Engineering Foundations: Development of a Multidisciplinary Freshmen Course

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Abstract

The University of Alabama Freshman Engineering Program has developed a technical cross-disciplinary course for all freshman engineering majors, ranging from civil engineering from computer science. This three credit hour course, Engineering Foundations, originated from the consolidation of three one credit hour classes, not common to all majors. This work outlines the approach taken to the development of the class with emphasis on the achievement of the primary goals-student success in higher level courses and retention of students. Appropriate methods of evaluation of freshman preparation courses, like Engineering Foundations, will be discussed. This work can serve as a model to other programs, as well as a means for further improving the experience of freshmen engineering students at The University of Alabama.

Keywords

Freshmen Classes, Course Development.

Introduction

In 2014, roughly 143,000 college freshmen enrolled in engineering programs in the U.S.[1]. This is up sharply from the 115,000 enrolled in 2009[2]. Historical data suggest that a significant portion of these students will not continue in these programs to completion[3]. With recent emphasis on increasing the number of students graduating with engineering degrees[4], many have felt the need to research possible causes of student drop out and different methods for improving the retention of quality students in these programs[5]. One of the primary causes for students leaving programs cited was the level of student preparedness. This is evident by the variability in retention rates when comparing more selective schools to less selective schools. The idea is that more exclusive programs will have a better prepared in-coming freshman that is more likely to succeed in the first two or three semesters, increasing the probability that the student will complete the degree program[6]. With this in mind, it is not surprising that a great deal of focus has been placed on the students' freshmen year.

The Freshmen Engineering Program at the University of Alabama has developed a multidisciplinary course for all incoming freshmen in the college of engineering with the goal of increasing student success at higher levels. This three credit hour course, ENGR 103 Engineering Foundations (EF), was implemented in the summer of 2013 and has been offered every semester since. On average 800 and 450 students enroll in the class each fall and spring semester, respectively. Typically between 15 and 24 sections of the class are offered a semester depending on enrollment. Teaching responsibilities are distributed amongst a team of 6-8 instructors consisting of both full-time faculty and graduate students.

Goals & Objectives

The primary goal of EF is to increase the potential of in-coming freshmen by ensuring that the students possess or receive the knowledge and skills necessary to succeed at the higher levels of their education. It is an opportunity to reinforce mathematical and analytical concepts that students learned before entering the program, as well as those being taught in core freshmen classes such as, Calculus, chemistry, physics, etc. Also a large focus of the class involves introducing and familiarizing the engineering problem solving process.

Course Development

To determine which topics should be included and what material to emphasize, past student performance and class makeup by discipline were analyzed. Before the implementation of EF, the student success and retention could be characterized by Figure 1.

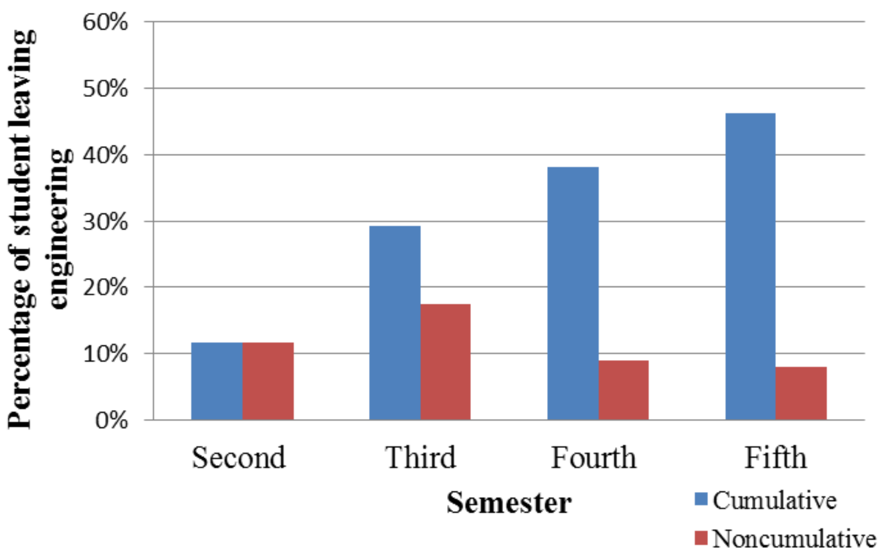

Figure 1. Percentage of Students leaving College of Engineering by semester averaged over 2002-2008 Cohorts.

It is shown cumulative drop-out rate that the most significant portion of students leaving the College of Engineering, leave after the first semester of their sophomore year. If a considerable percentage of this attrition can be attributed lack of preparation, as some suggest, an obvious place for focus is those skills needed to succeed in particularly the sophomore classes. In order to identify these skills, pivotal classes that coincided with these semesters needed to be identified. Statistics showed that both Statics and Circuits were two of these "turning point" courses for students. Historically, if a student passes Statics, he or she has an 86% chance of graduated with an engineering degree from UA. If a student passes Circuits, he or she has a 94% chance of graduated with an engineering degree from UA. Therefore it was reasoned that if the material covered in EF could increase the chances of a student passing these classes, it would increase the rate of graduation from the College of Engineering. With this in mind and the high number of students taking these courses, EF was designed to focus on preparation for Statics and Circuits.

When determining what material to cover in EF, developers discussed possible problem areas for students with Statics instructors. It became apparent that the students struggling in the course were struggling not because they could not understand the new concepts, but rather they lacked precursory knowledge and refinement of required skills. Particularly, these students displayed weaknesses in basic vector operations and trigonometry. If the students had no mastery of these skills, they had no hope of succeeding in the class. With this in mind, a significant portion of the course was devoted to these skills in an attempt to bring ill-prepared students "up-to-speed". By doing so, well-prepared students will have the opportunity to further refine these tools.

The portion of the class devoted to preparation for Circuits would involve reinforcing the fundamentals covered in freshmen physics classes such as, Ohm's Law, Kirchoff's laws, and the combinations of parallel and series circuit elements. This would be done through in-class examples and lab application. The idea was that if students could experimentally verify the circuits they solved in class through a hands-on lab, the concepts would be better understood.

Because of the number of students in the college that will be required to take Thermodynamics, developers of the course felt that some component of the class needed to expose students to its elementary principles. Although heat, work and conservation of energy are covered in freshmen level physics courses, extra exposure could help reinforce the concepts, and seeing the material in an engineering context would illustrate to the students its value and importance to their discipline.

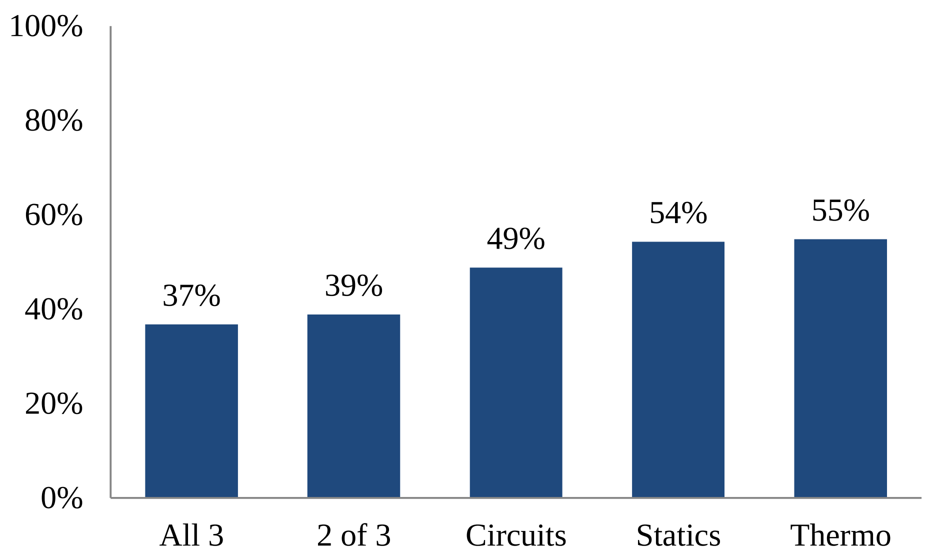

Figure 2. Percentage of Students to take Emphasized Sophomore Courses (2015).

Figure 2 shows the percentage of in-coming freshmen that will take the three emphasized sophomore level courses if they continue in their current discipline. "Circuits" encompasses both the course offered to electrical engineering majors and a separate course taken by non-electrical engineering majors. Undeclared engineering majors are not counted, so these percentages may actually increase as those students chose a discipline.

Although a significant portion of the students will not take Statics, Circuits, and Thermodynamics, reasons can be given for their introduction to this material. Mainly, one can argue for the philosophy of "engineer first, discipline second". Even though one may not encounter material related to these courses during their later education, certain knowledge and understanding of principles such as Newton's Law's of Motion or Conservation of Energy will ensure technically well-rounded students. Also, the problems encountered while learning this material will strengthen a student's understanding of the engineering problem solving process, as well as basic skills that will be needed to solve other types of problems that they will encounter later on. For example, all students will need to be able to analyze a system governed by n equations and solve for n unknowns. This is done continually through the solution of equilibrium equations and analysis of circuits.

Along with these points of emphasis, many other basic skills would be covered including, conversion of units, dimensional homogeneity, and engineering graphics. These were topics already discussed in the courses consolidated to form EF. A complete list of topics is shown in Table 1.

Table 1. List of Topics to be covered Engineering Foundations.

Subject	Subtopics
Basic Skills	Documentation
	Signficant Figures
	Unit Conversions
	Dimensional Analysis
Thermodynamics	Work/Heat/Energy
	Conservation of Energy
	Heat Engines
Electrical Circuits	Parameters
	Ohm's Law
	Element Combination
	KCL & KVL
Mathematics	Graphical Integration
	Vector Basics
	Vector Operations
Mechanics	Particle Equilibrium
	Centroids
	Moments
	Rigid Body Equilibrium
Engineering Graphics	Graphical Communication
	Orthographic Drawings
	Isometric Drawings

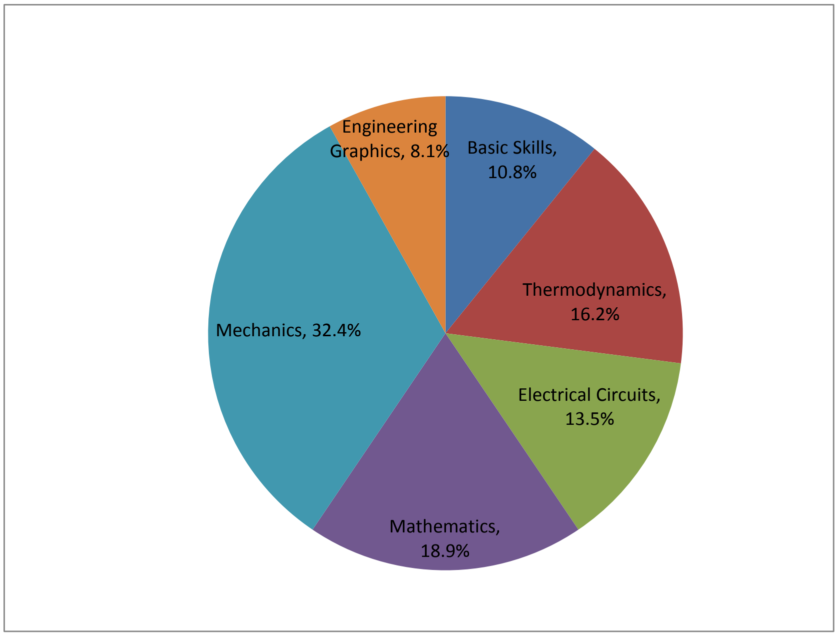

Figure 3. Time allotted to each subject by percentage.

Lectures for each major topic were accompanied by one-class labs. The specific format of these labs differed, but all involved collaborative and hands-on in nature. The engineering graphics lectures were intended not only to expose students to orthographic and isometric drawings, but also demonstrate the benefit of conceptual sketching in the evolution of an engineering design.

Metrics

One of the challenges of evaluating a course like EF is determining and appropriate and accurate metric for evaluation. This is further complicated by the change incoming student body, particularly in terms of average ACT score and high school GPA of freshmen class. The College of Engineering has seen a steady increase in both over recent years, as shown in Figure 4. This raises the question, "how are you sure that an increase in student success in sophomore level classes is a result of a course and not the result of a higher-caliber student?"

Once you have determined the appropriate method for adjusting a metric to account for variation in student body, you must select the actual gage of success. With retention being a paramount goal for many programs, it is only natural to compare graduation, retention, or attrition rates before and after the introduction of the course to evaluate its success. However, this maybe unfair to the course because, as mentioned earlier, many factors attribute to these rates. Most of these factors probably lie outside of the scope of the course.

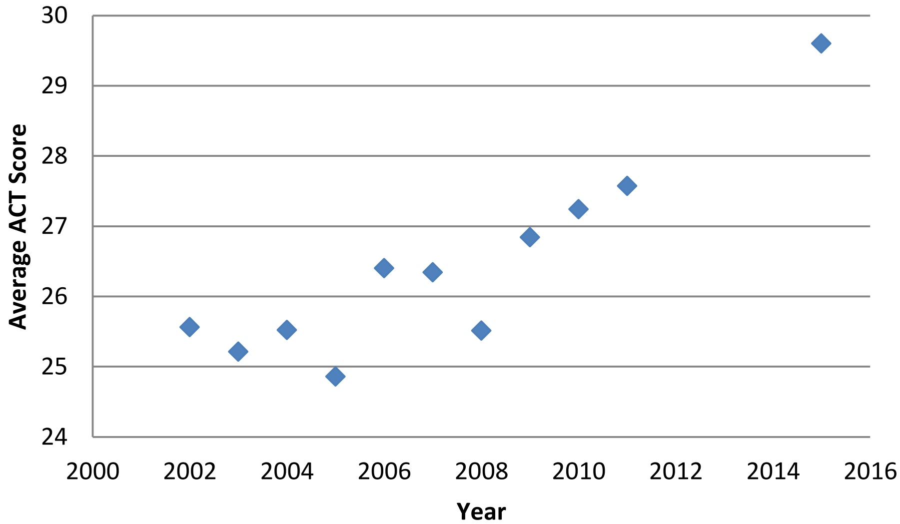

Figure 4. Average ACT score of College of Engineering In-coming Freshmen.

Since the primary objective of EF is to ensure that freshmen students are prepared for "turning point" sophomore courses, the best indicator may be pass or fail/withdrawal rates from these courses. Of course these rates would have to be adjusted as mentioned before to account for increase in student potential. Even with this adjustment it could be difficult to tie improvements in these rates to the implementation of EF. One could also point to changes made to the sophomore classes themselves, as the source of students' success. For example, a change in textbook, added help sessions, change in test format, availability of online resources, could all cause an improvement in these metrics. Student surveys could be the best way to eliminate this ambiguity. If a survey consisting of specific questions related to the benefits of EF in later classes were given to upperclassmen, the level of success of the course could be deduced. Surveys would be especially advantageous because not only could they be used to generate an overall measure of success of the course, they could be tailored with specific questions to determine the relevance of individual topics covered in EF.

A single effective metric for evaluation of EF is not realistic because of the wide-range of factors that goes into student success in sophomore classes and beyond. Instead, a combination of approaches should be taken, including analysis of pass rates in the three "turning point" classes and upper classmen surveys.

Evaluation

Because EF is a relatively new course, there simply is not enough data to offer a consistent and reliable trend in the success metrics already mentioned. With the course starting in 2013, only two cohorts have reached the classes necessary to evaluate performance. In spring 2015, the pass rate for Statics was 68% and is expected to rise. This rate, along with that of Circuits, will be monitored in future semesters. Surveys will be administered once the current cohort reaches junior year.

Future Recommendations

The development of the course should continue to change to account for an always-changing student body. Although the course objectives and base material will likely remain the same, the individual skills and assessments within each topic and point of emphasis may need to be adjusted to account for the strengths and weaknesses of in-coming freshmen. Therefore, continuation of dialogue between course developers and instructors of higher-level classes is critical.

The means for evaluating the course should be improved. The following can be done to do so:

- Determine a metric that applies to success of students outside of individual classes.
- Develop a more sophisticated method for accounting for the increase student readiness.
- Survey junior-level students to evaluate how effective the course was in preparing them for sophomore classes.

Conclusions

Statistics show that the majority of students leaving the College of Engineering, do between the first semester of their sophomore year and first second semester of their junior year. In the development of a comprehensive freshmen course it was decided to focus on establishing and reinforcing skills and knowledge that will help students succeed during these semesters. Particularly the emphasis was placed on preparation for Statics, Circuits, and Thermodynamics. This is because historically these classes have been "turning point" classes for students. Meaning that better than 90% of those that pass these classes will continue on to earn a degree in engineering from the University of Alabama. If success in these classes can be increased, so can the quantity and quality of students graduating with degrees in engineering. Due to limited number of semesters since the implementation of EF, reliable and consistent trends in student success are unavailable at this time. Pass rates in the "turning point" classes will be monitored to evaluate the success of the course. Student surveys will also be administered to upper classmen to determine the benefit of the course in terms of preparation for later classes.

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Morgan Minton is a graduate student and teaching assistant for the Freshmen Engineering Program at the University of Alabama. He received a BS and MS in Mechanical Engineering from the University of Alabama in 2011 and 2014, respectively. He has served as the instructor of record for two freshmen-level engineering classes over the past three years. During this time he has discovered an intense passion for teaching. He would like to continue work as an educator after he receives his PhD in Mechanical Engineering from the University of Alabama in May 2016. His primary research interests are space systems and complexity in engineering systems.