"Introduction of Technology in MA 401"
A 2004 LITRE Grant - Final Report
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1 Introduction

MA 401, "Applied Differential Equations II", introduces the student to the subject of *partial differential equations*. Students use the methods of separation of variables and eigenfunction expansions to solve the classical wave, heat and Laplace equations in various coordinate systems. The goal of my LITRE project "Introduction of Technology in MA 401" was to use technology, namely computers and Maple, at appropriate spots in the course to both enhance learning and improve teaching. Although it is clearly not appropriate to attempt to include Maple in all mathematics classes, MA 401 is an ideal course in which to introduce technology. Technology was incorporated into in my section of MA 401 in fall, 2005 in the following ways.

1. Maple's computational engine was utilized by the students to greatly simplify the extremely time consuming, yet conceptually simple, computations involved in using generalized Fourier series.

2. Students solved the standard ordinary differential equations encountered in the course using Maple's dsolve command. These students had learned to solve such equations by hand in "Applied Differential Equations I".

3. The instructor in the course was able to present beautiful multi-dimensional animations of the solutions of the wave and heat equations in 2 and 3 dimensions. The textbook provides only sequences of "snapshots" of the dynamical processes, whereas Maple's animations provide very beautiful dynamical representations of the processes.

4. The eGrader software (Department of Mathematics, NCSU) created, distributed and automatically graded the Maple homework assignments for the course. The computer homework assignments were created by the author in spring, 2005.

5. I created numerous Maple worksheets, two QuickTime videos and a number of pdfs as teaching aides for the course. Many of the materials were created during the semester in response to questions from students. All the materials are available on line at the webpage for the class at http://www4.ncsu.edu/~lkn/MA401/index.html

2 Summary

My opinion is that my actions to include technology in MA 401 was on the whole a success. Let me explain why "success".

First let me say that the students absolutely loved the animations of the solutions of the boundary value problems we studied in the class. The students saw animations of waves on a string with various initial conditions, waves on a 2-dimensional elastic membrane anchored on a rectangular wire frame, and waves on a membrane anchored on a circular wire frame. We also animated heat flow in 2 and 3 dimensions. The impact of the animations was quite clear when I saw the students comparing the sequences of "snapshots" in the textbook to the live Maple animations.

Point #1: *The use of Maple in MA 401 had a positive impact on student learning. Students were better able to grasp the meaning of the solutions to the various boundary value problems by "seeing" actual animations of the motions.*

At the end of the course I gave the students a questionnaire which included 3 questions designed to measure this impact, and the results together with the questions are listed in tables 1 and 2 below. Table 1 indicates rather convincingly that the students were impressed with the use of Maple in the course. None of the students disliked the use of Maple, and no one thought that less Maple would improve student learning.

Table 1: Use of Maple in the class

The Questions	Yes	No	About right
1. Did you like the way Maple was used in your MA 401 class?	83%	0%	17%
2. Do you think more work with Maple in MA 401 will bring more understanding to the course?	63%	0%	37%

The third question (see Table 2) sought to determine if the students would take the course if it was known that Maple would be used in the course. The results are quite interesting. 63% of the students would sign up for the section using Maple. 0% would opt necessarily for the non-Maple section, although 37% of the student had no preference. In addition 8% told me that at the beginnning of the semester their choice would have been the "non-maple" section, but the course work and use of Maple changed their minds about Maple. (Apparently these students could not get in the "other section" of MA 401!!).

Table 2: Would you do it again with Maple?

The Questions	With Maple	W/O Maple	NO PREF	WITH (Changed mind during semester)
3. If you had the chance to enroll in two sections of MA 401, one that used Maple and one that did NOT use Maple, which one would you choose?	63%	0%	37%	8%

2.1 Pre and Post testing ability to use Maple

At the beginning of the semester I gave the students a short questionnaire and a short quiz about their knowledge of Maple. Here is a summary of the results.

Questionnaire: From Table 3 we see that a super majority of the students had some familiarity with Maple. It also shows that almost 1/3 of the class had a negative attitude toward Maple at the beginning of the course. As we saw above those negative attitudes apparently changed during the semester.

Table 3: Familiarity with and attitude toward Maple

The Questions	Total #	% Yes	% No
Have you used Maple before?	28	96%	4 %
Do you think Maple is a useful tool to help you study and learn mathematics?	28	68%	32%

Short Quiz: In Table 4 we show the results of the three question pre-testing quiz. There was a very simple arithmetic problem to do in Maple, a more complicated question about how to plot a function of 1 variable, and finally a more difficult question that asked the students to use Maple's animate command in a plot. The results show that at the beginning of the semester the students had only a rudimentary working knowledge of Maple.[1]

Table 4: Simple Maple Exam

The Questions	Total #	% Correct	% Incorrect
Simple Arithmetic Question in Maple	28	96%	4 %
Simple question on plotting x^2	28	43%	57%
Simple question on using animation	28	0%	100%

Taken together Tables 3 and 4 show that although students were familiar with Maple, their "ability to use Maple" did not seem to extend much beyond rudimentary arithmetic skills in the Maple worksheet environment.

During the semester the students completed 5 computer-based homework assignments. These assignments were created by LK Norris in the spring and early summer, 2005. Each problem set had between 3 and 6 problems in a Maple worksheet format, and the problems had randomized data. The actual worksheets that the students downloaded were generated by the eGrader software in the Mathematics department. The problems were available for download from the egrader server at http://egrader.math.ncsu.edu/eGrader/gethw.php , and after completing the homework the students uploaded the homework to eGrader for essentially instant grading. eGrader returns a "total grade" together with a grade for each problem in each assignment. Students were give multiple submissions for each homework assignment (approximately 2 + the number of problems in the homework assignment) to allow the students to "de-bug" their work. The "average" of the averages of all 5 homework assignments is 87.5 with a standard deviation of 12 points, with 7 out of 25 students having a perfect 100 average for all assignments. These results clearly show that given sufficient help, students in MA 401 can efficiently use the Maple program to perform the many complex computations needed in MA 401. The most difficult part for me was helping the one student in the class who had almost no previous work with computers.

2.2 Materials developed for the course

Professor Robert H. Martin and I worked separately to build the materials for the course. Here is a list of materials we developed.

1. Animations, in Maple worksheets, of solutions of the wave and heat equations in various coordinate systems. The animations were presented in class throughout the semester after working out the solutions of various boundary value problems.
2. A set of 5 Maple homework assignments covering those aspects of the course where Maple could be utilized effectively. The assignments were generated, distributed and graded all using the eGrader software developed in the Department of Mathematics for the calculus sequence MA 141, 241 and 242.

[1] This result is not too suprising, as most Maple users only commit to memory a small number of Maple commands. One obtains explicit information about the syntax for more complicated Maple commands "on the job", using Maple's extensive Help facility that is part of the worksheet environment.

3. A number of powerpoint presentations for use in lecture class.
4. A number of Maple worksheets and QuickTime videos, available to the students on-line, designed to help students to better understand the material under study.