AC 2009-1866: ENGAGING FRESHMEN IN A HANDS-ON DISCOVERY OF MECHANICAL ENGINEERING

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Engaging Freshmen in a Hands-on Discovery of Mechanical Engineering

I. Abstract

This paper outlines a new approach in the introductory freshmen mechanical engineering course at Montana State University to increase student retention. The objective is to utilize, within the Introduction to Mechanical Engineering (ME101) course, a set of freshmen-level, hands-on laboratory modules across the breadth of mechanical engineering to introduce students to the character and scope of the mechanical engineering profession. It is put forward in this paper that students who understand the scope of their major are more likely to have a stronger belief in the correctness of their choice, thus resulting in fewer transfers out of the program. Through design of appropriate self-discovery laboratories, it is also hypothesized that freshmen students will develop a relational understanding between fundamental courses (i.e., physics, chemistry and math) and future curricula. This is important as many engineering students transfer out of the program before reaching upper level courses.

This paper will discuss the development and implementation of hands-on activities for freshmen students in the Mechanical Engineering (ME) program. Using techniques such as reverse engineering and design-build-test, students will be introduced to general mechanical engineering topics such as materials and structures and mechanical design. Integrated within each laboratory module are student presentations, curriculum investigation, and potential career opportunities. The success of this new approach will be discussed with regards to higher retention rates of mechanical engineering students as the program progresses, as well as, student confidence in degree choice, improved understanding of future curriculum and career potential.

II. Introduction

Every university, college, department and program struggles with attracting and retaining new students. From this motive, a significant body of research exists discussing these problems specifically for engineering programs across the nation[1,2]. Departments can no longer expect that students will choose a degree program based on reputation or salary potential. As departments within the Montana State University (MSU) College of Engineering (COE) compete nationally for entering students, the ability to attract, engage and motivate new students becomes an added requirement for the mechanical engineering program.

MSU is a land-grant institution of approximately 12,000 students located in a culturally-oriented Rocky Mountain community of approximately 30,000 situated between Yellowstone and Glacier National Parks. Roughly 2000 students are enrolled in the COE which is comprised of five departments. The M&IE Department contains three Bachelor of Science programs: Mechanical Engineering, Industrial Engineering and Mechanical Engineering Technology. The Mechanical Engineering program has a ten-year average undergraduate enrollment of approximately 400 students, as seen in Figure 1.

Departmental Size and Retention

As seen in Figure 1, the number of undergraduate students in the MSU ME program has remained fairly stable over the past ten years (394 students). This is an excellent trait in light of the fact that the department has minimally tracked, studied and responded to trends in undergraduate enrollment numbers, and has performed little external recruitment beyond that provided by the College and University. Also shown in Figure 1 is the number of freshmen, sophomores and juniors registered in the mechanical engineering program over the same ten-year period. The freshman average is 123 students, the sophomore average is 82 students, and the junior average is 74 students, thus yielding an average loss of 41 students after the freshman year and only 8 students after the sophomore year. It should be noted that these numbers are simply averages of classification numbers as provided by the registrar's office, and do not track individual students leaving and entering the ME program. However, the interesting and unsuspecting result is the narrow range between sophomore and junior classes. On the surface, this would indicate the greatest loss of students occurs in the freshman year and therefore not due to sophomore level math, physics and mechanics courses.

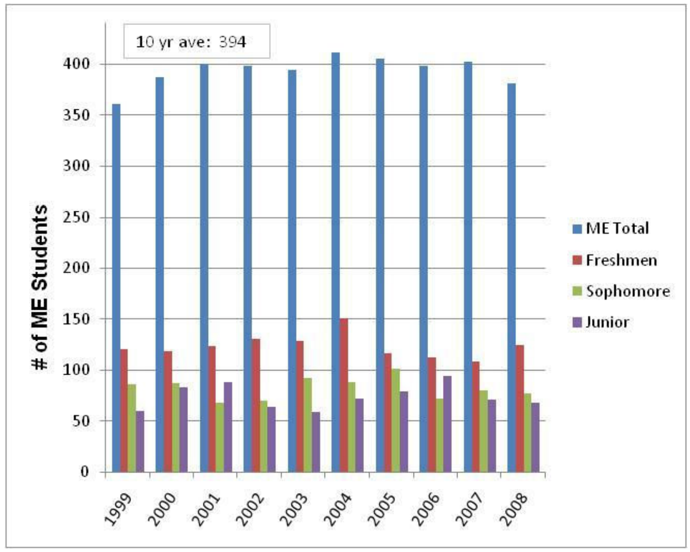

Figure 1 Number of Freshman, Sophomore, Junior and Total Undergraduates in the ME program (Oct. count)

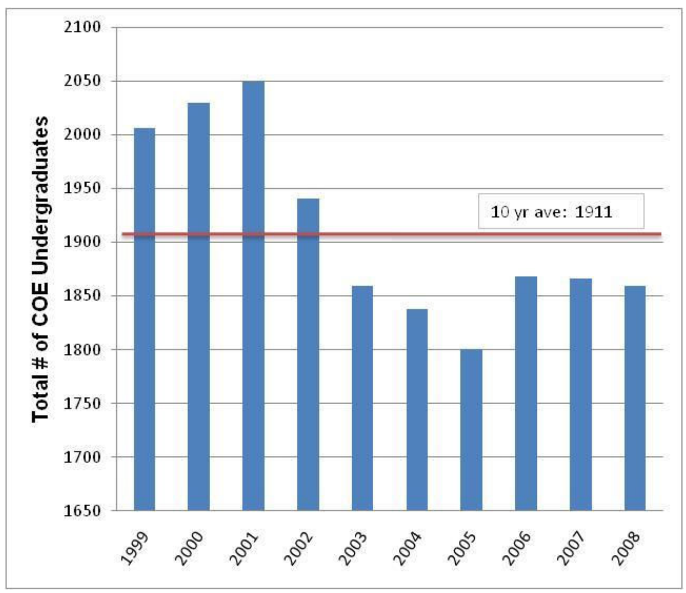

Figure 2 Total Number of Undergraduates in the COE (Oct. count)

The number of undergraduates in the MSU COE over a ten year period is shown in Figure 2. Comparing the trend of ME to COE undergraduates reveals an interesting inverse relationship. The ME departments higher enrollments are seen in years when the COE has its lower enrollments, and except for 2008, the ME departments lower enrollment years show higher COE enrollments. A one standard deviation drop in student numbers (15 for ME, and 88 for COE), while seemingly small fluctuations, have a significant effect at a school where budget dollars are strongly coupled with student credit hour production. Like the data above, this data contains the total number of students counted in October of each year, and does not track transfers to or from the college or follow cohorts from year to year. A process is currently being implemented that will track transfer numbers and survey attitudes of students coming in to and out of the ME department. Initial expectations of faculty are this data will show that few students transfer into ME from other COE departments after the freshman year.

The author acknowledges that the possible reasons behind these trends are numerous and complex, and it is anticipated that these trends will be studied in greater detail over the next few years. This paper represents the author's initial investigations into student recruitment and retention in the ME program at MSU. While recognizing that enrollment numbers are not showing a dramatic decline, the department has certainly not grown or advanced in this area either. Tracking cohorts through the first three years of the ME program is currently underway. This data will be valuable in understanding the past retention rates, and will serve as the starting point for any possible changes created by the exercises described in this paper.

Course Description

The Introduction to Mechanical Engineering course at MSU is a one (1) credit lecture course offered only in the fall semester. The catalog states the course includes:

> **The mechanical engineering profession, logical process of problem solving and design, professionalism, and ethics.**

Over the past several years, this course had become a series of disjointed presentations by a collection of professors. Lectures were loosely connected and the need for better coordination between professors was often cited in student surveys. The Fall '08 offering of this course was divided into two sections, with each section covered by a single professor, a marked change in course delivery. One section presented the material through a traditional lecturing medium, and the second section of the course presented the material through several hands-on exercises and team projects as described in this paper. The second section contained ninety eight students and was the authors first time to offer the course. These sections also provide excellent cohort groups to track through the early years of the ME program and measure the impact of each teach style.

As a one credit course, the content and breadth of ME101 is severely limited by the low student contact hours. It may be difficult to determine the true impact of the course on student retention due to the range of motives of why students leave the ME program. However, the optimal impact and outcome from the course would be convincing marginal and uncommitted students that ME is the correct program for them, while not reversing the commitment of students who already consider themselves ME's.

III. Hands-on Exercises

Over the past decade there have been many examples[3-12] of engineering courses that have successfully utilized design exercises or hand-on laboratories to enhance the learning environment and experience. These references are but a few of the expansive numbers of papers that describe successful hands-on experiences for engineering freshmen and have been shown to create positive classroom experiences for the students. However, while successful laboratory exercises are described, only a small number of these papers describe the exercise as a tool to familiarize students with the field of ME, and fewer still relate hands-on introductory classes to retention numbers. The stated aim of this paper is the combination of hands-on exercises, as presented in the literature, with curriculum exploration and examination of the mechanical engineering profession such that freshmen students develop a strong connection to mechanical engineering and a desire to remain in the program, thus raising retention rates.

Potential exercises were identified for implementation in the Fall '08 semester and assessed for their ability to meet the goals of the project, namely, involving students in the fundamentals of mechanical engineering, curriculum and professional investigation, written reports, oral presentations and characterization of a simple machine. The two hands-on exercises selected for implementation were a reverse-engineering exercise and a design-build-test exercise. The exercises not selected for implementation did not have the breadth to engage students in all aspects of the project described above. These exercises were typically more focused and resembled a traditional upper level lab exercise where a single topic in mechanics, fluids or heat transfer is investigated.

All implemented exercises were designed to be completed in groups of four students, with approximately 25 teams in the Fall '08 semester offering. Additionally, as freshmen, many of the students have never written a technical report; therefore, very explicit instructions were given concerning the section headings and required contents of the report. Items required included discussions of future curriculum that may expand their knowledge of the project, and potential ME careers where similar tests, data or functions are performed.

Reverse-Engineering Exercise

Many undergraduate students enter the ME program with an intrinsic curiosity of how systems work. This is easily confirmed by asking any mechanical engineering class, "Who has taken apart machines, cars, toys, tools, speakers, etc. to see how it works?" The author's experience has been that upwards of 85-90% of students answer that question in the affirmative. This reverse-engineering exercise has been developed to help channel this curiosity into an effective learning tool that introduces freshmen level students to topics such as mechanical systems, energy storage and transfer mechanisms, design and manufacturing considerations and curriculum discovery.

The reverse-engineering module starts with a lecture portion that defines the exercise:

> Reverse-engineering is the process of determining the engineering processes and decisions that were made during the design stages and manufacturing of an engineered item.

Teams of four students are then given the following responsibilities for the exercise:

- Agreeing on a choice of subject item
- Performing the required research and disassembly
- Addressing pertinent questions regarding design and manufacture of the item.
- Identifying courses in the ME curriculum that would help you solve these questions.

The following guidelines are also given:

- Parts must be readably capable of disassembly.
- Item must contain parts that have some relative motion (articulating parts)
- Cost lest that $15 (unless can be found for free)
- Small enough to fit in a student backpack.

In the Introduction to Mechanical Engineering course this exercise is performed over a two week period, consisting of three lectures. The assignment is given in the first week, along with a lecture describing the attributes of the reverse engineering process and examples of the process. The second week, enabled by visiting faculty members, each group meets individually with a faculty member during the class period to describe their selected item and their progress. Faculty members help facilitate the reverse engineering process, and place the engineering concepts from each item in context with the ME curriculum. The exercise culminates in the third week with presentations and a written report.

Design-Build-Test Exercise

This exercise was conceived around the following comment made to the author upon returning to academia after many years in a research lab, "ME students like exercises where they get to break things or launch things." The result was a design-build-test team exercise that utilized common and economical components, could be mathematically described and modeled by freshmen, and required experimental testing and characterization. Each team was supplied a 4 foot length of ½" PVC tubing, one ½" PVC ball valve, one ½" 90° PVC elbow and one ½" PVC cap with a tubeless tire valve press fit into the end. These parts can be assembled to create air-powered gun consisting of a breech, valve and barrel. The projectile for this exercise is a miniature marshmallow, which when "fresh", fills the inner diameter of the ½" PVC with minimal clearance.

A lecture on the basics of projectile motion was presented to the students before the exercise was assigned. The ME 101 course is mostly populated by incoming freshmen who will not take college physics until the sophomore year. However, polling of the students showed that a large majority of students have covered the topic of projectile motion in high school. After this lecture the following exercise was given.

> This exercise is designed to make you start thinking as an engineer. Simple experiments, toys and games all have critical design and engineering elements. As you progress through this exercise you will hopefully apply some of the skills that we have covered in this class, and carry them forward into your future classes.
>
> Engineers are often faced with the need to experimentally characterize a system in order to verify a theory, prove a relationship or some combination of both. This project combines the ideal solutions for projectile motion and the non-ideal projectile motion of launched marshmallows. Relationships must be determined that relate breech pressure and initial velocity, as well as identifying key experimental parameters such as muzzle length, breech volume or projectile shape. This project is more than just 15% of the class grade or the final project for this semester. This project is the summation of all the topics discussed and presented throughout the semester. Successful completion of this project will require a combination of design, theory, experiment, graphing, estimation, etc.
>
> The exercise entails the assembly, testing, simulation and performance of an air-powered marshmallow launcher. Each team will utilize the supplied materials as a basis for the launcher, but teams are allowed to add additional materials to enhance performance, as long as the basic principles are not violated. It is at the instructor's discretion to identify what is beyond the basic principles of the launcher. The project consists of two parts: 1) a written report, and 2) a performance demonstration and competition.

Two weeks were given between providing materials and the exercise completion. The performance demonstration required the students to hit two "targets", a vertical target elevated above the launch and a second horizontal target elevated above the launch point. Students were given the targets locations and were required to estimate the required pressure, launch angle, etc. for their system to hit the target. Each teams inputs (estimates) and results were recorded for each target and factored into the overall success, or grade, for the project.

Alternative Exercises for Future Development

Several of the exercises not implemented in the first year are currently now under development. As mentioned above, these exercises are more focused exercises intended to introduce freshmen students to the basic analytical areas of Mechanical Engineering and their interrelationship through the 4-yr. curriculum. These modules follow a more traditional laboratory exercise and explore the areas of materials and structures, heat transfer, and energy conversion. The materials and structures exercise utilizes photoelasticity to illustrate the concept of geometry on stress variations within a sample. A heat transfer exercise illustrates the property of thermal conductivity and heat transfer and is being developed along with an exercise that introduces students to energy conversion devices such as heat engines, peltier-effect devices and electric motors.

IV. Educational Outcomes and Assessment

The educational outcomes of the approach described in this paper include improving the student learning environment through hands-on exercises, introducing students to the character and scope of the mechanical engineering profession and increasing the retention rate of freshmen mechanical engineering students. The reverse engineering and design-build-test exercises were implemented for the first time in the ME101 course in the Fall '08 semester in an effort to address the first and second educational outcomes listed above. Student evaluations and comments from the end of semester course survey have shown these outcomes were qualitatively met. The hands-on exercises were described as interesting, stimulating and presented a good description of "what mechanical engineering is all about." This successful result matches the results seen in other hands-on laboratory approaches[3,4,7]. Assessment tools were not in place in the Fall '08 semester to compare the approach of this paper with the typical lecture methodology presented in a separate section; however, these tools will be in place for the Fall '09 offering. The effects of these exercises on student retention are simply not available at this time since implementation into the Introduction to Mechanical Engineering course has just begun. However, measurements of student attitudes and tracking student progress have now begun with the initial set of Fall '08 students. This work has also initiated a deeper investigation into tracking the ME program enrollment at a detailed level. Due to the steady enrollment numbers and high faculty workloads, a priority has never been set to try and understand why students leave the ME program. The author has taken this as a priority and considers the hands-on exercises presented here a first step towards increasing student retention. Additionally, successful assessment methodologies presented in the literature for similar hands-on exercises and retention programs will be researched and implemented for continued success. These will include student surveys at the beginning and end of the course to determine the change in student attitudes towards mechanical engineering, their belief that mechanical engineering is the correct major for them, and their desire to remain in the program.

V. Summary

Two hands-on exercises were discussed that use the techniques of reverse engineering and design-build-test to introduce ME freshmen to general mechanical engineering topics, mechanical design, student presentations and curriculum investigation. This new approach was well received by students, but success in regards to higher retention rates can not be immediately measured. Additional hands-on exercises are in progress that will introduce students to specific fields within the ME program. Tools to quantitatively assess the success of these exercises on the retention rates of freshmen in the mechanical engineering program are under investigation and will be implemented in the Fall '09 semester.

VI. Acknowledgements

The author would like to thanks Drs. Chris Jenkins, Michael Wells and Carolyn Plumb for the motivation to accept the challenge of engaging students at the freshmen level.

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