems involved in the experiments, providing context for how MATLAB® would be used by a practicing engineer.

Additionally, discussions are ongoing between faculty in Engineering, Mathematics, Physics, and Chemistry to develop a common set of practices within all first-year STEM courses. Since each of these disciplines requires students to write lab reports, a common report structure is

being developed so that students are exposed to a single set of guidelines. There are also talks in place to more closely match the order of topics covered in the first-year calculus courses to the content introduced in the Engineering Models courses. Finally, there is a long-term goal to expand the use of the MATLAB® and the DAQ device to physics and chemistry labs, again providing a unified front to the students. Ultimately, the goal is to develop a completely common first-year curriculum for all engineering students.

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. The ultimate goal is to develop a common first-year curriculum and 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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