Simulating Corporate Project Engineering for Freshmen

Eric Wang, Richard Wirtz, and Miles Greiner
Department of Mechanical Engineering
University of Nevada, Reno
Reno, NV 89557

Abstract - A novel approach to project engineering at the freshmen level is presented. For the past two years a pilot offering of a two-course sequence has been implemented. The goal of the sequence is to present a realistic view of mechanical engineering, provide the students with a set of basic skills, and develop team skills through the use of a simulated industrial environment. Practicing engineers and experts meet with the students to exchange ideas and discuss career paths. Technical writing, oral presentations, graphics, Internet access, and spreadsheets are also covered in skills labs. In the projects portion of the course, students play the role of design engineers within a “class corporation.” Incentive-based grades, peer evaluation, and the ability to sub-contract work to other teams are key components. Students must communicate their designs to both their peers and invited industrial representatives in written, oral, and electronic formats.

Results from the first two years are promising and student feedback has been excellent. The web-based courses have been team taught and developed by both senior and junior faculty. The project topics and outcomes from the first two years are presented along with the lessons learned from each of the four offerings. Since the courses were developed for a small engineering school, where the typical freshman class size is 50, possible methods to replicate the course structure within other (larger) departments and institutions are also discussed.

Introduction

The lack of responsiveness of many engineering curricula to both industrial and student needs has been well documented and serves as the motivator for most curricular changes. In terms of industrial needs, one of the major criticisms of universities and colleges in the United States is that graduates are not properly prepared for the tasks that lie ahead in industry [1]. In terms of student needs, most students choose to major in engineering because it is perceived as a very application-oriented field. However, the lack of hands-on and/or perspective building experiences in lower-division courses often causes students to withdraw from engineering as a major before they are aware of what engineering is all about.

With this in mind, and faced with both declining enrollments and retention, an ambitious freshmen curricular modernization was undertaken within the department of Mechanical Engineering at the University of Nevada, Reno in the fall semester of 1996. It was decided that the freshmen experience should provide:

- students with an overview of engineering practice;
- a realistic exposure to the environment which engineers generally work in;
- exposure to engineering role models;
- basic engineering and communication tools; and,
- an environment which nurtures good study habits, including self-learning.

Many introductory engineering courses do not fulfill the above course requirements, and the Introduction to Mechanical Engineering course that had been offered at UNR is no exception. Course development is the obvious solution, however, the small-school environment makes this challenging due to a lack of material and human resources. This is a particularly painful process if there is a need for computer and other physical resources. On the other hand, being in the small-school environment offers some advantages, the most notable one being that the Mechanical Engineering freshmen class is typically no more than 50 students. This very manageable number enables us to contemplate developing a course where there is significant professor-to-student interaction.

Using funds provided by an internal Instructional Enhancement Grant, a new Introduction to Mechanical Engineering two-semester (6 credit) sequence was initiated during the 1996-97 academic year. The sequence focuses on product development in a corporate environment. The first course focuses on prototype development where student teams carry a design concept, given to them as a product specification, from concept to working prototype. The second course focuses on client-based product realization, where student teams continue the product development process from working prototype to the point where it is conceivably ready for public release.

This paper describes what has evolved during the first two offerings of this sequence. We believe the course contains several novel concepts that can be implemented in other Introduction to Engineering courses.

Course Sequence Content

The course sequence, MECH150 and MECH151 (Introduction to Mechanical Engineering I and II), is designed around three parallel instructional “tracks”: Discussion Sessions, a Skills Laboratory, and a Product Development Project.
Discussion Sessions. (One hour/week). The discussion track is meant to provide the “big picture” about core characteristics of what engineers do, and expose freshmen to positive role models. Rather than lectures by faculty, the format centers about industrial guest speakers. No assignments are associated with the discussion track to encourage questions and understanding rather than note taking. However, attendance is mandatory and participation in discussions is graded (see below). The invited, guest speakers are simply asked to describe “what they do for a living.” The format includes a short, informal (usually 15 minute duration) presentation followed by an interactive discussion. The intent is to allow students to form their own concepts as to what constitutes design and engineering.

Skills Lab. (Two hours/week). The Skills Lab provides students with a working knowledge of a handful of useful tools. The working format for this lab consists of one of the two instructors giving a short instructional presentation at the beginning of the lab, followed by the students working on their assignment in the lab for the duration of the lab session with the instructor and course teaching assistant present. Assignments are structured so that successful completion requires the student to use some form of self-help, usually found in electronic or hardcopy support material. Assignments are such that most students can complete them within the two-hour time allotted. With the exception of some hand graphics assignments, all student work assignments are posted on the course web page, and students submit their “homework” electronically as e-mail attachments. Students submit assignments individually but are allowed to collaborate at their discretion. It is hoped that this informal group interaction encourages self-learning as opposed to just doing.

In MECH150, the Skills Lab included basic computer usage (use of the Internet and e-mail, Microsoft Word, PowerPoint, and Excel) and hand graphics (sketching detail, assembly, and pictorial drawings). Supplemental presentations and reading assignments are given on making effective presentations, and technical writing. These included the steps required in structuring a report or presentation and reporting formats. Two outside management professionals were also brought in to discuss group dynamics/teaming and planning/critical path analysis techniques. In MECH151, the Skills Lab emphasizes CAD (Pro/Engineer) and technical report writing and presentations.

Students are required to use skills learned in the Skills Lab in the Product Development Lab activities described below.

Product Development Lab. (Three hours/week). The purpose of the Product Development Lab is to simulate the industrial work environment and provide exposure to one large aspect of engineering activity: the product development cycle. In addition, it provides a medium which encourages group activities; promotes the development of interpersonal, written and presentation skills; and cultivates a sense of intuition about design and the behavior of thermomechanical systems through hands-on learning.

Students are assigned to design teams within the “class corporation.” The teams, consisting of five students each, designate their own Project Manager who acts as the liaison between the team and the two faculty instructors (who play the roles of the CEO and COO). Project Managers are rewarded for the extra work with additional merit pay (i.e., higher salary). Student duties, team structure, grading scheme (described below), and expected conduct are outlined in a “student contract” that each student signs at the beginning of the semester.

During the first semester the projects focus on the development of a working prototype from a set of design specifications. Students are expected to design, construct, test, analyze test data, and refine their designs. During the second semester the projects focus on the development of a product for an actual client. Currently, the clients are local school teachers and the William Raggio Science, Math, and Technology Center (located on the UNR campus). Interaction with a client provides the student teams with experience in translating customer needs into engineering specifications.

For both courses, the project begins with a written proposal in which the students have to respond to a design specification, propose a solution, request a specific budget, and state the deliverables. Progress is monitored with an oral progress report and a written and orally presented design review. Both semesters conclude with a final report and presentation to both University and Industrial representatives. The presence of industrial representatives is considered important so that students can receive feedback from practicing engineers.

Student Resources

The volume of material conveyed to the students in the Discussion Sessions, Skills Lab, and Product Development Lab is large. The Internet serves as the underlying medium for conveying all course materials including handouts, syllabi, lecture notes, assignments, announcements, grades, and presentations. As mentioned earlier, students submit all Skills Lab assignments (except the hand graphics) electronically as e-mail attachments. All written reports have to be word processed and PowerPoint is required for all presentations. The e-mail addresses for all guest speakers are provided and the presentations of several of the speakers and all instructor presentations are made available on the course web site (www.scs.unr.edu/meceng/me150).

Hard copy resources include (see reference list for complete citations) for MECH150:

- Dally and Regan’s “Introduction to Engineering” [2],
Goldberg's "Life Skills and Leadership for Engineers"[3], and
- Etter's "Microsoft Excel for Engineers" [4]
For MECH151, we use an in-house developed workbook to teach Pro/Engineer and the three texts above as references.
Dally and Regan's book specifically addresses the product development cycle, and it includes the design specification and technical information at an appropriate level for freshmen engineering students for the design project adopted by our course for the 1997-98 offering. It also includes chapters on some of the skills that we want to pass on to our students through the Skills Lab component of our course.

We feel that there is a need to supplement the skills component of the Daily and Regan text, so we specified two additional texts. Goldberg's text is very readable. The main components that we utilize from it are chapters on technical writing, presenting, innovation and brainstorming, and organizational behavior. Etter's text on Excel is used to support the component of the Skills Lab that covers spreadsheets.

In MECH151 we teach Pro/Engineer in the Skills Lab. Because we do not spend a great deal of time on Pro/E, we have opted to use a workbook developed in-house. This serves to keep student expenses at a minimum. Additionally, a new version of Pro/Engineer is released every six months which makes it difficult to locate a current-version text.

It should be noted that all of the texts specified for our course sequence are available in soft cover format, and this tends to minimize textbook costs passed on to students.

**Grading Scheme**
The grading method used is both unique and complex. As shown in Table 1, the final grade is based on four components: Discussion (10%), Skills Lab (30%), Product Development Lab (50%), and Merit (10%). A rigid scale (i.e., B=83%-87%, etc.) is used so that students know their standing at all times during the semester. Since grade points earned in the Product Development Lab could be traded as currency (see below), a 10,000 point scale was used to emphasize a relationship between grade points and dollars.

<table>
<thead>
<tr>
<th>Course component</th>
<th>Percentage (points)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discussion</td>
<td>10% (1000 pts)</td>
</tr>
<tr>
<td>Skill Labs</td>
<td>30% (3000 pts)</td>
</tr>
<tr>
<td>Product Development Lab</td>
<td>50% (5000 pts)</td>
</tr>
<tr>
<td>Merit</td>
<td>10% (1000 pts)</td>
</tr>
</tbody>
</table>

The 10% of the grade based on discussion attendance and participation utilizes a novel approach to encourage active participation in discussions. Each student is assigned a "C" grade for each discussion attended. Positive, active participation (e.g., questions and comments) earn a higher grade. Conversely, negative participation (e.g., sleeping or abrasive attitude) earns a lower grade. By rewarding positive, active participation, students are enticed into participating in and understanding the discussion.

For the Skills Lab portion of the grade (30%), a Total Quality Management (TQM) approach is used [5]. Students are considered the end product of the Skills Lab and a zero-defect product is the goal. Only assignments of "B" quality and greater are accepted. Assignments of less than "B" quality are assigned a "Retry" grade. Students have 3 days to rework the assignment and re-submit it (for a 10% penalty). This process or re-submitting work continues until the student turns in an assignment that is at least 80% correct. Thus, by the end of the semester, every student has submitted at least "B" quality assignments.

For the Product Development Lab, the grading policy is based on a corporate pay structure. There are six graded assignments each semester: a proposal, 3 progress reports (2 oral, 1 written), a final presentation, and a final report which serve as deliverables to management and generate income for the team members. Every team member receives the same score on these items (true team grading) which are given in terms of "points" rather than grades. The points earned on assignments serve as currency that can be used to sub-contract with other teams. For example, if one team developed a talent for CAD, they may be subcontracted by another team to help produce drawings. The "price" for services rendered is negotiated by the teams. Since points are based on performance, they represented a limited resource which has to be carefully managed just like money. Students are often faced with the decision of whether to spend the time developing new in-house talent or "buy" it from another team and concentrate on other tasks better suited to their skills. This also stresses the concept of exploiting in-house talents to advance the overall success of the group.

Merit constitutes the final portion of the grade (10%) and mimics a corporate reward structure by addressing the issue of rewarding individual effort within a team. An additional 10% of the score earned in the Product Development Lab is distributed by the management (course instructors) to Project Managers as "merit pay." This merit pay is then distributed by the team-elected Project Managers to individual team members based on internal performance reviews. The final award level is approved by the course instructors. Based on this system, it is possible for students to attain more than 10,000 points. While A+ grades are not given, students who earn more than 10,000 points are individually congratulated.

Since merit pay is essentially based on individual effort, 50% of the course grade is based on individual effort and 50% on team effort. Thus far, this balance between individual and team grading has worked very well.
Sample Project

In the most recent offering of MECH150 (Fall '97) the class corporation was called Reno Desalination and the project activity was to design and build a small portable solar desalination still which had the following characteristics:

- Produces at least 1 oz/hr clean water
- Costs less than $125,
- When disassembled would fit into a photocopy-paper box, and can be assembled in 45 minutes

This project has been utilized at the University of Maryland and it is documented in one of the course texts [2].

The class was divided into 10 development teams (5 students/team), each with an elected project manager. Students were free to use any desalination method, so long as it was purely solar powered. Students were responsible for financing their own projects (up to the limit of $25/student), which relieved the strain on departmental resources and encouraged budgetary restraint.

Not surprisingly, every team developed a unique solar still. Construction materials typically included glass, foam, wood, acrylic plastic, and aluminum foil. Prototype tests were conducted 4 weeks prior to the end of the semester to allow students time to re-design their stills after testing. An example of a final (re-designed) still is shown in Figure 1.

In the current offering of MECH151 (Spring 98), students are using the concepts developed in MECH150 and developing classroom teaching kits on solar desalination for local elementary schools. The kits include still construction plans, data sheets, discussion topics, and teacher lesson plans. Product design criteria are largely unchanged with the exception that the still must cost less than $25 to build and be reusable or be less than $5 if disposable. Local teachers serve as the clients and students are required to arrange beta testing within the classroom setting before the semester is over.

Assessment

While student attitude surveys [6] are planned for implementation in the next offering, current assessment data consists of enrollment data, solicited student comments, and course evaluations.

Interpreting enrollment data is always difficult. As an initial assessment measure we defined a “success rate” as the ratio of students receiving a “C” or better grade to the total number of students enrolled (A+B+C/Total). We also calculated the “drop-out rate” as the number of students who dropped the course sometime during the semester divided by the total number of students enrolled. From an engineering standpoint, both the “success” and the “drop-out” rates are measures of the quality of the process (course sequence) in that they are measures of the ability of the process to result in a quality product (students). A high success rate indicates that the products produced are all of high quality. Similarly, a low drop-out rate indicates a robust process because the process is insensitive to the input.

A recent history of success rate is shown Figure 2 for the years 1992 to 1997. Likewise, Figure 3 illustrates the drop-out rate as a function of semester the course (MECH150) was offered. Qualitatively, both figures indicate that course development has had a marked effect on the quality of the students produced and the quantity of students retained. Of course, factors such as grade inflation and
teacher preferences are biases that limit the conclusions that can be drawn from this data (these are possible reasons for the high drop-out rate in F94, S95, and F95).

Discounting the possible bias effects, there has undoubtedly been an increase in success rate and dramatic decrease in drop-out rate (zero drop-out in fall 97) since the introduction of the sequence in the fall 96 semester. This is positive trend is also reflected in student attitudes.

In addition to enrollment data, informal student feedback was solicited at the conclusion of each course during the 1996-97 and 1997-98 academic years. This solicitation was in the form of a pizza party hosted by the faculty (another advantage of a small school). The general themes of this informal feedback can be summarized as follows:

Courses are too demanding: Students almost unanimously thought the courses were too time consuming. This is especially important when considering the time management skills of the typical freshman.

Student attitudes were positive: While demanding, the courses were viewed as extremely useful by nearly all students. The realistic work environment and rewards for individual effort were both positives.

Students' attitudes changed: The sequence “solidified” the decision of whether or not to stay in engineering. Almost all the students were surprised that engineers only spend a fraction of their time doing “number crunching” and so much time communicating.

Merit pay system: Students like the incentive-based reward system implemented. However, the peer pressure felt by the project managers served to reduce differentials in merit pay.

Discussions are good: Students like the Discussion sections. Recent graduates or relatively young engineers have been received best by the students. Likewise, students were more enthusiastic about discussion of a case study than description of a process (e.g., design).

Skills Labs were very useful: Students enjoyed this traditional course format and appreciated learning “high tech” software early in their studies. Most students were indifferent towards the TQM approach to assignments.

Drafting and graphics skills suffered too much: The original Intro to Mechanical Engineering course was a traditional engineering graphics course. In an attempt to modernize the curriculum, too much graphics material was deleted from the course. As a result, the students' geometric visualization skills suffered.

Projects must have a useful purpose: Motivation and creativity was enhanced in MECH151 because a real client was identified for the project.

Projects should be of the build-and-test type: Freshmen had trouble with the analysis portion of the projects. Intuitive design supported by rudimentary analysis is preferred.

Projects were the most useful part of the course: Students felt that the team skills learned while working on the projects was the most useful part of the course. The actual project assignment appears to be incidental to the team skills learned.

Need feedback on electronic homework: Skills Lab assignments were submitted electronically. Even though grades and grading criteria were posted on the web, students asked for traditional hard-copy feedback.

More Structure to the course: Students had continual problems with the lack of structure typical of project design courses.

Lessons Learned and Conclusions

Not surprisingly, the first two offerings of the sequence has been as much a learning experience for us as it has been for the students. General conclusions drawn by us include:

- Physically large projects are hard to complete. Students are not able to work at home and the financial resources required are too great.
- From a course management standpoint, having all student teams work on the same project topic greatly reduces individual contact hours because general concerns/advice can be given to the entire class.
- Skills Lab material must be connected to activities in the Product Development Lab. For example, Mathcad was introduced in the first offering of MECH150, but not used for the projects. Students completed the homework but did not learn the software. Post course interviews revealed that students have not used the software in any subsequent courses.
- As enrollment grows, we are learning that exceeding a limit of about 25 students per faculty serves to diminish the effectiveness of the course sequence. This may have significant implications for larger schools interested in conducting a similar course.
- An increasingly larger proportion of new students lack drafting experience and geometric visualization skills. Thus, devoting time to the development of hand graphics skills is very important. This also feeds into CAD, where students with strong graphic skills seem to readily adapt to CAD software.
• The majority of the entering students have received no technical writing instruction and many have not had any English courses beyond high school. Thus, a very regimented format to written reports and presentations is necessary at this level. Our next offering of MECH150 will include a more “programmed” approach to technical writing which will break down a technical report into small weekly assignments (e.g. abstract, introduction, etc.).

• Presentation skills of the students improved markedly during the course of the sequence. However, individual team de-briefings are required to provide feedback to students. This aspect of the course would be very difficult to replicate in large schools since each de-briefing takes about 30 minutes.

• The team environment has created a more cohesive student body as a whole. Participation in student organizations, such as ASME, has increased dramatically.

• Students need to have reference materials to consult and, in this respect, the textbooks used were very helpful. The only exception was that the Excel workbook [4] was for a previous software version. We are also considering developing an in-house graphics manual since we do not feel the cost of a textbook on graphics is warranted.

An underlying theme to this effort has been to develop a sequence that can be sustained on a very small financial budget. The total cost of this effort was less than the cost of a single desktop computer. We achieved this by having students finance their own projects, using physically small projects to reduce material costs, and using two 50% FTE (10 hours/week) teaching assistants rather than one full-FTE TA (increases number of support personnel).

Based on the two initial offerings, the immediate future plans include better assessment strategies, including tracking of students as they matriculate. The TQM grading policy will most likely be dropped because it has resulted in more work for the teaching assistants and has had little effect on the overall quality of the homework and student attitude.

References


