An Integrated Freshman Engineering Curriculum, Why You Need It and How To Design It

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Abstract:

The Foundation Coalition (FC) is a seven school coalition working to define the undergraduate engineering curriculum for the next century. One goal of the project is to produce a technology rich, active learning environment for undergraduate engineers. There are three facets to the FC curriculum development philosophy at A&M:

1. *Curriculum Integration,*
2. *Technology Utilization,*
3. *Active/Cooperative Learning and Teaming.*

This paper discusses these facets and highlights the Texas A&MFreshman Curriculum Integration Team's (TAFCIT) achievements over the last year.

Curriculum integration means typical first year courses (Engineering Problem Solving, Calculus, Graphics, Physics and English) are tightly coordinated to form a mutually supportive environment. Although students receive individual credit in each course, the courses are truly co-requisite. Each course strives to bring relevance to the others, often presenting different aspects of a common problem. Material presentation timing provides students with a ''need to know before knowledge'' sequence. Information and skills introduced in one course are promptly and regularly espoused in at least one other.

This paper will discuss the philosophy and motivation behind an integrated curriculum and the process used in its development. The paper will continue with a discussion on classroom implementation including how to develop lesson plans, schedule classes, gather and use student feedback. Although the first year is not yet complete, we will give some preliminary results, and discuss our plans and concerns.

Design Objectives

One reason for designing an integrated curriculum was to provide higher motivation for subjects other than engineering. In the traditional first year program at Texas A&M, students take two calculus courses, one physics (mechanics) course, one chemistry class, English, one engineering problem solving, and a graphics class. The traditional mathematics and science material is never ‘‘really’’ used in the freshman engineering classes. Instead, the engineering courses rely heavily on a student’s high school background in algebra and trigonometry. Therefore students are left with the impression that the mathematics and science they are learning does not relate to engineering. Couple this sensation with the fact that retention is poor and one can understand why traditional students get the impression that the purpose of mathematics and science is to *weed them out.* How can the faculty expect the students to be motivated to learn the material? Sure, they fight for their grade, but that is not true learning. By integrating the subjects, engineering applications immediately provide perspective for the mathematics and science.

The lack of applicability does not end after the freshman year. The dilemma continues as students begin their Sophomore program and are exposed to higher levels of math and science, most of which has no direct relevancy to their Engineering Statics course. Therefore, for three semesters, students have struggled to learn concepts in these fundamental courses and have yet to apply them to anything looking like ‘‘engineering’’. Finally, in the second half of the Sophomore year, many students enter Dynamics where they are expected to use first semester Calculus. The average student suddenly fights off 18 months of mental atrophy and learns Dynamics as well. Integration allows students continual practice in a variety of situations.

Another objective of the project was to provide the first year students with a more realistic view of engineering problem solving. This was accomplished utilizing technology.

Design Process

We did not want major content changes in the first year material so the participating departments were selected based on the material taught in the traditional first year. In December 1993, a large group of faculty from the participating departments was formed. These faculty members formed an advisory team. The advisory team met approximately twice a month to discuss the possibility of generating an integrated curriculum for the first year engineering students. The initial reaction was one of denial. Few believed it would be possible to integrate a curriculum and even fewer believed it would be profitable to take on such a task. After visiting Rose-Hulman Institute and observing their integrated first year, the team became convinced in both the merits and possibility of the design task.

From the advisory group arose several faculty members that assumed responsibility for developing the actual curriculum. These volunteers were put on the payroll to buy them some time. In Mathematics and Physics, we negotiated with the Department Heads to identify people for the design task. We sought and found faculty that were interested in doing the work without salary support but provided support anyway. This smaller group of faculty members formed the development team. From the development team, a teaching team was selected.

The development team began in April 1994 to define the content of the traditional first year curriculum. *Experts* from each traditional course were consulted to determine an hourly (equivalently daily) list of topics covered in the normal program. At the same time, some lists were constructed that prioritized the topics. At the time, the team was concerned that something would have to be cut. As it turned out, only minor topics were replaced.

Once the traditional topic lists were constructed, the development team met to determine which course had the least flexibility in arrangement. We felt that Physics (mechanics) was the least flexible so we chose it as a *pacing* course.

Once the development team selected the pacing course, they integrated the subjects together. The method we used for integrating the subjects required several decks of Post-It Notes and thirty poster boards. One deck of notes was given to a representative from each course. Each deck was a unique color. Each week of the first year was represented by a poster board. Every representative listed their course's content, hour by hour on Post-It Notes. The goal was to place the notes on the poster boards thus designing the year. When placing the notes on the boards, we maintained some basic constraints such as:

1. It was not necessary that every week contain every subject. Some weeks may not have any Physics for example.
2. No week could contain **too much** of any one subject. For example, a week with nothing but mathematics would not be allowed.

To begin filling the poster boards, Physics (the pacing course) picks up the first physics Post-It, briefly explains what the objective of the class is and what mathematical concepts are needed for it. Mathematics then pulls out some notes (most likely more than one) that will provide the necessary knowledge as quickly as possible. Mathematics then sticks the notes onto the posters followed by the one Physics note. As the mathematics notes go onto the poster, the representative describes the objective of each note. After a couple of weeks of Mathematics and Physics are placed, Engineering and English content are placed such that they reinforce the math and science components.

Since the notes are multicolored, one easily gets a visual impression for the overall balance in the curriculum. Areas with excessive math or science are located quickly and are resolved via discussion and some minor juggling of notes. Once the curriculum is laid out, weekly themes are defined that describe the week's material. For the most part, it was not difficult to identify the themes. At other times the theme is slightly contrived. The integration process was accomplished in 16 hours (8 hours in two days) by *locking* the development team into a large conference room.

After the integration was accomplished, the development team began filling in hourly objective statements and short descriptions of classroom activities. As this progressed, the team met three times a week for approximately two hours to describe and discuss lesson plans. During these times, the team worked at developing assignments that were mutually supportive.

The average faculty member on the development team was supported between 1.5 and 2 months over the summer. By the beginning of the Fall semester, the team had weekly themes for the entire first year program plus hourly plans for approximately 85%of the year. Throughout the year, students were provided with a reading schedule and a class meeting assignment for three weeks ahead.

The Teaching Environment

Out of the development team, we formed a teaching team. We selected two mathematics, one physics, one English, and two engineering faculty plus several graduate teaching assistants. The faculty teaching team has a weekly two hour planning meeting in which they discuss problems, up coming events and lesson plans. Additional meetings are required to develop the integrated exam questions (to be discussed later), as well as grade the common portion of the exam.

One hundred students were admitted to the first year program; sixty were white males. All students admitted were deemed to be ready to take the traditional first calculus course. The student group had an SAT range from 930 to 1450 with an average of 1177. The students are most often in a class size of 50.

The room used for our students is approximately 1000 square feet. Students are grouped in fours around 3 by 5 foot tables. Each table has two 17 inch color computer monitors driven by networked pentium computers. The room has a file server, printer and computer projection system and traditional chalk boards (actually a white board).

Students are taught interpersonal, teaming skills and expected to work together in groups of four. The instructor engages the students to create an active cooperative environment. Lecture is limited to short bursts. Students have access to computers at all times except specific times during exams. When questions arise during an activity, students are strongly encouraged to get answers from a student group, either their own or another. If that fails, the students are expected to check texts and on-line documentation. As a last resort, they ask the instructor.

Student-Faculty interaction and communication is encouraged. Students routinely provide *plus/delta* feedback regarding the learning process. A plus/delta posting area was provided in the classroom for each of the courses involved in the project. A plus comment is a positive aspect. A delta is something that needs improvement. Initially, students use the plus/deltas as an opportunity for faculty bashing but with direction from the teachers it has turned into more constructive feedback. Subsets of the student population are divided into *interaction* groups. Each faculty member from the teaching team was assigned to an interaction group and served as a liaison between the students and the teaching team. The purpose of this group was to provide a more personal means of obtaining student input, as well as dissemination of information (eg. why we choose to do things the way we did).

Every third week, the students are given a two hour exam. The number of hours of exams in the program is roughly equivalent to the number in the traditional program. Each exam has a Physics, Mathematics, Engineering and integrated component. The discipline specific sections of the exam are similar to traditional exams. There generally are no multiple choice or true/false questions asked. The integrated portion of the exam is unique to the Coalition program. In general the students are put in their teams, given the problem and given a time period to *solve* the problem. When time expires, the students separate and work out their individual solutions to the question. Integrated problems generally require the students to apply knowledge from at least two technical subjects, and to write an essay based on the problem. The student's grade is based partially on their individual performance and partially on the performance of the team members.

The following is an example of an integrated question.

> Suppose you are working as an intern for XXX, and your boss asks you to review the ad copy shown on the attached page. The ad states, in part, ‘‘It's a student who can stay in midair for 2.5 seconds while shooting a lay-up.’’ Your boss is particularly concerned about the technical accuracy of this statement.
>
> Fortunately, you have in your back pocket a copy of the 1994 edition of the Guiness

Book of World Records, where you find the following world records (which may or may not be useful to you):

Records include Men's and Women's sprints, high and long jumps.

Provide a technical analysis of the validity of the ad's claim. In one or two paragraphs, write a report to your boss about your findings. Make a specific recommendation about whether XXX should modify the ad or print it as it is. Explain your reasons clearly, avoiding technical jargon as much as possible-the report is not for engineers, but for executives who need to make a business decision.

Results

The theme for one integrated week was to mathematically describe data. In Calculus the students just finished studying optimization therefore the least squares technique was a great application for the material. In Physics, the students were studying velocity and were performing an experiment in which a sonic sensor was used to measure position versus time of a mass. These measurements formed data used in the application. In Engineering Graphics, students were learning about techniques for plotting and visualizing data. Taken all together, the students gathered data, displayed it, fit an equation to it then used the equation to make predictions about the system.

One unexpected advantage of the new curriculum is that more material can be covered in the Engineering and Physics classes. We expect that this happens because the duplication in the traditional program is removed. The Engineering material was covered with five weeks left in the year. The extra time was spent providing the students with a design experience and enrichment of previously discussed material. As an example, there were traditionally five weeks of *engineering applications* which were removed from Physics and covered as part of the engineering course.

Table 1: Physics Exam Results. All Numbers Are %.

	Traditional			Coalition		
Problem	Mean	Std. Dev.	Median	Mean	Std. Dev.	Median
1 (10pts)	70.5	28	80	74.9	24	70
2A (5pts)	60.3	37	60	72.2	38	100
2B (5pts)	37.6	29	40	47.4	36	40
2C (5pts)	26.2	31	20	57.2	37	60
2D (5pts)	24.0	33	0	47.6	37	60
3 (20pts)	55.8	24	65	57.6	27	55

Based on faculty observations, the students are performing well above students in the traditional program. The students are inquisitive and read more outside of class. Industrial representatives that form an advisory committee for the Mechanical Engineering department also expressed their enthusiasm for the students' apparent maturity level and professionalism.

We anticipate that 75 students will successfully complete the first year. Of the 25 we lost, only 2 have left engineering. This is approximately 10%better retention than the traditional program has.

The best measure we have now is a direct comparison between the way we present Physics and the traditional method. On a given exam six identical problems were given to coalition students and students taking traditional first semester physics. The problems ranged in difficulty from a *plug and chug* to one in which the students had to apply multiple concepts. Table 1 shows the performance on each problem.

Concerns and Future Work

Our major concerns at the present time concern the faculty, the students and the budget constraints. The pedagogy used in the new curriculum is distinctly different from the traditional mode of lecturing. One concern is how to retrain enough faculty to make the program sustainable. Because of the integration, it is difficult to maintain a uniform faculty load. For example there is no Physics during the first three weeks. As the semester progresses more time is devoted to Physics. The faculty working in the Coalition program have learned to work as a team. Most faculty have become successful by working independently. We are concerned about what might happen when a large number of faculty members are teaching in the first year curriculum.

We are also concerned with the students when they fail a component of the integrated curriculum. If a student fails the Mathematics component, how can it be repeated without having to retake the entire year? We are also concerned about transfer students. A large number of our student engineering population transfer in. It is not clear how to handle students that transfer in with one Calculus or Physics course. Another worry is what to do with students who are not yet ready for Calculus. In the traditional curriculum, someone who is not ready for Calculus can take an Engineering Graphics while taking remedial mathematics. In the Coalition program, there is not an engineering course separate from the integrated courses that the students can take. As a result, if a student is not ready for Calculus, the best they can do is take humanities along with their remedial mathematics.

Finally, we are concerned with the cost of delivering the coalition program. At the present time, considerable faculty time, and technology is used. It is important to reduce these costs so it will be competitive with the traditional program. We have confidence that this can be accomplished. We will be experimenting with larger class sizes in the Fall of 1995. With larger class sizes, greater retention and students with an attitude for studying outside the class, we hope to reduce the effective cost of education. We'll see.

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