Calculus in an Integrated Freshmen Curriculum

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BACKGROUND

The ***Connections*** program at the Colorado School of Mines is an integrated series of freshman year active-learning based modules and seminars which will allow first year engineering students to develop significant connections among their humanities, physical and social Science, and engineering course-work. It is sponsored by the Fund for Post Secondary Education of the United States Department of Education. The program is designed to address two areas: 1) poor integration of humanities and social science into technical curricula, and 2) freshman-level instruction that discourages students from pursuing careers in engineering and mathematics, By enhancing higher order thinking abilities, the hope is that the students will discover important connections among their various courses and that the learning will be deeper and more complete,

The ***Connections*** program proposal promised that it will allow students to:

- discover and develop significant connections among their freshmen core subjects.
- enhance their higher order thinking abilities and apply these abilities in humanistic, scientific, and engineering contexts.
- understand the historical and cultural contexts which have influenced developments in science, humanities, and engineering.
- struggle with some of the world's great ideas and issues,
- further develop their sense of ethics and values, particularly concerning the applications and limitations of technology in the modern world.
- improve their oral and written communication skills,

Again referring to the original proposal written by Barbara M. Olds, Principal Tutor of the McBride Honors Program, and Ron Miller, Coordinator of the EPICS Program, the key features of the program are:

- modifying existing freshmen course syllabi in humanities, physical and social sciences (chemistry, physics, geology, mathematics, and economics), and engineering practices (EPICS) to feature a series of integrated project modules which allow students and faculty to explore appropriate connections between these disciplines,
- adding a two-semester ***Connections*** interdisciplinary seminar series in which students and faculty will further develop and explore the interconnectedness of appropriate topics from each of the freshman humanities, social science, physical science, and engineering courses,

- modifing existing pedagogical practices (primarily passive lectures in most courses) to include extensive use of active learning and cooperative learning strategies, team teaching, and writing as a learning and inquiry tool.
- developing a comprehensive peer study group system to encourage interpersonal growth and support among freshmen in the ***Connections*** program.

We started the program in the first year with eight faculty members from the areas represented: mathematics, physics, chemistry, humanities, EPICS, economics, and geology. During the first year we met weekly and planned the program. We also enrolled in each others classes. My class assignments were EPICS and Physics I. We kept journals and wrote about our impressions of the classes in which we were enrolled. The second year we implemented the program with a class of forty-nine, The third year we limited the class to thirty-five. The students were chosen to be in the middle of the class academically. We wanted to test the program on average Colorado School of Mines students. The professors were chosen for their reputations as teachers and for their interest in piloting such a program,

IMPACT

With this program background, what has made calculus in ***Connections*** different than the course taken by the rest of the freshman class? What kind of results have we seen with the students in the two years of the program? What are the successes and failures of the program?

The emphasis in calculus is on conceptual understanding of the central themes of calculus and the applications in all the other areas in ***Connections*** Classes are conducted with a minimum amount of lecture instead the students work in groups to solve problems. We use standard texts: year one , Edwards and Penney, Calculus with Analytic Geometry, Fourth Edition[i], and year two, Thomas/Finney, Calculus, Ninth Edition[ii]. Calculus I is a four hour course and Calculus II is a three hour course. In year one first semester, we used the ***Mathematica*** projects furnished by the authors, in the second semester, the *Mathematical* projects were coordinated with their work in physics. Topics of those projects included: Catching the Train (a problem analyzing the conditions which must be satisfied for a passenger to catch a train before it leaves the station), Measuring the Volume of a Tank (finding the volume of an underground storage tank), Work along a Curved Path (finding arc lengths and using line integrals to compute work), Harmonic Motion (plotting graphs illustrating variations in constants in simple harmonic motion), Force to move a box (find the minimum force required to move a box on an inclined plane), Heat Flow along an infinite, uniform rod (an application of L'Hopital's rule), and Plotting Polar graphs, The use of technology to solve problems which bridged two courses strengthened the understanding of concepts in both courses.

In addition, the *Connections* students used *Mathematica* in their EPICS projects. EPICS, Engineering Practices Introductory Course Sequence, is a four semester sequence in which the students do open ended problems, The *Connections* projects were designed to connect subject matter from their other courses. First semester, the students worked in teams to design and build a solar collector which would boil water. This project was revised in the second year to allow the students to cook whatever they wanted. Second semester, the project was Remediation of Surface and Ground-Water Contamination. This project called upon knowledge from geology, math, chemistry, humanities, and economics. For the mathematics connection, the students used *Mathematica* in an inquiry-based laboratory environment to solve the one-dimensional transport equation (Darcy's Law) for flow through a porous medium (such as sediment underlying a contaminated site). They then performed a sensitivity analysis of the parameters which had been identified in their geology class. The students perceived their projects to be much more valuable than the regular EPICS projects as they emphasized connections and enabled them to use material from a variety of their classes.

The mathematical and computer sciences department is presently assessing the value of the use of technology in the teaching of the first two semesters of calculus. The biggest problem we have faced is the aging of our NeXT Laboratory and the frustrations that students have when the machines do not perform.

As part of the program, the students attended regularly scheduled seminars, The topics for the seminars in the first year were:

- Critical Thinking.
- Looking ahead to Physics,
- Biographies of noteworthy people from the various disciplines.
- Snell's Law applied to calculus problems.
- Methodology in the disciplines.
- Smog.
- Revolutions - Scientific, Industrial, Darwinian, and what's next ?
- Limits to Growth,
- More math-physics connections.

The students had very strong reactions to some of the seminar topics. Their primary criticism was they wanted the immediate connections between the courses and were less interested in the "big picture." For the second year, we incorporated the input from the first year students and concentrated more on direct connections. We kept the biography and revolutions units as the students enjoyed those. They also liked the math-physics connections sessions which emphasized conceptual understanding. We asked students to pose problems from their other courses which would illustrate calculus concepts. The notion of a derivative came to life. We asked them to interpret problems and to rephrase scientific theory into mathematical terms. In the second year, one of these modules referred to the traditional "shoot the monkey" demonstration done in physics. In the class lecture, several assumptions were made such as: the gun was aimed at the monkey, the monkey fell at the instant the gun was fired, air resistance can be neglected. The students were asked to investigate in their small groups what the consequences of each of these assumptions were. They were instructed to be quantitative. These sessions seem to have reinforced the concepts. *Connections* students have consistently outperformed the other sections in calculus.

IMPLICATIONS

The program evaluator is Dr. Gloria Rogers, Dean of Academic Services and Assessment, Rose-Hulman Institute of Technology. She visited the campus each year to interview faculty, administration, and students. She made suggestions on goal clarification, student input, and the project assessment. Her suggestions were incorporated into the second year program,

Possibly the greatest benefit from this project was an opportunity for faculty to work closely together for an extended period of time. Strong faculty-faculty ties formed. Colorado School of Mines is undergoing a curriculum revision and four of the eight members of the Curriculum Reform

Steering Committee are members of the *Connections* team. The new curriculum features "Systems" courses: The-Earth as-a System, Engineering Systems, and Economic and Political Systems. These will be interdisciplinary courses and are based on *Connections* experiences.

We were able to plan a program which eliminated some of the scheduling problems for the students such as exam scheduling. We were able to track the student progress and provide extra help for those who faltered. After the first year, the students wanted an even closer tie to an individual faculty member so we divided the students so that each of us had six advisees. This has provided good support for the students. Thus, we have strengthened faculty-student ties.

Having all their classes together provided strong student-student interactions. The second year students had their "Crossroads" (Humanities) class in their own section, The rest of the freshmen were in large lecture sections. Feedback from this experience indicates that the small class mode is a much better way to deliver humanities. This forum also allowed Dr. Olds to integrate the humanities and the technical curriculum which was one of our original goals, Writing was stressed through all the courses, The students became very competent in working in teams and in fact were comfortable in interchanging teams. The retention rate was better for *Connections* students as they had a sense of belonging. Their grade point average was also better than the class average. Student comments suggested that: . . . "it eases you into college and you can easily make friends,,, we did problems in class and didn't just sit and listen to lecture, the time went by quickly, I actually learned a great deal which is abnormal, . . . provided a chance for teamwork, own work schedule, one goal, already in most demanded profs' classes."
The social aspects of the program were as important as the academic ones for many of the students,

The conclusions are that an active learning environment helps the students learn, Having a socially supportive environment helps retain students. Forcing the students to think beyond mechanics deepens their understanding. Forget the "big picture" with freshmen and concentrate on survival skills. Interdisciplinary projects require more time and effort, but the rewards are great. Results from this program can be incorporated into the new curriculum. In retrospect, reviewing the original goals for the program, all have been reached.

i C .H. Edwards, Jr. and David E. Penney, Calculus with Analytic Geometry, Fourth Edition, Prentice Hall. Englewood, N. J., 1994,

ii George B. Thomas, Jr. and Ross L. Finney, Calculus with Analytic Geometry, Ninth Edition, Addison Wesley, Reading, MA, 1996.

Biographic Information:
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