Computing, Information, and Communication Technologies: Impacts on Undergraduate Mathematics

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For Andrea, Jennifer, and Peter there is no doubt about the value of their mathematics education. Presenting the results of their investigation into bungee cord jumping, they feel good about what they have accomplished. All three are first year students. Andrea is a computer science major, Jennifer is a double major in chemistry and mathematics, and Peter is a civil engineering major. After it is all over, the presentation complete, Peter comments that he has never had so much fun learning. Jennifer and Andrea ask when they will have another opportunity to "show their stuff." The presentation is for a group of campus visitors, high school students and their teachers from across Montana.

Andrea, Jennifer, and Peter are using MS Power Point with imported mathematical formulations, solutions, tables, and graphics. The look is professional and the results are impressive. They explain to the audience how they performed an experiment on a bungee cord to obtain data that they used to formulate their differential equation model for the bungee cord jump, how they solved the DE and generated graphs of the solutions including phase diagrams using *Mathematica* (a computer algebra system by Wolfram Research, Inc.), and how they tested their results. The challenge they were given was to determine how long a piece of bungee cord (from a local hardware store) would have to be cut so that a 200 gram mass would just "kiss" the floor when dropped from an arbitrarily specified height. (This was intended to mimic a contemporary TV commercial where a bungee cord jumper dips a corn chip, held in his mouth, into a bowl of salsa, located on the ground, without bumping his nose.)

The campus visitors challenge Andrea, Jennifer, and Peter with a fall distance of 1.6 meters. They do some quick calculations, cut the cord to length, and tie on the weight. The weight is dropped and falls to within one-half of a centimeter from the floor. The visitors are impressed not only by the good results and professionalism of the presentation, but also by the depth of the students' understanding. One of the visiting teachers comments that he did not encounter such sophisticated problems until he was in graduate school.

Technologies Make It Possible

Students can address more sophisticated problems earlier because computing, information, and communications technologies make them accessible to undergraduates. Bungee cord jumping, design of an automobile suspension, lake pollution, the bison in Yellowstone Park, the spread of AIDS, computer-assisted tomography, RADAR detection, the global positioning system, and many other problems can now be tackled by undergraduates from their first year on. High speed, desktop and notebook computers and hand held calculators are ubiquitous. Spreadsheets, numerical packages, computer algebra systems, as well as simulation and modeling software provide extensive resources for mathematics students. The Internet provides students unprecedented access to information including databases and datasets. And finally, students are communicating with the

aid of visualization and presentation software, and they can collaborate with others worldwide about their work via the Internet.

Promises for the Future

In the old days (i.e., five or more years ago) we taught and learned undergraduate mathematics with promises for the future. "You need to know calculus and differential equations so that you will be able to learn physics, engineering, economics and/or more advanced mathematics." The problems were simplistic and contrived - they had to be. For many students the promises were empty, especially for those enrolled in our service courses. They saw through the simplicities and motivation was lacking. The best example of this is pre-calculus.

At Carroll, the vast majority of our students in pre-calculus were business majors who were taking it to fulfill a general education requirement and who would take no more mathematics after pre-calculus. I am sure that this was and is the case elsewhere. While pre-calculus was taught as if to prepare students for subsequent studies in calculus, in reality, it was pre-nothing. Last year we changed our course offerings to add a course in discrete dynamical systems, which includes the study of systems of difference equations using matrix algebra. Now many of the students who would have taken pre-calculus take the discrete dynamical systems course instead. The problems are real and relevant, with many (but not all) of the applications taken from business and economics. This change was possible because computing technology and spreadsheet software enable students to do, with relative ease, realistic problems related to their major interest. It seems ironic that in many ways our new discrete dynamical systems course is better preparation for those students who wish to take calculus than our pre-calculus course is. It is our hope that many students who would normally not take calculus will be motivated to do so by their experiences in discrete dynamical systems.

Today, students see the importance of mathematics as they learn it. Technology allows them to engage real, contemporary, and relevant problems. Mathematics still holds promises for the future, but now they are more evident to its students. The study of mathematics motivates students to learn, it changes their worldview, and it enables them to pursue with confidence a wide variety of interests using newly acquired skills and knowledge.

Communication and Access to Information

Students in elementary statistics now access databases and obtain data sets from a myriad of Internet sites including the World Health Organization, the Center for Disease Control, and the U. S. Census Bureau. They download data sets and use a statistical package and/or a spreadsheet to perform statistical analyses of the data. From this they draw interesting and relevant conclusions and present their work, often times using electronic media such as Power Point or a web site of their own. Projects have included studies of poverty in America and the spread of AIDS worldwide, among others.

Some of our faculty now require students to develop web pages as part of a project, and these are posted on a class web site. (I know from personal experience that students are much more responsive to developing a web page than they are to writing a paper or a report.) Many parents are quick to respond and often times send us email notes expressing pride in the work done by their children. (I guess this is a modern version of hanging schoolwork on the refrigerator.) In addition to my own web page other sites to check for periodic postings of student works are Prof. Terry Mullen's and Prof. Marie Vanisko's web pages at www.carroll.edu.

When studying numerical integration in calculus, I have students access current, up-to-the-minute stream flows that are collected at stream and river monitoring stations from around Montana and transmitted via satellites to the Montana Natural Resource Information System web site at http://montana.usgs.gov/www/rt/imagemap/rt_imagemap.html. The data is provided graphically as well as in tables. Students are asked to estimate the net accumulation of water due to stream flows on the Missouri River in a string of three reservoirs near Helena over a specified time period. During this project students are often found checking on streams near their hometowns.

Different but Not Any Easier

Computing technology has made the study of mathematics different, but not any easier. There are new challenges for all of us who study mathematics. Once we learn to effectively use computing software like *Mathematica*, for example, (which in itself is no small task) we can readily obtain solutions for more substantial problems. But, how do we know whether these solutions are correct? How do we test them for validity?

Today's students may not spend as much time learning methods of integration as we did in "the old days", but now they need to learn how to use computers effectively and test their results. In essence, however, the challenges are the same. After all, how does one know that an antiderivative calculated by hand is correct? (You check the answer in the back of the book, of course.)

Today's students are adept at using computers and accessing information on the Internet. They have grown up with these technologies and are generally uninhibited in using them. In fact, most seem to enjoy it. The challenge is to help them learn to use these technologies effectively.

My Position About Technology

In 1993, we initiated an effort at Carroll to revitalize our mathematics curriculum. We set the following goals:

1. To integrate mathematical topics so that students would see and appreciate the connections and unifying themes among seemingly disparate areas of mathematics.
2. To motivate mathematics with applications drawn from a wide variety of disciplines in the sciences, engineering, computer science, the social sciences, and the humanities, so that students would see the study of mathematics as relevant and thereby change their worldviews.
3. To integrate the use of technology throughout the mathematics curriculum so that students could access significant and important problems and use mathematics effectively in trying to solve them.
4. To present perspectives from other disciplines in mathematics courses so that students would see the relevance and usefulness of mathematics and the connections mathematics has to most if not all areas that are of interest to them.
5. To include problems for students that require them to address ethical, social, and aesthetic issues in their study of mathematics.

It is this set of goals that embody my position about the future of mathematics education and the role that technology should play.

Over the past seven years, we have had considerable success in achieving our goals and we are proud of what we have accomplished. It is our most sincere hope that our students are the beneficiaries. I often ask beginning students whether they like mathematics. Almost always, the answer is yes. I sincerely believe that most students come to us liking mathematics and desiring to

learn more. It is our responsibility to nurture these likes and desires, building more confident problem solvers and better thinkers. Computing, information, and communication technologies make this job much easier.

In my twenty-three years of teaching college mathematics, I have never seen a better spirit and enthusiasm among our students than there is now. Andrea, Jennifer, and Peter are now juniors, progressing toward the realization of their personal goals, and mathematics is an integral part of what they have learned and accomplished. I am confident that their mathematics education will serve them well after they leave Carroll to pursue their professions. Their worldviews will be changed and mathematics will be an integral part of how they think and how they approach and solve real world problems. The use of technology has been a primary catalyst in making this possible.