Partnering for an Innovative Freshman Design Experience: The Case of Mechanical and Industrial Engineering

Linda Ann Riley[1], Edgar Conley[2]
Department of Industrial Engineering[1], Department of Mechanical Engineering[2]
New Mexico State University
Las Cruces, New Mexico 88003
linriley@nmsu.edu, econley@nmsu.edu

Abstract

Freshman Design is a common course offering in many engineering programs. Typically, this introductory class has several objectives:

1) to excite and motivate students about engineering in general, and further, to foster enthusiasm about a discipline-specific field such as mechanical or industrial engineering;
2) to provide students with elementary tools and methods useful in the design process and to encourage students to apply these tools by means of carefully crafted design exercises;
3) to develop teaming, interpersonal, time management and creative thinking skills;
4) to further refine communication, writing and presentation skills; and
5) to begin the process of relationship building among individual students, the instructor teaching the course, and the student's home department.

From a faculty perspective, achieving these objectives with a group of freshmen may seem daunting. Such a class is nevertheless often the student's first exposure to discipline-specific material, thus an improperly designed, uninteresting course can negatively affect engineering program attrition rates.

The precise influence of initial course offerings on attrition is unknown but statistics indicate a problem does exist - engineering drop-off rates from the freshman to sophomore year are notable. Even more compelling is the large percentage of students leaving one engineering discipline for another, or choosing an entirely different major in another college. This raises the question, what happens during the freshman year? What did the student witness or experience that caused a rejection of an engineering area of first choice? In contrast to the sophomore and junior years, during the freshman year the level of difficulty and technical nature of engineering material to which students are exposed is elementary. So the problem, we believe, owes not to the sudden increase in academic rigor - it lies in the initial subject matter, its presentation and the student's various interactions with faculty and other students.

Introduction

This article presents the framework, challenges and rewards in creating an exciting and useful alternative and/or complement to the traditional engineering-tools freshmen offering. Aimed at reducing attrition rates, a multi-disciplinary freshman design course was initiated by two faculty members in the mechanical and industrial engineering departments at New Mexico State University. The partnership focused on the design and implementation of an innovative approach to captivate relatively inexperienced students early in their engineering studies. Viewed as a strength of the respective mechanical and industrial engineering programs, this course was positively highlighted by accreditation reviewers.

Having evolved over the past 20 years, the freshmen curriculum in the College of Engineering at New Mexico State University was influenced in no small part by ABET. This is especially so with the recent adoption of the ABET 2000 criteria which emphasizes the development of problem solving skills applied to the engineering design process. As a result of ABET, the freshmen course offerings here, and indeed nationwide, accentuate this essential skill of practicing engineers.

Yet, even with new and innovative approaches to engineering curricula design, the problem of student attrition lingers. One of our solutions was to create a new teaching approach and develop new freshman course content while maintaining the focus on engineering design. The primary goal was clear – prompt students to become excited about a career in engineering.

Background of the Attrition Issue

A number of studies measuring engineering attrition rates suggest that between 50% and 70% of freshmen starting in an engineering program will not graduate with an engineering degree. In some of the definitive studies on the subject, Astin and Astin[1,2,3] followed 25,000 engineering students at more than 300 institutions. The Astins found that attrition rates for engineering students were 57%, and further only 43% of first-year engineering students graduated with a degree in engineering. The Astins also documented the number of students leaving engineering altogether: 40% left to study in a non-science or mathematics field. In an Iowa State study, Moller-Wong and Eide[4], found attrition rates at that institution were between 55 and 60%. However, in this case, only 32% of the students starting in engineering programs actually graduated with a degree in engineering within five years.

Additional research has identified the many reasons students decide not to remain in an engineering program of study. Contrary to popular belief, academic inability is not a primary reason.[5,6] Instead, the combination of many factors, including faculty interaction, faculty enthusiasm for engineering, classroom experiences, interest in engineering and curricula delivery models are but a few of the reasons why students chose an alternate major, or drop out of school altogether.[7,8,9,10]

Attrition rates in engineering at New Mexico State University follow closely the national patterns. Table 1 on the following page shows the retention and continuation rates for the College of Engineering at this institution. This table highlights some interesting points. First, our four-year graduation rate averages only about 4%. Second, after six years, the university has graduated approximately 45% of the starting freshman in Engineering. What is not exactly clear, however, is how many of these students that have graduated actually graduate with a degree in engineering. Last, we lose approximately 24% of students who started in engineering after the freshman year.

One point that is clear with respect to engineering attrition is the importance of the freshman experience as a mechanism to captivate and interest students in the field of engineering. But voluminous as it is, the literature suggests no magic formula for creating or providing this experience. Therefore, in view the literature and our own teaching experiences, our approach was to assign fun, challenging, hands-on projects that strongly encouraged multi-disciplinary team building and problem solving. We also made it a point to interact with each student individually once or twice weekly.

Table 1 - New Mexico State University, Main Campus - College of Engineering
First-time, Full-time Freshman Cohorts, Fall 1994 - 1999
Retention Rates*

Cohort	Head-count	1 year Retention Rate	2 year Retention Rate	3 year Retention Rate	4 year Grad. Rate	4 year Contin. Rate	5 year Grad. Rate	5 year Contin. Rate	6 year Grad. Rate	6 year Contin. Rate
1991	320	77.8%	67.2%	59.7%	3.1%	52.5%	27.8%	30.3%	45.6%	10.3%
1992	325	77.5%	63.7%	57.8%	5.2%	49.2%	27.1%	27.7%	44.3%	11.4%
1993	312	78.8%	62.5%	58.3%	3.8%	54.5%	33.0%	26.9%	46.5%	12.2%
1994	258	77.5%	67.1%	62.4%	5.4%	54.7%	29.5%	32.2%		
1995	247	76.5%	64.4%	59.9%	2.8%	53.4%				
1996	275	78.5%	67.6%	62.2%						
1997	262	80.5%	63.0%							
1998	337	76.3%								

* Source: Office of Institutional Research, New Mexico State University, August 2000

Course Specifics

General – Syllabus - In detail, the syllabus describes course credit awarded in an even mixture of engineering basics and projects, with the remaining 40% based on sign-in attendance plus the final exam. We are satisfied with this blend, though we care not to weigh mere attendance quite so heavily. But, if accompanied by frequent verbal reminders, sign-in attendance seems essential. These admonitions are necessary in early morning classes, and especially so during times of group projects, when, by necessity, members must cover for one another.

Engineering Tools - The engineering tools part of the course stressed some fundamentals. We began the term with a patent search which compelled students to explore the genesis of what each had written was, in their view, a clever design. The exercise also served to introduce a surprisingly large percentage of freshmen to the college computer and email system. Later, the MEs studied gears, bolts and 4-bar mechanisms while the IE students explored process improvement strategies using such tools as Lego activities and simulation.

Project design -Regarding project design, we have expended considerable effort creating project assignments that contain the 'right' assortment of task planning, logo design, hands-on fabrication, testing, and report writing. These project assignments were performed in teams consisting of both mechanical and industrial engineering students. As always, the problem was to create projects that both interest and engage all team members, ensuring that those students who may possess fewer manipulative skills are fully occupied. The projects must be inexpensive and simple, of course, and not require the students to produce precision machinery. Finally, we have confirmed that the most compelling projects are evaluated in head to head competition between the project groups. The contests were assigned with clear objectives and were carried out with strict adherence to specifications and competition rules.

Forming multidisciplinary teams - Our intent was to carry on separate classes for the engineering tools topics, but then, during the project periods, merge the MEs and IEs into multi-disciplinary design groups. We found that students seemed to adjust well when they were assigned to a particular group, but when allowed to select their own design group members, students opted for their in-class neighbor. One of the greatest challenges here was the logistics of the class time as well as nature of the two freshman courses. First, the classes did not meet at the same time. Second, the mechanical engineering class carried three credits while the industrial engineering carried only two. As a result, the mechanical engineering class met three times a week whereas the industrial engineering class met twice weekly. This logistics conflict impacted the successful interaction of multidisciplinary teams.

Providing motivation - During the middle of the term, and following the completion of a project, a peer evaluation was requested of each student. Each design group member was asked to evaluate his fellow members' contribution to completing the project. The evaluation was to remain confidential, so the form was not collected during the same class period it was handed out, leaving the individual student with a convenient excuse not to divulge his/her evaluation. The forms were later assessed to detect large disparities among individual group members' contribution estimates. We spent a bit more time talking about task assignments with the (surprisingly few) groups that showed a wide range of estimates. These groups seemed to respond and then were able to carry out future projects satisfactorily. As a result of this process, it became evident that additional instructor effort was needed in working with the students on team management, team communication and team building skills.

Log books – Student log books, the purpose of which was clearly spelled out in the syllabus, were not utilized to the extent possible. We had asked the students to write a brief description of each class day's activities along with pretty much anything else that popped into the their head. This format obviously provided a great deal of flexibility. The problem, we believe, is that we prescribed no specific structure for entries into this log. On the other hand, the inherent flexibility may provide the opportunity for some students to express an opinion or thought they may not otherwise voice. A more thorough evaluation of the logbooks is to come.

Challenges

The greatest challenges in creating and providing a course such as the multi-disciplinary freshman experience were the following:

1. Logistics of different meeting times and different credit weights for the two courses.
2. Slightly different departmental objectives with regard to the purpose of the freshman design course.
3. Creating design exercises at a very elementary level that incorporated both mechanical and industrial engineering components.
4. Amount of time required for the two faculty members to coordinate all facets of the course including syllabus, design exercises, grading, etc.
5. Size of the classes - two ME classes with approximately 35 students each, and the IE class with 33 students.
6. Ensuring the two student groups (IE and ME) understood each other's field and respect each other's contributions.

Rewards

1. We believe that by means of the design of this course, students have gained a much better understanding and appreciation of mechanical, industrial, and, more important, engineering in general.
2. Students report that they have enjoyed the course and are satisfied with their respective decisions to study either industrial engineering or mechanical engineering.
3. The course was fun to teach.

Recommendations

We offer several recommendations for faculty interested in re-conceptualizing the freshman design experience. They are:

1. Encourage students to work together both inside and outside of scheduled class hours.
2. Create multi-disciplinary projects so as not to require the production or use of precision machinery. The appended project handout is one such example.
3. Design projects so that the level of analysis is not much beyond high school physics. The practice of engineering based mathematical principles may be brought to bear in terms of prediction of performance rather than failure analysis.
4. Maintain a schedule for both collecting log books and also commenting on log book contents.
5. Provide a great deal of feedback to students in both written and verbal form on all components of design and discipline specific exercises.
6. Meet the class in a room outfitted with tables suitable for seating up to four students. Such a facility provides a convenient means for the design groups to interact among themselves and provides a similarly convenient place for the instructor to interact with the individual design teams.

Conclusions

We have described a teaching situation not routinely encountered in the standard lecture course. That is, close interaction with each student provided the main satisfaction in teaching this class. Alternatively, this close interaction creates in the student a sense of belonging to, and contact with, a specific engineering department. Thus we feel the rewards for both students and instructors far outweigh the challenges. Furthermore, this alternative approach to teaching this particular class is one positive step in the process of addressing our first year attrition rates.

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Appendix – Sample Project Handout

ME166/IE152 Fall 2000 – Design Project III

FROM EARTH TO THE MOON, ETC. – Jules Vern Catapult

Objectives

1. Develop creative thinking skills
2. Practice teaming skills
    a. Developing consensus
    b. Understanding team member competencies
    c. Defining the steps associated with completing the assignment
    d. Assigning task responsibilities to each team member
    e. Preparing team documents for submission
    f. Creating a "team" product
    g. Understanding the concept of concurrent engineering
    h. Documenting the team experience in logbooks
    i. Creating a team name and logo
    j. Meeting deadlines
3. Reading and understanding specifications: achieving team consensus on taking written specifications to product prototype.
4. Evaluating various construction materials and production processes for strength and low weight. Documenting the evaluation process.
5. Developing a prototype machine to meet specifications.
6. Testing your prototype machine in trial runs to optimize the design.
7. Preparing supporting documents for the machine design.
8. Demonstrating in a class setting that your catapult meets the required specifications.
9. Submitting a full design package and prototype machine.

Your Team's Challenge

Summary

The Jules Vern Catapult Manufacturing Company wishes to market reliable machinery that has the capability to hopscotch across the solar system using a series of **lightweight but powerful catapults**. Your engineering team's task is to design and create a light weight catapult prototype, powered solely by two official Aggie Racing rubber bands, that will **launch all other design teams' catapult as far as possible**.

As is common in engineering practice, the design process as well as the machinery itself must be well documented. Thus, a series of design drawings, bills of material, exploded product diagrams, manufacturing supplier information, assembly precedence charts, cost information and launch modeling equations, will support the catapult machine.

The performance of your catapult will be evaluated in a round robin trial with all other designs. Each team will launch all other catapults. Your team score will be the **sum of the distances you launch all other catapults times the sum of the distances your own catapult is launched. See the example scorecard below.**

Design Specifications

1. Your team must incorporate the supplied 3x3x½ (approximate) inch wood platform into your catapult. This platform will serve as the launching base, so it must be located on the catapult launching arm.

2. Your catapult must measure less than 40 cm in any direction
3. You may use any materials to construct your catapult.
4. All catapults must be powered by official Aggie Racing rubber bands, used for the preliminary prototype demonstration and for the final trial. Rubber bands may be obtained exclusively from the instructor.
5. You must incorporate a convenient means to replace the rubber bands with fresh ones.
6. Burning through a length of thread (with a cigarette lighter) must trigger your catapult. Therefore you must incorporate a convenient means so the launching arm may be cocked and tied with thread. The catapult is to be triggered without contacting either the launcher or the launchee with your hands.
7. You may not modify your catapult in between trials but minor repairs are allowed.
8. Your catapult must balance (hands off) on a standard 3x3x½ wood platform.

Responsibilities

As either a ME or IE team member, you fulfill shared as well as specific project responsibilities as indicated below.

Shared

1. Team name and logo.
2. ME design timeline and IE support package timeline.
3. Anything else you need to do to make your team score high in the trial.

ME

1. Design the catapult; produce a hand sketch of your device before you begin construction.
2. Construct the machine carefully using good craftsmanship; do this early in the three-week period scheduled for this project.
3. Test the catapult in a safe place. Stretched-tight rubber bands store a surprisingly large amount of energy. So you must be careful, especially of your eyes, when stretching the rubber bands and when you trigger your mechanism.

IE

1. Create the catapult design drawings in Pro E or AutoCad based on the final design concept from the MEs.
2. Determine a full bill of materials for manufacturing the catapult.
3. Draw an exploded product diagram.
4. Illustrate the assembly process of the catapult with an assembly precedence diagram.
5. Using Thomas's Register, identify a minimum of five suppliers for each component of the catapult design.
6. Brainstorm on equations and methods of modeling how far the catapult will launch.

Project evaluation

Each ME/IE group will have the opportunity to earn 100 points with 50 points generated from the ME responsibility areas and 50 points generated from the IE responsibility areas.

ME primary responsibility areas: 50 points

5 points if your catapult will balance in a standard plywood platform just prior to the Preliminary Prototype Demonstration.

10 points (maximum) based on the distance your catapult will launch a standard 180 gram weight divided by the catapult's own net weight (including two Aggie rubber bands) at the Preliminary Prototype Demonstration.

5 points provide IE team members with final design and assembly plans by deadline (Monday 12/4, 11:59 PM)

30 points (maximum) for Final Trial score

A sample scorecard for the Final Trial for four design groups would look like this

⇓ Launchers / Launchees ⇒	Grp 1	Grp 2	Grp 3	Grp 4	row sum
Grp 1	X	3	4	6	13
Grp2	2	X	8	4	14
Grp 3	6	8	X	1	13
Grp 4	7	6	1	X	17
column sum	15	17	13	11	X

Example score for Group 2: 17 x 14 = 198

IE primary responsibility areas: 50 points

Report containing:

- Catapult design drawings with discussion of the design process: 10 points
- Bill of materials for manufacturing the catapult: 10 points
- Exploded product diagram: 5 points
- Assembly precedence diagram: 10 points
- Tomas' Register: 5 points
- Equations and methods of modeling how far the catapult will launch: 10 points

Project Schedule

1. Project assignment Friday 11/17
2. Respective task plans, team name, and logo, due at class time on Monday 11/20
3. Preliminary Prototype Demonstration, Wednesday 11/29
4. Final design and assembly plans provided to IE team members by Monday 12/4
5. Final Prototype Trial, to take place in sand lot adjacent to JH, Wednesday 12/6
6. Report due Friday 12/8 **at class time**.