Curriculum Integration in the Freshman Year at The University of Alabama - Foundation Coalition Program

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Abstract

The University of Alabama presented its first set of freshman year courses as part of the NSF sponsored Foundation Coalition during the 1994-1995 academic year. The three major thrust areas of this coalition are: (1) curriculum integration, (2) technology-enabled education, and (3) human interface issues (learning styles, active and cooperative learning). The focus of this paper is on the integration aspects of the freshman year engineering, mathematics, and sciences curriculum.

Most freshman level mathematics, chemistry, and physics courses are taught in isolation from each other. Students respond by "compartmentalizing" their technical knowledge without awareness of the connections between subjects. The traditional "cafeteria" style process for selection of courses further componds the problem. Most engineering programs view the "output" of the freshman math and science courses as the "input" into their courses. Consequently, there is relatively little interaction on the education level between engineering professors and their colleagues in the math and science departments.

As a result, most engineering programs lose many students during the freshman year. Our solution to this problem is an integrated set of courses for all engineering majors in chemistry (CH 131/132), engineering (GES 131/132), mathematics (MA 131/132), and physics (PH 131/132), which must be taken together. The authors of this paper were the instructors for the initial offering of the courses mentioned above. The paper will focus on several specific examples of curriculum integration that have been attempted, along with observations about the success of the program.

The Foundation Coalition consists of the following: Arizona State University, Maricopa Community College District, Rose-Hulman Institute of Technology, Texas A&M University, Texas A&M University - Kingsville, Texas Women's University, The University of Alabama.

Introduction

A group of engineering deans and industry leaders has identified several goals for improving the engineering curriculum [1]. Among the twelve stated goals are team skills, including collaborative and active learning, communication skills, leadership, integration of knowledge throughout the curriculum, and a multidisciplinary perspective. The NSF sponsored Foundation Coalition (FC) was founded on three of these basic concepts for improving engineering education - curriculum integration, human interface issues, and technology enabled education. Many engineering, science, and mathematics professors have found that engineering students often compartmentalize their knowledge of basic science and mathematics (i.e., "that’s not engineering, that’s math/chemistry/physics ..."). Another problem among students in traditional undergraduate education is that their is oftentimes little recognition of the same material presented differently (i.e., "I’ve never seen that before ..."). A student is introduced to integration in their calculus course, but may completely fail to recognize the same concept when it is presented again the next semester in physics. By integrating curriculum material across chemistry, engineering, mathematics, and physics, we hope to improve student understanding of related material through reinforcement, motivation, and additional exposure. Our goal with curriculum integration is for students to understand that mathematics, chemistry, and physics are not simply hurdles that they must leap to enter engineering, but are the foundations upon which engineering is built.

Human interface issues, such as active learning and teaming, have been shown by many educational researchers to significantly improve the learning of many students. Active learning strategies offer the potential to greatly increase student understanding and retention of new material. Our FC program offers numerous occasion for students to work in two or four member teams, from their chemistry and physics labs to their engineering design projects. Other active learning strategies that have been used include short, in-class recitation exercises, five minute "brainstorming" exercises, and anonymous "plus/delta" student feedback. Teaming offers other potential benefits not associated directly with learning. For example, our experience has been that teaming is particularly effective in reducing the isolation that many students feel during their freshman year, which should positively impact retention rates.

With the current proliferation of low cost computing, a technology-enabled education is vital. For our initial offering of the program to 36 students, we purchased 20 Apple Power Macintosh computers (one computer for the instructor and another acts as a file server). The PowerMacs were selected primarily due to their multimedia capabilities, which we have not yet fully exploited. We have incorporated many personal productivity tools, such as word processors, spreadsheets, presentation graphics, e-mail, etc., into our FC curriculum. These tools allow students to greatly improve their written and oral communication skills, while also exposing them to the realities of modern engineering practice. We have also incorporated the symbolic algebra program Maple into our program, primarily in the mathematics course. The use of Maple can remove many of the tedious calculations from problem solving and allow students to focus on the concepts and ideas that are important.

At The University of Alabama, our Foundation Coalition freshman year involves a 13 credit hour sequence of integrated courses in chemistry, engineering, mathematics (calculus), and physics. These new courses were offered for the first time in the Fall 1994 semester, and replaced a traditional set of chemistry (CH 101, 102), engineering (DR 125, GES 126), mathematics (MA 125, 126), and physics (PH 105, 108) courses for the students in the pilot program. The course titles and credit hours for the new courses are

- CH 131 - Chemistry for the Integrated Curriculum (3 credit hours)
- GES 131 - Foundations of Engineering (2 credit hours)
- MA 131 - Calculus for the Integrated Curriculum (4 credit hours)
- PH 131 - Physics for the Integrated Curriculum (4 credit hours)

Our program combines features from two of our fellow coalition schools earlier efforts. In particular, the Integrated First Year Curriculum in Science, Engineering, and Mathematics (IFYCSEM) program started at Rose-Hulman in 1988 [2]. The early emphasis on engineering design as a motivating and integrating theme was been a significant contribution by Arizona State University.

The focus of this paper is on the curriculum integration issues in our Foundation Coalition (FC) program. Material common to two or more courses is introduced simultaneously to improve student understanding. For example, the introduction of the derivative in the calculus course is paralleled with the use of derivatives to solve simple mechanics type problems in physics. On a more advanced level, the physics and chemistry courses introduce the molecular structure of matter from slightly different, but parallel viewpoints. The engineering course incorporates several three week, open-ended "design" problems, which are integrated with the material presented in the other three courses. The goal of these design projects is to motivate students by showing them how engineers actually use their fundamental knowledge of basic science and mathematics to solve real world engineering problems. These design projects are discussed briefly in this paper, and in much greater detail in another paper at this conference.

Curriculum Integration

The integrated curriculum was designed by the co-authors of this paper, with significant input from other members of the FC at Alabama. We met for two to four hours per week during an academic year period to discuss topics and search for opportunities for integration. In addition, each co-author was provided one to two months summer salary (in 1994) to finalize the details of the new courses. In the following paragraphs, we present a more detailed discussion of the specific topics that are integrated between the four courses in our Foundation Coalition freshman year program.

The physics and mathematics subjects provided one of the best opportunites to reap the benefits of curriculum integration. Early in the first semester, the mathematics faculty introduced the symbolic algebra program Maple as an aid in plotting and understanding of functions - trigonometric, exponential, logarithmic, normal distribution, etc. This allowed the rapid introduction of the concept of the derivative and slope of curves in the math course. The physics course created an immediate application for this material by introducing the one-dimensional kinematics of particles and rigid bodies, i.e. velocity and acceleration. Later in the mechanics sequence, students complete a force table experiment which involves two dimensional motion and Newton’s laws. The mathematical topics of vector addition, vector components, and coordinate systems was introduced in parallel with this experimental material. Towards the end of the first semester sequence of courses, the concept of simple harmonic motion became a major unifying theme. Although this is an introductory calculus course, the mathematics faculty introduced the simple second order ordinary differential equation with constant coefficients which finds many applications in physics and engineering. They also introduced the concepts of solution behavior, and the effects of initial conditions on the solution. The primary physics application was the undamped spring/mass system, but there were additional applications in the other courses. Finally, the second semester courses lead to several instances of math and physics integration in the area of vector fields, line and surface integrals, and gradients when the physics concepts of electric and magnetic fields, and the laws of Gauss, Biot-Savart, Ampere, Lenz, etc.are introduced.

The integration of material from mathematics and chemistry proved to be difficult to accomplish. The math content of most freshman level chemistry is algebra based (balancing equations), which requires little or no calculus. However, some instances of real curricular integration were accomplished. At the beginning of the semester, students collected real data in their chemistry and physics laboratories. Individual data points were plotted (using Maple) and the students were asked to "fit" functional curves of the appropriate type to the data. In the chemistry lab the students collected data from a sample of nail weights (normal distribution), measuring the pH of aqueous HCl or NaOH (logarithmic), and determining cooling curves (exponential). At a later point in the first semester, the students used error analysis techniques to find error bars for their experimental data. This error analysis required them to use their derivative taking skills to find partial derivatives for several different analytical equations. Also, one of the chemical kinetics lab exercises was used to demonstrate the concept of integration where the students were shown the kinetics equation in both the original derivative form and the final integrated form.

Several instances of curricular integration between chemistry and physics were accomplished. In the laboratory component of both courses, the normal distibution curve and error analysis were treated in a uniform fashion at the same point in the semester. For example, the physics instructor introduced the concept of normal distributions and error analysis, and each student determined the mass of a commemorative coin the next morning in their chemistry lab. A more involved instance of integration concerned the concepts of collisions and the kinetic molecular theory. In physics the students studied collisions on an air table, then simulated the collisions of thousands of balls in a Maple worksheet. The results of these simulations were used to derive the Maxwell-Boltzman velocity distribution, which was incorporated into the chemistry lectures on the temperature dependence of kinetic energy in a gas. Another instance of integration was a parallel treatment of the concepts of temperature dependence on the rate of chemical reactions. In the second semester, one of the chemistry lab experiments on

emission spectra involved the diffraction of light and was actually performed in the physics lab!

Most of the integration of topical material between the engineering course and the science and math courses occurred through the use of several three week long "design" projects. There were three design projects that integrated topics from the areas of chemistry and engineering. One project required students to size a storage tank of storage of compressed natural gas (CNG) for an alternative fuels transportation application. The early stages of this design require the use of the ideal gas law, and it also provides an opportunity to discuss the real behavior of non-ideal gases at high pressures. A second design project - sizing a catalytic converter for the same alternative fuel transportation application - involved the use of chemical kinetics, balancing chemical reactions, and catalysis. The final project of the second semester was an exploration into the area of engineering material properties. The chemistry instructor introduced the concept of polymers and their physical properties while an engineering design problem required students to find new applications for polymers that they had created in the laboratory. Many of these design projects are discussed in greater detail in another paper presented at this conference.

Several of the design projects involved direct examples of the application of physics concepts in engineering. Since the physics and chemistry courses both covered the ideal gas law, the CNG tank sizing problem related to physics concepts as well. A more specific example occurred during the physics (and mathematics) coverage of the simple harmonic oscillator. A project to design a water tower to resist earthquakes was used to demonstrate a real application of the concept of natural frequency. The water tank was modeled as a mass and the tower as a cantilever beam , which created a simple harmonic oscillator. This project also presented an ideal place to review units (both SI and English), dimensions, and geometry, as well as the introduction of new concepts (area moment of inertia). A later project involved the design of a battery-operated seat warmer for football games. This project required the practical application of series and parallel circuits as well as an introduction to energy storage devices (batteries).

Observations

Our Foundation Coalition program made significant changes in the freshman year experience for our original group of 36 students. Since we are in the early stages of the pilot program, quantitative data concerning long-term retention rates, grade point averages, and student understanding of the material are not available. All but two of the original 36 students are still enrolled at The University of Alabama for the Fall 1995 semester. Thirty of of these 34 students remain in the engineering program (two students have transferred to business, one student transferred to education and one student transferred to arts and sciences).

As with any new program, there were both positive and negative aspects to our initial offering. Our FC courses were the first at Alabama to use the Maple program as an integral part of an academic course. The mathematics professors developed several tutorials that introduced Maple topics and mathematical concepts in a parallel fashion. Students were often asked to predict Maple’s output and then compare with the actual result. As expected, some students struggled with the software while others learned quickly. Our focus on Maple shifted during the year from treatment as a standalone topic to viewing Maple as simply another tool. By the end of the year, students were never specifically asked to use Maple to solve a problem, but could use it if they desired. We plan to use this concept throughout our 1995-1996 courses.

Some student feedback to specific questions about their FC experiences is given below.

1. What do you like best about your FC classes and experiences?

"The fact that, more so than other freshman engineers, we were shown why we are learning all of this stuff. Because, without practical application, the highest order math known to man is just a bunch of silly symbols (most of us think so anyway!)"

"I really liked seeing the same people every day. It really helped to have friends that had all of the same classes as I did. We really supported each other and helped each other get through the semester."

"In the FC, I think I like the most the amount of attention to and genuine care for my total understanding of all my subjects. They make sure that we thoroughly comprehend a subject before moving to the next one."

2. What do you like least about your FC classes and experiences?

"I dislike the large amounts of work that it expected by the FC. I'm not sure how the work load compares to a regular curriculum but I do know that everybody I talk to seems to have a lighter load (Who knows?)."

"I dislike having 4 out of 5 classes with the SAME people in the SAME room everyday."

"The thing that I like least about the FC Coalition is that it is very time consuming. It takes up a lot of our time and we never have time to spare to do the things that we would like to do."

3. What would you tell next year's freshman coalition class about the program?

"I'd let them know what they are getting into, lots of hard work, but I'd also let them know that they had better major in English if that scares them. I'd tell them that they need to learn to study and keep on top of things and they'll do just fine."

"It's really a great experience. You think you're going to die but you won't. The friends you make are worth it."

"I would tell them to be ready for a challenge and to work."

"Go for it...It's not as bad as it may at first seem."

"I would tell next year's freshman class to be prepared to do a lot of studying, and get very familiar with the computer lab because you will be spending a lot of time there."

Summary

We have presented an overview of the new Foundation Coalition freshman year program at The University of Alabama. We have focused on the integrated aspects of the chemistry, engineering, mathematics, and physics courses which comprise the program. The authors of this paper are in the process of refining the program for delivery to a much larger group of students (two classes of 32 students each) in the Fall 1995 semester.

References

1 "Engineering Education for a Changing World," ASEE Prism, December, 1994, pp. 20-27.

2 Winkel, B.J. and J.E. Froyd, "An Integrated First-Year Curriculum in Science, Engineering, and Mathematics: Progress, Pitfalls, and Promise," 1992 Frontiers in Education Conference, pp. 557-561.