Lilly Teaching Fellows Program

PROJECT PROPOSAL

Douglas B. Meade

29 March 1994

Introduction

The USC Department of Mathematics is in the process of improving the effectiveness of its undergraduate curriculum. The Science and Engineering Calculus sequence (MATH 141, 142, 241) has received the most attention (e.g., reduction of class size, increased contact hours with faculty, updated syllabi, and enrichment workshops). The time has come to begin to systematically extend the scope of these changes to other parts of the Mathematics curriculum.

Professor Ralph White, from the Department of Chemical Engineering, has agreed to serve as a mentor for this project. Together, we will work to strengthen the course Elementary Differential Equations, MATH 242. The primary goal of this collaborative effort is to improve student preparation for upper-level engineering and science courses. Specific objectives include increasing awareness, appreciation, and application of fundamental mathematical concepts. Our goal is to revamp this course into a course more beneficial to the modern engineer.

Background & Rationale

Differential equations is typically the first mathematics course beyond the three-semester Calculus sequence. Students often think of this course as a large set of long, complicated, and disjoint solution techniques that must be memorized and mastered. I believe this completely misses the objective of the course. Differential equations is the natural mathematical setting for discussing topics such as Newton's Laws of Motion, Maxwell's Laws for Electromagnetics, the Laws of Thermodynamics and pattern formation in biology. To comprehend later discussions of topics such as these, students need to be conversant in the "language" of differential equations; MATH 242 is the logical place to start to learn this language.

I will be teaching one section of Elementary Differential Equations (MATH 242) in the Fall 1994 semester. This course is taken primarily by Engineering students. This fact can, and should, be exploited to simultaneously improve understanding of differential equations and preparation for subsequent engineering courses. To achieve these goals, the Department of Mathematics and College of Engineering must work together. Professor White will be able to draw upon his extensive research and teaching experience to identify engineering principles that illustrate fundamental concepts in the theory of differential equations.

Symbolic algebra software has recently matured to the point that it can be considered as a pedagogical tool. Unlike numerical software, which operates on numbers, symbolic algebra systems directly manipulate mathematical expressions. A high-level language is used to perform basic operations such as limits, derivatives, integrals, as well as solving algebraic and differential equations.

In June 1993, I attended the 1993 Maple Summer Workshop and Symposia (MSWS) with the intent of expanding my ability to use Maple in my research. In addition, I also became convinced of the feasibility and effectiveness of using this new technology in the teaching, *and learning*, of mathematics, primarily Calculus and differential equations.

The decision to use symbolic computation, in particular Maple, in the attempt to improve student understanding was reached only after much deliberation. Reasons in support of this decision include student access, ease of use, and applicability throughout the mathematics curriculum.

Description

Symbolic algebra is used in support of my scientific research on a daily basis. Two of my primary uses are for basic manipulations of complicated expressions and the use of graphics to enhance my intuition and understanding. This allows me to devote more of my time to the understanding of the interesting questions, and not become overwhelmed with time-consuming, but essential, calculations.

It has been several years since I first realized that the same benefits could be realized in the classroom. However, there were a number of obstacles that have prevented the implementation of this idea until now. First, there is the question of access. How can I bring the technology into the classroom? A handout is no different from the figures in the text; active student participation is a must. Demonstrations do not enable students to acquire the ability to use these tools. To optimize this contact, convenient in-class access must be available (as compared with outside labs).

Two recent developments at USC have removed these roadblocks. In 1993 the College of Science and Mathematics purchased several portable, high-intensity projection systems designed for classroom demonstrations. Also, both Engineering and Mathematics are in the process of creating classrooms designed to permit in-class student access to computers.

I have already started to utilize the projection system in my classes. These demonstrations, which have been well received by students, are very helpful in emphasizing the problem solving process more than mechanical details.

Some specific issues related to the use of the computer in the classroom that will be critical in the re-design process are:

- What is the optimal combination of demonstration, in-class exercises, and homework assignment?
- What steps can be taken to avoid student dependence on the computer?
- What is the proper combination of hand and computer exercises?

While I have not yet resolved all of these issues, my limited attempts have been encouraging. For example, students quickly realize that the computer can be used to solve a problem only after the problem is properly formulated. One benefit of a high-level language such as Maple is that communication with the computer promotes the use of the language of mathematics.

The transfer of emphasis away from manipulation skills and towards understanding and problem solving skills will require a complete re-examination of the course content. One change will be an increased emphasis on engineering applications of differential equations, including the mathematical modelling (pre-processing) and the interpretation of analytical results (post-processing). Another objective is to design classroom situations in which students will be able to discover new results on their own. Additional issues are:

- Which topics are of fundamental importance to Engineering? Mathematics?
- How should the topics be arranged for optimal clarity and comprehension?
- To what degree should group work and/or course projects be included?
- What can be done to improve the scientific and technical communication skills?
- How are each of the above reflected in the evaluation of student performance?

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Summary of Teaching

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I was hired as an Assistant Professor at the University of South Carolina in Fall 1991. In my three years at USC, I have had the opportunity to teach all levels of undergraduate and graduate mathematics. (A full listing is provided in the attached vita.) As a member of the Undergraduate Advisory and Calculus Renovation Committees, I have also participated in departmental discussions and decisions with regards to the revision of the Calculus sequence.

Other teaching experience has been accumulated at Carnegie Mellon University (1984–1989) and Purdue University (1989–1991). Both of these schools have long-standing and strong ties between their Mathematics and Engineering departments.

These experiences reinforce the importance of good communication on a variety of levels.

Inter-departmental communication is essential to maintaining the effectiveness of many lower-level mathematics courses, which are primarily populated by non-majors. For example, our differential equations requirement for Engineering students is MATH 242, while the corresponding course for Mathematics majors is MATH 520).

Two-way communication between student and professor is needed on a daily basis. One technique I use to initiate student communication is to require that all students visit my office hours at least once during the first three weeks of the course. Also, before the middle of the semester, I perform an informal course evaluation. The purpose of this evaluation is to solicit anonymous student feedback that can be used to improve the remainder of the course. A noticeable benefit of these exercises is that students realize that I am truly interested in assisting them in optimizing their benefits from my course.

One philosophy that I attempt to relate to all students is an appreciation of basic principles. This means I am much more interested in the process used to formulate and solve a problem than in the final answer the student obtains. And, when the final answer is of interest, I insist that students identify the significance of the answer. Since this approach is new to most students, there is often a large amount of initial resistance. However, in a matter of weeks, students begin to see that this approach facilitates understanding of the material. The impact of this deeper understanding are diverse: increased confidence in their mathematical ability, improved problem solving skills, and increased interest and appreciation of mathematics, to name a few.

Communication of these general concepts is not a simple matter. One technique I have found particularly effective is to create visual images for the students. In other words, I encourage students to "see the idea". In many situations it is possible to create an illustrative image on the blackboard. This becomes very difficult, time-consuming, and is less effective when the pictures are three-dimensional and/or require animation. In such situations I prefer to utilize the computer to create the images.

The ratings and comments on teaching evaluations provide reassurance of the effectiveness of my teaching. In the words of a MATH 520 (Fall 1992) student: "Dr. Meade is the type of guy that is able to present something that can be utterly terrifying in a very harmless manner. He doesn't try to intimidate you into learning the material, he's more of a coaxer and coach."

I believe that participation in the Lilly Teaching Fellows Program would provide an opportunity to further advance the effectiveness of my teaching and to implement new ideas in collaboration with a mentor.