

An Engineering Experiences Course for Non-Calculus Freshman

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Abstract

We have developed and taught several times an engineering experiences course for our non-calculus ready freshman students. Students, usually in teams, perform a series of active learning exercises that expose them to typical engineering tasks, to the various engineering disciplines, and to engineering ethics. Reading assignments allow them to explore engineering successes and failures of the past as well as strategies for doing well as an engineering student. Mathematics assignments provide an introduction to fundamental engineering concepts and calculations such as stress and strain. Weekly assignments are given that require students to provide written reactions to the readings as well as to solving basic engineering problems mathematically. The course helps build student interest and enthusiasm for their engineering education as well as assisting students to decide whether engineering is a profession that suits their interests and abilities.

1. Introduction

Approximately half of all students who declare engineering as their major upon entering Grand Valley State University (GVSU) from high school are not prepared to enroll in the first calculus course. This is due to a variety of reasons. Student may not have had the opportunity for adequate mathematics preparation or may not have the ability necessary to handle college level mathematics. They may need to improve upon their problem solving skills and other learning skills. They may need time to explore whether or not their interests and abilities are sufficient to effectively learn the mathematics and science that are prerequisite for success in engineering. They may need more exposure to engineering to make a final commitment to the intense education process that lies in front of them.

Such students have unique advising and educational needs. Thus, a fundamental issue in any engineering curriculum is how to engage these students in the engineering educational process as well as to assist them in developing the skills necessary for success while they gain the mathematics background required to begin calculus. Student interest in and enthusiasm for engineering education must be built. Through instruction and advising, students must gain the information and insight necessary to decide if their interests and abilities are well suited to a career in engineering.

Various approaches could be employed to meet these requirements. Astatke and Mack¹ discuss the use of a web-based mathematics course to prepare students to take a mathematics placement examination. This course helped students place above a remedial (non-college) algebra course into calculus or a pre-calculus course. Fisher, Della-Piana, and Crawley³ as well as Fisher, Quinones, and Golding⁴ discuss the establishment of learning communities for non-calculus ready freshman students. This program uses the clustering strategy. Students are placed in cohorts and scheduled for the same sections of three classes: Introduction to Engineering and Physical Science, a module-based class in pre-calculus, and a first-year English composition class. Students in each cohort work closely with each other and faculty teaching the block scheduled classes.

Our approach to meeting the requirements of non-calculus ready freshman is the subject of this paper. The structure of the course is presented including expectations for student work. Each active learning exercise is discussed.

2. Course Structure

Each freshman student who declares engineering as a major at GVSU must pass a calculus readiness test in order to enroll in Calculus I and the first required engineering course. Those who do not take or take and do not pass this test are enrolled in EGR 100: Introduction to Engineering. While some mathematics problems are covered in EGR 100, the primary mechanism for preparing a student for Calculus I is the pre-calculus course sequence taught by the mathematics department: Algebra, College Algebra, or Trigonometry. These courses help a student meet the topical pre-requisites for Calculus I. Students take one or more of these course concurrently with EGR 100.

EGR 100 was developed to help students gain an understanding of and an appreciation for the engineering profession as well as the requirements of an engineering education. The course provides a first experience in doing engineering activities. In so doing, the students are exposed to the engineering disciplines available in the Padnos School of Engineering(PSE) at GVSU. The course includes graded writing assignments, engineering problems that require mathematical solutions, and an introduction to engineering ethics.

EGR 100 deals with the question: What do engineers do? This question should be addressed independently of engineering discipline. Thus the activities of the course are organized according to the issues common to engineering disciplines: product design, process design, and operations design.

The course meets for two hours (110 minutes) once per week in a laboratory room. The nominal class size is 20 students. This meeting time is divided approximately as follows:

1. Discussion of engineering successes and failures based on the readings in Petroski⁵ and current events (15 minutes).
2. Discussion of engineering student success strategies based on Donaldson² as well as Grand Valley State curriculum requirements and educational opportunities (15 minutes).
3. Mathematics problems, occasionally (15 minutes).
4. Active learning exercises (65 – 80 minutes).

Grading is based on attendance (42%), weekly questions that cover the assigned reading in Petroski⁵ and Donaldson² as well as an occasional mathematics problem (48%), and a course notebook (10%). The course notebook contains lecture notes, records concerning the active learning exercises, and all returned work.

The reading and discussion in Petroski's book gives students insight into how engineers learn from experiences and from failure. The Donaldson book provides a useful counter balance by discussing the typical engineering student experience. Taken together and added to the class activities, students are able to see how they could fit into the engineering profession.

It should be noted that calculus ready freshman share at least some of the educational needs of their non-calculus ready colleagues. However, we have recognized that mixing calculus ready and non-calculus ready students creates a non-homogeneous audience for introducing engineering. Thus, the calculus ready students take a distinct course, Engineering Strategies, which has some topical overlap with EGR 100. For example, both courses use the Donaldson book as well as discussing product design and ethics. Engineering Strategies presents topics, as appropriate, from a more mathematically sophisticated point of view.

3. Active Learning Exercises

The active learning exercises are the primary mechanism for exposing students to what engineers do. The exercises span the engineering disciplines offered at GVSU: computer, electrical, manufacturing, and mechanical. Some exercises are specific to a particular discipline and others address common issues. There is equal emphasis on problem analysis and synthesis to a design as well as realization of the design. In many activities, individual students or teams create an entity that can be kept as a reminder of their engineering efforts.

The active learning exercises are summarized in Table 1. Many of the activities have a common structure. Students are divided into teams of three or four. The activity is stated as a set of requirements to be met by the team. The team develops a design to meet the requirements and then implements the design. The implementation is tested to see if the requirements have been met. Most teams do not meet the requirements completely. This leads to a review of the design with possible improvements identified. If time permits, the design is re-implemented.

Table 1. Summary of Active Learning Exercises

Module	Activity	Relevant Disciplines
Product Design	Design procedures	All
	Redesign a glider	Mechanical
	Design and build a bridge	Mechanical
	Sketching as a part of design	All
Process Design	Electronics assembly manufacturing	Computer/Electrical
	Casting using Alumilite (two part thermoset resin)	Manufacturing
	Casting and finishing	Manufacturing
	Environmentally friendly processes	All
Ethics	Engineering ethics	All
Operations Design	Assessing quality	All
	Computing gasoline mileage	Mechanical
	How many should I buy?	Manufacturing
	Building the Gateway Arch	All

Other activities are performed individually. For example, students learn to sketch in proportion. A sketch of the carillon tower on campus or another building is made. The height of the tower is estimated based on a measurement of the width of the base and the use of a scaling factor equal to the measured width/sketched width of the base. Each student learns to make an Alumilite (two part thermoset resin) casting by selecting a mold that has been prepared in advance, mixing the two Alumilite components, filling the mold, and waiting for the Alumilite mixture to harden. Students are asked to identify factors that affect the quality of the casting. The next class meeting takes place in the paint shop where students do finishing work on their cast part.

Some activities introduce the use of computers in solving engineering problems. Rather than computing an answer to a problem for each of one or two sets of parameter values, graphs showing the behavior of the quantity of interest over many sets of parameter values are constructed. Spreadsheet-based computer simulation models are constructed and the use of such models in decision-making is illustrated.

Six of the 14 active learning exercises are relevant to all engineering disciplines. The introduction to the course is a video describing the product design process used at the company IDEO. Students view the video, discuss it in small groups, and report their findings to the class as a whole. As a summary at the end of the course, a video describing the construction of the Gateway Arch in St. Louis is shown. Students discuss all of the aspects and disciplines of engineering that were required to successfully complete this one project.

Each module of the course contains activities of interest across all of the engineering disciplines. The use of sketching is a common part of any design activity. Ethics issues concern all engineers and are a fundamental part of any curriculum. The honor code of our engineering school is presented including rules of thumb for dealing with ethically challenging situations. A video portraying several short vignettes focused on ethical issues in student life is shown. Each vignette is discussed with students asked which rule of thumb helps resolve the issue and what a good resolution would be.

Environmental impact concerns are a fundamental part of any material transformation activity and include waste disposal. To illustrate this, students are asked to develop a process for painting a cardboard square green on one side by mixing blue and yellow tempera paint. The process must produce as little leftover paint as possible and contaminate as few items as it can. Students may use gloves, paint brushes, cups, cotton swabs, and similar items. After the square is painted, each student team and the instructor review the process for possible improvement.

Quality of products, processes, and operations is of interest to all engineers. For the quality exercise students are divided into teams. Each member of each team is given a small bag of peanut M&M's and asked to list the types of defects seen in the individual candies. The number of defects of each type is recorded. Students, first in each group, and then in the class as a whole, determine which defects are most numerous, discuss what might have caused them, and propose solutions involving changes to the manufacturing process or in material handling.

Three of the exercises are in the mechanical engineering area. Two of the exercises follow the initial class meeting that discusses design. At the second class meeting, student teams are given a balsa wood glider and asked to design, implement, and test improvements to make the glider fly further. Typical improvements include adding canards to the wings as well as weight to the fuselage. Pre and post improvement flight distances are recorded and compared. At the third class meeting, student teams are given a paper bag containing various common materials such as drinking straws, paper, and paper clips. Each team is asked to design and build a bridge using only these materials. The design criteria specify the longest bridge that is self-supporting when placed between two 3-inch high blocks and with a deck wide enough to support a particular toy car. The third mechanical engineering exercise has to do with developing a spreadsheet model of the fuel economy of an over-the-road truck. Factors considered in the model include relative wind speed, truck speed, drag, and tire efficiency. A graph showing fuel economy versus wind speed results from the analysis.

Two types of activities relate to manufacturing, one to processes and the other to operations. Students each create an object from one of several available molds using Alumilite and subsequently finish their creation as was previously discussed. In addition, pairs of students use a pre-constructed spreadsheet based simulation model to determine the number of Christmas trees a merchant should purchase. Demand is a random variable and only one order is permitted. The cost and selling price of trees are taken into account.

One activity is related to electrical design. An electronics assembly manufacturing exercise is performed by each student. The components of a light emitting diode (LED) circuit are given to

each student along with assembly instructions. These components include resistors, the LED's, capacitors, and transistors as well as a printed circuit board. Each student assembles and solders the components to a board, thus creating a souvenir of the class.

4. Summary

We have developed, implemented, and taught a course introducing engineering to non-calculus ready freshman. Engineering is viewed as involving product, process, and operations related tasks. Students, both individually and in teams, perform activities that introduce engineering in each area. Some activities are specific to a particular discipline. Most apply to engineering in general. In addition, the course reviews current and past engineering successes and failures as well as strategies for being an effective engineering student.

While a complete assessment of the effectiveness of the course is not available, our experience has been that the course does build enthusiasm for the engineering profession. Of the 37 students who began college at GVSU and entered our junior class in May 2002, nine (24%) were non-calculus ready freshman.

Bibliography

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CHARLES R. STANDRIDGE

Charles R. Standridge has taught and has helped refine the course discussed in this paper. He is also the co-developer of a freshman level course in engineering measurement and statistics. In addition, he develops teaching approaches for systems simulation courses for undergraduate and graduate students in manufacturing engineering as well as simulation-based approaches to industrial problems in supply chain operations.

SHIRLEY T. FLEISCHMANN

Shirley T. Fleischmann piloted this course in the active learning mode complimented by readings and writing assignments in Petroski's book. She also teaches courses in the thermo-fluids area of mechanical engineering. She has a long standing interest in studying how students learn and in particular, how current students understand and use mathematical modeling.

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Paul D. Johnson serves as the scholarship co-ordinator for the Padnos School of Engineering. He teaches materials science and digital systems courses as well as recently beginning to teach the course described in this paper.