Experiences with a New Engineering Sophomore Year

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Abstract:

This paper discusses first-year experiences in the implementation of a new engineering sophomore year at The University of Alabama (UofA). This curriculum development process is a part of The National Science Foundation's Foundation Coalition (FC) Program at UofA. To provide background for the new sophomore year, the paper discusses the philosophy behind the UofA FC effort. This philosophy focuses on improving the classroom culture of engineering education. This is to be accomplished through teaming, course integration, and technology enabled classrooms. With this philosophy as a starting point, the paper discusses new course objectives, the course development process, and first-year results. The course development process includes discussion of faculty input procedures, input from other FC campuses, and related experiences from the UofA FC freshman year. The paper describes four new courses that resulted from this development process. In conjunction with FC philosophy, these courses integrate mathematics and engineering, and introduce teaming and technology into the classroom. Results from the first year are discussed, including quantitative assessment, student journal comments, instructor impressions, and departmental reactions. Particular attention is paid to how the classroom is affected by team assignments and in-class computer use. Concluding comments include pros and cons of the new sophomore year, and plans for its refinement in the coming years.

Introduction

The University of Alabama is a participant in the National Science Foundation's Foundation Coalition. This coalition has the goal of reformulating undergraduate engineering curricula, with three specific foci:

- Integrating technology in the classroom
- Making students more active, team-oriented participants in learning
- Integrating course material between engineering, mathematics, and science courses.

The overall goal of these efforts is to alter the classroom culture of engineering education. It is widely believed that engineering education has become dominated by one-way communication from lecturer to student, and by passive involvement in textbook problem solving. While this may produce students that are technically adept, it often produces students whose knowledge is rigid, and whose ability to work in the real world of engineering is stunted.

Some History

In 1994, the University of Alabama Coalition Team (UACT) introduced its newly developed freshman engineering curriculum to its first class of 36 incoming freshman. The progress of this effort is reported on in detail in [1]. During this year, the UACT Sophomore team was charged with finalizing development on the first UofA FC sophomore year. The courses developed through this process were to be offered to the FC students in the Fall of 1995.

To gain insight into the UofA FC sophomore year, it is important to have some facts about the UofA FC freshman year [1]. The incoming freshmen were selected for the FC program based on existing UofA mathematics placement exams. If the students were ready for the first differential calculus course, they were offered the

opportunity to join the FC program. This screening was not an effort to make the FC program a selective or advanced program. In the long term, UACT intends to offer a FC freshman year to all incoming engineering students, as the program becomes institutionally accepted. However, given the limitations on the ability to develop courses, it was decided to use this math-based screening process.

The freshman year offered 4 courses per semester: one each in engineering, chemistry, physics, and mathematics. These courses were tightly integrated with one another. They also featured extensive use of technology in the classroom. The students used Maple for symbolic manipulation in all their classes. They also used Microsoft Office software in reports and presentations. The freshman courses also focused on teaming, through in-class work and projects. The students gained presentation skills through project presentations.

The freshman courses in math, chemistry, and physics covered some material from existing courses. In administrative terms, these courses were substitutes for courses in the existing curricula. The two-semester FC math series substituted for differential calculus, and a large portion of integral calculus. The physics courses substituted for the first two physics with calculus courses, and their labs. Likewise, the chemistry courses substituted for two semesters of introductory chemistry, and the associated labs.

This was the background that the students would have when they emerged from the FC freshman year. Based on this expectation, the Sophomore group set about developing the Sophomore year.

Course Development Philosophy

As a part of the FC effort, it was necessary to do more than simply identify subject matter for the sophomore year. It was also necessary to focus on a philosophy of changing the classroom culture. For instance, the lecture is not always the most effective process for communicating ideas, though its the predominant method used to teach university students. A student can rarely pay full attention for the entire period of a lecture (50 minutes for a normal class at our university) and it is often hard for students to take notes and listen with good comprehension at the same time. Therefore, part of the sophomore year philosophy was to cut down on the amount of lecturing. In its place, we decided to use teaming and technology in the classroom to work various sample problems during normal class time.

Teaming not only teaches students how to effectively work in groups (a necessary skill for their chosen profession), but allows them to discuss difficult concepts with each other and with the professor for better understanding. Moreover, it simply encourages multi-party communication in the classroom, which enhances the learning experience.

Technology in the classroom was made possible by one computer for every two students. The sophomore year curriculum planned to extend the use of the software employed in the freshman year as a matter of philosophy.

Given these philosophical directions, it was our intent that instead of listening and taking notes for the entire class period, students would listen to a short discussion on the current topic, be presented with a sample problem, divide up into teams, and use computer resources, to find a solution.

It was also our philosophical intent to develop courses that integrated material from the sophomore year for students from as broad a variety of engineering disciplines as possible. Many engineering students take a variety of math and physics courses in their studies, without any idea of how they will use this material later. Moreover, they often fail to see how this material spans several of their engineering courses. Thus, it was felt that we needed not only to have integration of material in each course, but integration between separate courses.

Development Efforts

In some ways, the development of a reformed sophomore year engineering curriculum proved more administratively difficult than that of the freshman year. In the freshman year most engineering programs take similar courses. This is not true of the sophomore year. Therefore, issues of course substitution with existing curricula and possible interference with those curricula were more critical in the sophomore year. Knowing this, the UACT Sophomore team proceeded to obtain input from a number of sources. These included other Universities that had implemented reformed sophomore curricula, including Texas A&M, Rose-Hullman, and other schools. The team also sought out input from UofA faculty, department heads, and administrators. After some deliberation, it was decided to offer four FC sophomore courses: one each in mathematics and engineering. The engineering courses roughly followed the conservation principles based model used at Texas A&M.

In the first semester, the FC engineering offering was a course in conservation principles that spanned several engineering disciplines. This course was called Integrated Engineering Systems I. It used a text developed at Texas A&M entitled *Conservation Principles and the Structure of Engineering* by C. Glover, K. Lunsford, and J. A. Fleming. The course primarily dealt with the application of conservation of mass, charge, momentum, and energy in engineering systems. However, the course was primarily limited to static and steady-state systems. Dynamic systems were the basis of the second FC sophomore year course, Integrated Engineering Systems II. This course used a text that was also developed at Texas A&M, entitled *Understanding Engineering Systems Via Conservation* by L. Everett.

The sophomore team decided that cross course integration between the first-semester mathematics course and Integrated Engineering Systems I would be difficult. Given the steady-state basis of the engineering course, there would be little need for more than algebra and basic calculus. Therefore, it was decided that the first math course would cover linear algebra, some differential equations, and the topics from the traditional first two calculus courses that were not included in the FC freshman year. This course was called Mathematics III for the Integrated Curriculum. This course used the texts *Calculus* by Hughes-Hallett and Gleason, and *Linear Algebra and Differential Equations (2nd edition)* by Cullen.

Although Mathematics III was only loosely integrated to the engineering course, it was designed to extensively utilize active learning and technology in the classroom. It was also felt that there was significant integration of material from several traditional courses within the Integrated Engineering I course.

Integration of the engineering and mathematics courses in the Spring semester of the Engineering sophomore year was quite natural. Since Integrated Engineering Systems II focused on dynamic systems, it was natural to interface it to a mathematics course that dealt with differential equations. This led to the Spring semester mathematics course, which was entitled Mathematics IV for the Integrated Curriculum. It continued from Mathematics II by using the text *Linear Algebra and Differential Equations (2nd edition)* by Cullen.

This four course sophomore year plan was reviewed by UACT, the engineering departments, and by college administration. After some consideration, the plan was accepted as a part of the regular curricula in the College of Engineering, with the exception of Chemical Engineering. Due to inevitable constraints in the existing Chemical Engineering curriculum, it was decided that Chemical Engineering students in the FC program would take only Mathematics III for the Integrated Curriculum. Then they would proceed with courses from the traditional curriculum.

The First Attempt

With all of this planning in hand, the sophomore UACT group proceeded to teach the first FC sophomore year at the UofA. The courses were highly project centered. In Integrated Engineering I, these projects included:

- Design of a continuous fermentation process, in two stages:
    - conservation of mass balance and configuration.
    - momentum balance of the fermentation plant to mount it in a physical facility with minimum force and space constraints.
- Design of a device to launch a 10-pound pumpkin the furthest distance.

The course also included in-class team assignments, homework, and quizzes. An emphasis was placed on minimizing in-class lecture time, and maximizing student participation in the classroom.

Mathematics III for the Integrated Curriculum included the following projects:

- Applications of Improper Integrals and Taylor Series:
    - Escape Velocity
    - Einstein's Equations for Bending Light Rays
- First Order Differential Equations Applications
    - Banana Republic's Currency Replacement
    - Pollution of Lake Cachuma
- Matrix Algebra Applications
    - Spy vs. Spy - Cryptology
    - Traffic Control - Network
    - Forrest Gump's Shifting Strategy - Markov Chains
- Bases, Linear Transforms and Eigenvalues

* Tan-Yu Rental Car Agency - Markov Chains and Eigenvalues

The course also included in-class work and homework.

Integrated Engineering II included the following projects:

- System modeling and force analysis on fighter jets in carrier landings.
- Analysis of a guitar distortion pedal.
- Design (on computer) of a crossover for a stereo system by using passive filters.

The course also included selected topics in thermodynamics, statics, and multiple-discipline systems like electric motors.

Results: Quantitative and Qualitative

One could say that a course is a success if the students feel they learned the appropriate amount, and the teachers feel likewise. Therefore, there are two categories of results for the first FC sophomore year at UofA: those reflecting student opinions and those reflecting faculty opinions. Moreover, each of these categories can be re-divided into quantitative and qualitative varieties. These opinions can be further divided into those on the courses themselves, and those on the implementation of the courses in the first attempt.

The most obvious quantitative feedback from the teachers is in the student grades. Although details cannot be presented here for the sake of brevity, this measure reflects that the students performed as well or better than peers that are not FC participants. However, this quantitative feedback does not reveal the complete picture. Qualitative evaluations of the engineering courses themselves are mixed. Although the courses were felt to be a valuable learning experience for the students, some of the founding principles of these courses are now felt to be flawed. In particular, the first semester course, Integrated Engineering Systems I, is felt to be problematic. The course's restriction to steady-state and static systems proved to be extremely difficult.

The mathematics courses were well received by the students. We began with the introduction of L'Hopital's rule, improper integrals, and Taylor approximations to fill in the gaps for the first year's calculus sequence, then followed by the fully integrated treatment of linear algebra and differential equations. The only complaint from the students is the requirement of the use of an additional software package (Matlab). Maple was the primary package used in the first year's mathematics courses. However, by the end of the semester, the students seemed pleased to have learned both Matlab and Maple.

It was uniformly felt by the teaching faculty that the projects were their most successful part of the courses. Qualitatively, these were the strongest learning experiences for the students in these classes. Because of experiences in the FC freshman year, the student's presentation and teaming skills were also impressive, and led to positive project results in nearly every case.

Student feedback on the courses was obtained in a variety of ways, including journals and end-of-semester surveys. Qualitatively, the student comments on the survey and journal entries reflected students who were far more interested and enthusiastic than students in traditional curricula. The teaching faculty feel this enthusiasm reflects the change in classroom culture induced by the FC, and that it is the most positive outcome possible from this effort.

Future plans

The coming year will be the second time an FC sophomore year is taught at the UofA. In response to the results of the first year, several changes are being made:

Integrated Engineering Systems I is being removed from the curriculum. It is being replaced in the Fall semester with a version of Statics that will include teaming and technology integration in the classroom. A similar version of Statics has been taught for two semesters at the UofA. It is the sophomore group's intention that the techniques used in this class become fully integrated into all statics classes, such that this course rejoins mainstream statics.

Integrated Engineering Systems II is being split into two courses: Mechanical Engineering Systems and Electrical Engineering Systems. Both of these courses will be taught in the Spring semester, where they can be more tightly integrated with the FC mathematics offering.

It is also planned to change textbooks for all of the FC Sophomore year courses. Several texts are under consideration for each course at this time.

These changes not only reflect the in-class experiences of the first sophomore year, they also are an

effort to encourage institutionalization of the FC courses. The proposed new course offerings more adequately streamline into the remainder of the traditional curricula. However, they will attempt to do so without sacrificing the key aims of the FC: course integration, active learning, and technology in the classroom. By combining these goals with our experiences in the first year, it is felt that we can improve the quality of the sophomore year learning experience for a body of engineering students.

References

[1] J. Parker, D. Cordes, C. Laurie, A. Hopenwasser, J. Izatt, and D. Nikles (1995). Curriculum integration in the freshman year at the University of Alabama: The Foundation Coalition program. In *Proceedings of the 1995 Frontiers in Education Conference*, Atlanta, Georgia, November 1-4.