The Freshman Engineering Course Balancing Act

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Abstract
In an effort to increase student retention, many colleges have instituted a first term freshman engineering course to help students understand what engineering entails, and how to succeed in obtaining an engineering degree. The Union College freshman engineering course has been evolving over the past six years and last year we implemented an innovative format that provided a remarkable result. At the center of this model are: a unifying theme, use a single instructor to teach a section (rather than each instructor teaching a single component of the course to all sections), and faculty working as a team to improve and teach the course. This paper describes the changes we have made implementing this model and to address the issues of course content, exams, student work, and student/faculty assessment used to evaluate our success.

I. Introduction

Union College was founded in 1795 as a small liberal arts college, and was the first fine arts college in the US to offer engineering as part of its curriculum. Union College is still a small college with an undergraduate student population of about 2000. Union admits about 120 freshman engineering students each fall. Since Union College is primarily a liberal arts college, it provides students the opportunity to switch their major among the various engineering and the liberal arts programs offered. Within engineering, Union offers degrees in Electrical Engineering, Mechanical Engineering, Computer Engineering, and Civil Engineering. Many students find all these choices daunting because they enter college not understanding what engineering is and thus enter with their major listed as "engineering undecided." In order to complete an undergraduate degree in four years, students need to decide on a major during or before their sophomore year.

For the past six years Union has been requiring freshman engineering students to take a first-term freshman engineering course to help students make good decisions about studying engineering, and to increase student retention and success in engineering. Based on student and faculty feedback the course underwent a major revision and was first presented in its current form in the fall of 2000. To continue to improve the freshman engineering course and meet the

changing needs of students we are continually evaluating and revising the course. In planning for the fall 2001 freshman engineering course it became obvious that we needed to address two specific issues: course content and the problem of different faculty teaching the course each year. This paper includes the details and evaluation of changes implemented in the fall 2001 freshman engineering course.

We have continued to reevaluate the course using student and faculty feedback. In the feedback last fall some students and some faculty expressed concern about whether the course contained sufficient content while other students and faculty expressed concern that we were trying to include too much information. The task of "balancing" course content to provide a challenging course with a desire to nurture and encourage students is made difficult because the students entering Union College come with very different skill levels. We discussed the issue and decided to increase the depth of the material presented and the level of mastery required, while at the same time providing support for students having trouble. The key support strategies we have implemented are:

- Using a more interactive teaching style to monitor student progress and modify the pace based on frequent student feedback.
- Introducing a problem solving strategy in the presentation of all course material.
- Offering a weekly review session which students were encouraged to attend.
- Providing students with a textbook that we wrote to accompany the course and to be used as a reference.
- Instructing students in the skills and the advantages of forming student study groups.

Much of the success we were able to achieve in the fall of 2000 can be attributed to the quality of the faculty team we assembled to teach the course[1]. The ideal situation for this year would have been to have the same professors who taught the course the previous fall teach the course again this year. However, due to many factors, only one of the instructors who taught the freshman engineering course last year was able to teach it again this year (me). We were able to minimize the impact of having a largely new faculty by implementing the following:

- To provide continuity I was assigned to teach one section of the course and act as coordinator.
- We selected only instructors who expressed a desire to be part of the freshman engineering team, i.e., no one was "coerced" into teaching freshman engineering.
- We held a training session for instructors over the summer.
- We held frequent meetings during the term to review course material and discuss problems.

II. Course Description

The faculty who taught the course in the fall of 2000 presented a paper to the ASEE describing the details of the course as it was presented in fall of 2000[2]. It was a ten-week course with two hours of lecture, three hours of design studio, and a common hour for outside speakers and exams each week. The lecture and design studio portions of the course were essentially independent, with separate learning objectives.

In the fall of 2000 the first two weeks of the lecture portion were devoted to looking at some of the engineering careers involving each of the engineering disciplines taught at Union College (Electrical Engineering, Mechanical Engineering, Civil Engineering, and Computer Engineering). In the fall 2001 this material was moved to the last two weeks of the term. A recurring theme in all of the material presented in the freshman engineering course was that of problem solving. Students prefer to study problem-solving concepts in the context of a practical application. For this reason, in part of the course (the design studio) students learned about engineering principles by applying them to solving the problem of implementing a series of designs, culminating in a large team-oriented design project. Each year we change the final design task to prevent students from usurping a solution from the previous year. In the fall of 2000, students designed a machine to dump/shoot ping-pong balls through a small hoop. To add interest to the project student teams competed by pitting their machine against each other to see who could place the most balls through the hoop in the shortest time. The problem-solving theme was also used in the lectures. The concepts presented in the lectures were connected using a "Smart Car" theme, which also involved problem solving. For example: the problem of increasing gas mileage, decreasing pollution, and improving drivability in an automobile is an important contemporary issue. To understand the problem and the possible solutions, energy, fuels, combustion, air/fuel ratio, and the Otto cycle are discussed in the “Cars and Energy” section of the course. In the “Cars and Computers” section of the course, students study a computer-controlled feedback system that is used to control the air/fuel mixture in an automobile engine to provide maximum efficiency and/or performance under various driving conditions. This use of themes provides a framework for presenting an interesting and cohesive freshman course.

III. Course Content

In the assessment of the fall 2000 course some students and some faculty expressed concern about whether the course contains sufficient content while other students and faculty expressed concern that we were trying to include too much information. The task of balancing course content to provide a challenging course with a desire to nurture and encourage students is made difficult because the students entering college come with very different skill levels. The ten week trimester system used at Union and the rigor required in studying engineering makes it particularly important that students develop good study habits their first year, if they don't already possess them. The course faculty discussed this issue and decided to increase the depth of the material presented and the level of mastery required, while at the same time providing additional support for students having trouble (thus bringing the less prepared students up to the level of the better prepared students). However, it is important to keep in mind the difference between presenting facts and presenting a process for studying engineering. Increasing the quantity and difficulty of facts presented will not achieve better student performance. The material must be presented in a way that provides examples of how to study engineering. The key support strategies we implemented are detailed below.

A. Using an interactive teaching style.

Most freshmen do not know that they are responsible for their education and have learned to be passive learners in high school[3]. While Union College provides small classes and a nurturing

atmosphere students must learn how to do well in classes taught by instructors using different teaching styles. However, the "chalk and talk", and its modern equivalent "click and talk", style of teaching leads to passive learning. To encourage student participation in the learning process we had individual students and groups of students solve problems on the board. We also developed in-class group exercises to help students master important concepts (see Fig. 1, Boolean Algebra In Class Group Exercise in the Appendix).

B. Developing a problem solving strategy

When students are having trouble with course work or assignments we frequently tell them that they must work harder, but we don't tell them how to work harder. For example, word problems in assignments and on exams frequently cause students trouble. To help students understand how to develop strategies for dealing with troublesome concepts we developed a process for solving word problems in class with the students. The following rather standard format was used:

1. Understand the problem completely by reading it several times if necessary and asking questions. Draw a picture if possible.
2. List the given facts labeling the picture with the given facts.
3. List the unknown(s) to be found.
4. List the equations that relate the given facts and the unknown(s) to be found.
5. Use the equations from step 4 to solve for the required unknown(s).
6. Check the answer for reasonableness (and correct units).

C. Review sessions

As course coordinator I provided a review session each week for students who wished to attend. While attendance was not mandatory, students from all sections were encouraged to attend. The review sessions were not presented in a lecture format but rather in more of a group learning session. However, because most of the students came to the review session just before the midterm exam, it was not as effective as it could have been. With this in mind, we arranged for five review sessions just before the final exam each one attended by one of the five faculty members teaching a section of the freshman engineering course. We encouraged students to attend as many or all of the sessions. The final sessions were also conducted using group study techniques. In the design studio students learned teamwork skills as related to their design project and in the review sessions students learned to apply teamwork skills to the course material.

D. Course Text

Since no commercial text was available for this course format, we developed a set of course notes with solved examples that served as a textbook manuscript. Even though we told students that they must read the course notes we, found in the fall 2000 that students didn't seem to use the course notes at all. The first chapter in the notes covered units of measure, unit conversions, accuracy and significant figures. To help students understand the importance of reading assignments in the fall of 2001 we told them the first week of classes that we would not be covering the material from chapter 1 in class but that there would be homework and a quiz on the material the second week of classes. We also told them that we would answer any questions they had about this material. While the students in general did poorly on the quiz, we noticed that for

the rest of the term students read the course material and asked questions about the reading in class.

E. Group learning.
The correlation between student group and cooperative learning skills and success both in academia and the work place is well documented[3,4]. What is surprising is that most of our entering freshman engineering students seem to have very poor group learning skills. To help students develop effective cooperative learning strategies we have begun integrating formal instruction and exercises into the lecture, design studio, and review sessions.

IV. Course Faculty
For a small college like Union it is hard to ensure that the same faculty can teach the course each time or that some faculty are as good at teaching the course as others. Special skills such as nurturing and interactive teaching are critical to engaging freshmen as opposed to "hardened" upper class students. This year the faculty consisted of the following instructors: one from electrical engineering, two from mechanical engineering, one from civil engineering, and one with a background in the history of technology. I was the only one who had taught the freshman engineering course before.

To provide continuity I was assigned to teach one section of the course and act as coordinator. Instructor training began over the summer when we presented the course material to each other and introduced new instructors to interactive teaching techniques.

Once the term began weekly meetings were held to discuss problems and to prepare for the next week's lecture and design studio. We used these meetings to discuss the teaching techniques we were using and to share what was working and what was not working so that we could work together to develop good teaching strategies. These meetings were used to develop homework assignments and exams as well as rubrics for grading them.

V. Assessment
For the course to be considered successful the students must feel that the course was useful in achieving the stated goals and must show a mastery of the material presented. The 2001 course was evaluated using student feedback and the final exam and the results were compared to the 2000 results.

A. Final Exam
We gave two exams: a midterm and a final. In fall 2000 both of the exams were multiple-choice exams. In addition, in 2000 we spent the first two weeks talking about engineering professions and didn't cover enough "testable" material by the midterm exam to make it rigorous enough. Thus, students reported that the midterm was too easy, and based on their experience with the difficulty of the midterm exam they didn't prepare sufficiently for the final exam. This year we moved the discussion of the engineering professions to end of the course and had mainly word problems on the exams, requiring students to show all work to get full credit (thus evaluating

their solution process and their ability to apply concepts as well as their final answer). The final exam was comprehensive and thus is appropriate for evaluating student progress.

A spreadsheet was used to analyze the final exam data for each student by section. Each student's exam results were entered with the result of each question in a separate cell. Questions were classified as ME, ECE, or CE, and the total number of points correct for each category for each student was calculated. The average number of correct points for each category for each section was calculated as well as the average for all students in all sections for each category. Figure 1 shows a plot of the percentage difference between the section averages and the average for all students by category. Thus, each vertical column of five points represents the relative ability of the students in each section to answer questions relating to that topic. Sections taught by a professor from the relevant department are labeled "Expert". The results from the 2000 exam were added to the graph of the 2001 final exams. From the graph it can be seen that there is no correlation between the expertise of the instructor and the ability to teach the concepts for either year. It should be noted that the percent difference from the overall average for the lowest section to the highest section is large for the 2000 exam (for example –14.29% for the lowest and +14.18% for the highest – for CE) while the 2001 exam results are closer to the average (-4.69% for the lowest and +2.77% for the highest – for CE). In addition the average exam grade for all sections of the 2000 exam was 66.78% while the average for the 2001 final was 85.52%.

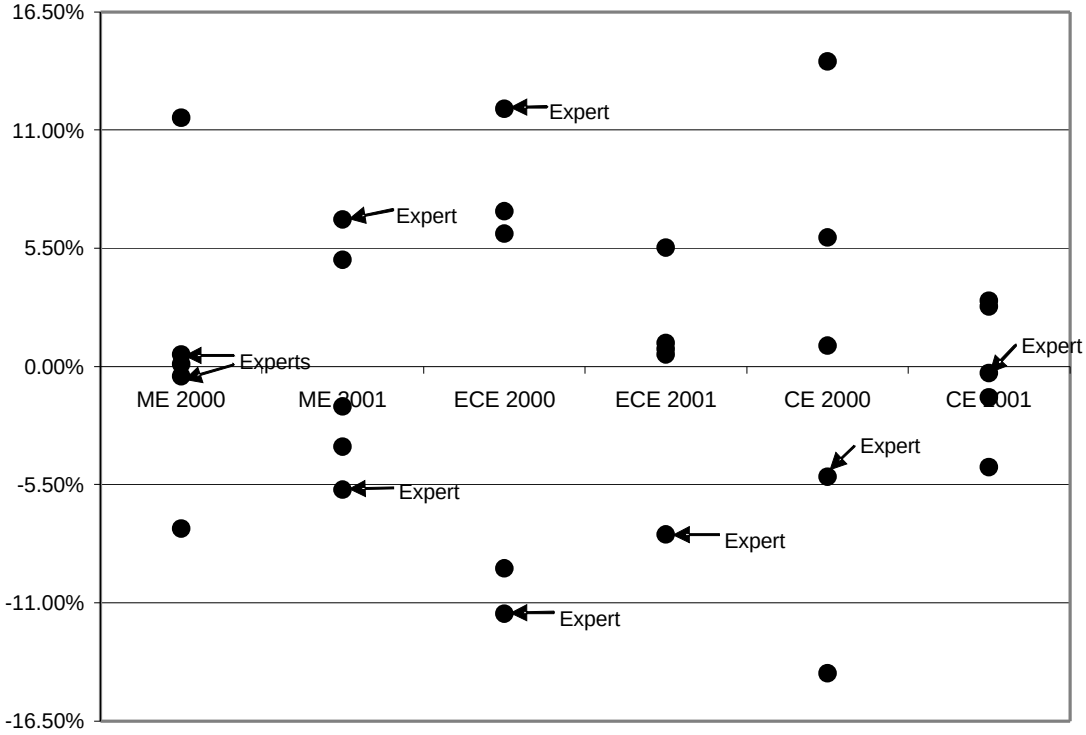

Figure 1. Percent difference between the average number of correct points by section and topic and the average for all students by topic using the final exams fall 2000 and fall 2001

B. Engineering survey

In addition to the standard Union College student evaluation form freshman engineering students were asked to answer a survey with questions relating specifically to freshman engineering. For example, we wanted to know how well students felt we met course objectives. Course objectives are included in the syllabus that is given to students in printed form the first day of class and is also available on the freshman engineering WEB site. The survey consists of questions relating to the two parts of the course (design studio and lecture) and asks students to evaluate how well they feel the stated objectives were met. The students' responses have been summarized in Tables 1 and 2 below for both 2000 and 2001. It is interesting to note that an overwhelming number of students felt that all of the goals for the course were either met well or very well, and in particular the goal of teamwork skills, more than 90%. While the results for 2000 were very good the responses for 2001 were better except for the common hour presentations.

Course Survey for Freshman Engineering Summary Results	**Fall 2000**				**Fall 2001**			
Survey Question	**Very Well**	**Well**	**Not Well**	**Not at all**	**Very Well**	**Well**	**Not Well**	**Not at all**
One of the objectives of this course was to inform you about the engineering programs available at Union. How well do you think this was done in the lecture portion of the course?	16%	58%	20%	1%	13%	72%	14.%	1%
How well did the "Common Hour" speakers help you understand the engineering disciplines?	22%	58%	18%	2%	3%	66%	26%	5%
The lecture portion of the course was based on a "Smart Cars" theme. This was chosen because modern automobiles are complex systems that involve the contributions of many different engineering disciplines. How well do you think these lectures provided you with the basic principles associated with:								
a) energy and energy transformation processes	10%	63%	27%	0%	14%	74%	10%	2%
b) logic, binary numbers, control, feedback, algorithms	17%	54%	29%	0%	19%	69%	12%	0%
c) transportation infrastructure and associated engineering principles	23%	55%	21%	1%	20%	66%	13%	1%
We also introduced several topics listed below. How important do you think they to your college education?								
a) Spreadsheet, email, internet	NA	NA	NA	NA	64%	30%	5%	0%
b) Professional ethics	NA	NA	NA	NA	44%	48%	7%	1%
c) Teamwork skills	NA	NA	NA	NA	72%	26%	1%	1%

Table 1. Summary of the 2000 and 2001 student surveys. Questions relating to the lecture portion of the course

Topic	As a result of this Course I can now do this: Fall 2000				As a result of this Course I can now do this: Fall 2001			
1) Design concepts	**Very Well**	**Well**	**Poorly**	**Not at All**	**Very Well**	**Well**	**Poorly**	**Not at All**
a) I am able to carry out the design of a simple system.	55%	41%	3%	1%	46.2%	53.8%	0%	0%
b) I am able to define the five basic steps in the design process.	41%	53%	6%	0%	23%	72%	5%	0%
c) I understand basic manufacturing and project scheduling.	40%	53%	6%	2%	37%	64%	1%	0%
d) I have carried out several design projects during the course.	NA	NA	NA	NA	45.2%	54.8%	0%	0%
e) I have an appreciation for the role of ethics in engineering.	31%	53%	3%	42%	52%	5%	1%	
2) Teamwork concepts	**Very Well**	**Well**	**Poorly**	**Not at All**	**Very Well**	**Well**	**Poorly**	**Not at All**
a) I can identify the skills required for good teamwork.	61%	33%	5%	2%	67%	32%	0%	0%
b) I can identify the characteristics of good teams.	64%	32%	2%	2%	66%	33%	1%	0%
c) I have completed exercises requiring a team effort.	60%	32%	8%	0%	65%	34%	1%	0%
3) Technical communications skills	**Very Well**	**Well**	**Poorly**	**Not at All**	**Very Well**	**Well**	**Poorly**	**Not at All**
a) I can complete a sketch and a drawing of a simple system.	47%	48%	4%	1%	46%	53%	1%	0%
b) I have prepared written design reports during the course.	54%	41%	5%	0%	45%	54%	1%	0%
c) I have organized and delivered oral presentations of design work to a group of peers during the course.	45%	50%	4%	1%	43%	46%	3%	8%

Table 2. Summary of the 2000 and 2001 student survey. Questions relating to the design studio portion of the course

VI. Conclusions

In a field like engineering where the body of knowledge is growing quickly it is easy to confuse the transmission of facts with teaching[4] and the memorization of facts with learning. Thus, the primary goal of a freshman engineering course should be to use the course content to provide an environment in which students can learn the process of how to learn rather than just what to learn.

Analysis of the final exams indicates that the level of mastery of the concepts as presented in the fall of 2001 was much higher than in the fall of 2000 while student satisfaction not only remained high but improved. I feel that the improvement in our freshman engineering program this past fall is due to two things: first is our focus on using the course material to help students to develop good learning strategies, second is the spirit of cooperation among the faculty both in preparing for and in implementing the course. Cooperation was not limited to the formal meetings and all of us felt comfortable asking for and providing assistance at any time. Several times I asked colleagues for help in preparing for class (both lecture and design studio) hours before class started and have done the same for them. I have attended classes taught by colleagues in order to do a better job of presenting the same lecture to my own class and have had them attend my class for the same reason. All of us have suggested the name of a faculty team member from the appropriate department to a student when we were unable to give a complete response to a student's question. I feel that this cooperative teaching model was responsible in part for the students' perception that the goal of achieving teamwork skills had been overwhelmingly met. That is, students were able to observe faculty teamwork in presenting the freshman engineering course.

As with all courses, the freshman engineering course as taught at Union College must remain dynamic and continue to be evaluated and improved. With this in mind I will be gathering data to evaluate the fall 2000 students who are now completing their sophomore year to determine how many are still in engineering, how well they are doing, and ask them it what ways the freshman engineering course helped prepare them for studying engineering.

We have developed a course that deals well with the problem of the uncertainty of faculty availability to teach the course and provides a challenging and nurturing environment in which students can develop the skills necessary for success in studying engineering. Since this is the goal of most freshman engineering courses course I believe that the course I have described can serve as a model for success at other schools with engineering programs.

The Union College Freshman Engineering Team for the Fall 2001 Term: Robert Balmer (Dean of Engineering - did not teach a section but acted as overseer), James Hedrick (coordinator), William Keat, Andrew Wolfe, Philip Kosky, and George Wise.

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Biography

JAMES HEDRICK

James Hedrick received a B.S. and M.S. in Electrical Engineering from Union College. He has taught both electrical engineering and computer science for the past six years in the EE/CS department at Union College. He was one of the instructors who collaborated in the development and teaching of the freshman engineering in fall 2000. He taught freshman engineering in 2001and was course coordinator.

Appendix

Fig. 1
Boolean Algebra In Class Group Exercise

Esc016
In Class Exercise

Name 1:_____

Name 2:_____

- Seat Belt Warning Light

-**D** is true if any door of the car is open.
-**Ps** is true if there is a passenger in the passenger seat.
-**K** is true if the key is in the ignition.
-**M** is true if the motor is running
-**Db** is true if the driver seatbelt is fastened
-**Pb** is true if the passenger seatbelt is fastened

1. Finish the following statement:
"The seatbelt warning light should be on in my car if":
2. Write a Boolean expression that will implement the statement in part 1