SURVEY OF MULTIMEDIA ENHANCEMENTS FOR CALCULUS

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With the availability of mobile computer laboratories, teachers have more flexibility than ever to creatively facilitate the understanding of basic calculus concepts while increasing the enthusiasm of the students about the material. The challenge of implementing this technology in the classroom lies with the teacher, who needs to develop interactive projects and presentations for each lecture. Leaving the burden of publishing class web pages aside, questions often arise about what software packages and websites are available, and which are best at conveying the topics of a given course. Therefore, we designed a project to review current multimedia materials used in teaching college level mathematics and to produce a guide to help faculty use the resources we identified in their own calculus classrooms.

Our focus began with evaluating tools for lower level calculus classes, since these classes are most widely taught. There are a variety of new Web- and CD-based enhancements for these courses, some linked to specific textbooks and produced by traditional publishing houses, and some produced by independent operators. We surveyed these sites, wrote a concise review, and built a common area on our department web page where this information was made available. The review focused on quality, relevance to the calculus curriculum, and ease of integration into faculty development and student learning practices. We wanted these materials to generate ideas for new tools tailored to our classes.

In particular, we were interested in materials that facilitate multimedia demonstrations and interactive tutorial software. This would give students an opportunity to learn the material in ways other than listening to their professors or reading their textbooks. Additional reviewed resources included introductory multimedia lectures that students could look at before class, as well as packages for faculty to create presentations to enhance in-class lectures. Another area of interest was interactive homework-helper software that generates exercises and gives focused guidance based on incorrect responses. For example, the University of Rochester has a program called WeBWorK (http://webwork.math.rochester.edu/) that enables students to check calculus homework problems on the web and get instant feedback. We envision a Web-based calculus learning support center that is available 24/7--outside the classroom whenever the student desires assistance.

One example of a successful program that uses multimedia enhancements is the Dynamical Systems and Technology Project at Boston University, supported by the NSF. This group has brought technology to the classroom in classes such as Ordinary

Differential Equations to emphasize the importance of interpreting solutions displayed graphically as well as symbolically. This leads to a much deeper conceptual understanding and avoids the all-too-common problem of students thinking about mathematics naively because they are distracted by the computations:

> *We find that many of our students become proficient at certain symbolic calculations. However, if we ask them general questions about the fundamental mathematics involved, we find that there is little understanding of the basic concepts. We need to encourage students to see the forest as well as they see the trees.*[1]

Classical-style courses in Differential Equations and in calculus tend to present analytic (symbol-manipulation) techniques to solve certain classes of problems, never mentioning that these techniques were largely useless for actual problems that come up in the field. By using numerical approximations and qualitative analysis in a technologically enhanced environment, students can approach these formerly unsolvable problems. But simply handing a student a graphing calculator does not enhance learning. Deficiencies in current curriculum and the discomfort of faculty who don't have curricular support lead to the failure to integrate technology to "finish the story." For example, a student rarely uses their calculator to graph a curve to interpret the information a derivative provides. Instead, they use it for trivial tasks such as approximating improper fractions and numbers with negative exponents. Computer animations combined with pointed questions can present difficult, rarely understood traditional topics in new ways.

Interactive projects can also be brought to the students in class to engage discussion. Instead of moving classes to computer labs, we subscribe to the use of mobile labs in the classroom. These are banks of laptops with wireless Internet connections that can be transported to any classroom for individual student use. This opportunity, which affords the use of technology in all classes, initiated the development of a resource center to help encourage others to expand their pedagogy. Since we have experience and have found success in this area, we volunteered to communicate our experiences and create a forum for others to share. Dr. Billings has actively used computer-based assignments in her Differential Equations classes. She also participated in the integration of interdisciplinary labs. These types of projects not only help students develop a variety of skills but also convince the students that they can complete large-scale projects if they break them down into manageable parts. Dr. Weinstein taught application-oriented calculus that included intensive use of computers and calculators. He is also familiar with using technology to enhance mathematical modeling and problem solving. He currently teaches a course for schoolteachers that involves them in innovative ways to use computers in mathematics classrooms. Some of these teachers have little experience using computers, so he has learned how to get people excited about and engaged in using technology in mathematics education.

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[1] Paul Blanchard, "Teaching Differential Equations With a Dynamical Systems Viewpoint," College Mathematics Journal, Volume 25, no. 5, November, 1994, pp. 385-395.

As an integral part of the project, we hired a student assistant for the summer, Rajni Jain. Rajni was a graduate student in Computer Science who took the undergraduate calculus class the previous semester. This student was an accomplished java and database programmer and appreciated the programming effort behind the well-organized, comprehensive sites. Also, having recently struggled through this same material, she could objectively evaluate the content through a student's eyes. Rajni had many ideas to enhance the course, focusing on the topics she found most difficult.

We began with a search of the Internet for sites that provided free resources for teaching and learning calculus. We recorded the title, the authors/producers, the link, the topics covered, and some general comments about the site. We then categorized each site by type:

- **Comprehensive Link List**: A site with a comprehensive list of links to external sites with each calculus topic categorized and sites with each category distributed.
- **Link List Site**: A site with a list of links to external sites but not so comprehensive a listing.
- **Categorized List**: The links are categorized according to calculus topics, such as differentiation, integration, etc.
- **Searchable Links**: The topics in the web site are searchable by a search engine on the web site.
- **Categorized Topics**: Another categorization scheme where the topics are categorized according to different modules.

These categories are intended to aid in quickly searching for a specific topic to present, or supplemental exercises to suggest. Then, a rating system was developed to describe the quality of the resources:

- **Excellent Site**: A very comprehensive site with a categorized and/or searchable list of calculus topics, a good tutorial with examples and animations, problems with solutions and a list of links to external calculus sites, and other calculus resources for the student as well as the instructor, such as tips on how to ace a calculus exam.
- **Very Good Site**: A site with a categorized list of calculus topics and a tutorial with some examples but no animation and few problems with feedback.
- **Good Site**: A site with a good tutorial but not very comprehensive. It may or may not have examples and problem sets with solutions.
- **OK Site**: A site with a mediocre tutorial. It will have some examples and problems, sometimes with solutions.
- **Very detailed tutorial**: A site that contains a very comprehensive tutorial only.

Only the functional, favorable sites were included.

From our category and rating system, we created our Classroom Resources site, http://www.csam.montclair.edu/mathsci/classroom/classroom.html. First, we formed a condensed list of recommended sites for the following topics: Online Textbooks and

Tutorials, Animations and Graphics, Supplemental Calculus Problems, and Additional Resources. This list is intended as a quick reference for teachers. We also included the full ratings of 45 sites on this page. From a subset of these ratings, we then created another list to highlight sites with supplemental calculus problems and quizzes. A typical entry for our rating system would look like the following:

Title	Type	Authors/Producers	Topics
Visual Calculus	Link list Comprehensive Tutorial Interactive Animation Problem Sets Right/Wrong	Lawrence S. Husch and the University of Tennessee, Knoxville	Precalculus, Differential and Integral Calculus
Link: http://archives.math.utk.edu/visual.calculus/			
Comments: *Excellent Site.* Linked List of calculus topics from precalculus to derivatives and integration. The comprehensive tutorial explains calculus topics with graphics and visuals. Uses Java Applets and plug-ins for LiveMath (an interactive program to do calculus, product of maple) and Macromedia Flash for some illustrations and animations.			
Applied Calculus	Categorized List Comprehensive tutorial True/False quiz Java Graphing Utility GIF animations Interactive Graphics	Stefan Waner and Steven R. Costenoble	All of Differential and Integral Calculus
Link: http://www.ohaganbooks.com/StudentSite/tccalcp.html or www.appliedcalc.com			
Comments: *Very Good Site.* The links are categorized according to chapters in a book. The site is based on the Applied Calculus book by the authors. Whole chapters with summary, interactive examples, true/false quiz without feedback, review exercises, and Excel tutorial. The tutorial is very comprehensive and explains the topics in a very detailed manner with interactive examples. Also contains math tools and utilities such as the Java Graphing utility, the Function Grapher, and an evaluator where in the user can input the problems and check them and get help on the wrong ones.			

We also produced a curriculum guide that recorded sites that work particularly well in the Calculus I syllabus. Useful enhancements were recommended for typical areas of difficulty such as Related Rates, Derivatives and Shapes of Curves, Optimization, The Definite Integral, The Fundamental Theorem of Calculus, Applications of Integration, and Limits. These sites were found using the review, and each has its own purpose. Some sites are ideal for a demonstration in class, while others are nice tutorials for review for students on their own. In the future, we plan to include sites for each purpose for each topic, especially hands on experimenting of students in class.

We are not the first to adopt technology, but we will be among the first at Montclair State University to facilitate the intensive use of mobile computer laboratories. Most pedagogical information, innovation, and advice are passed by word of mouth. These successes in the classroom are usually lost as class assignments change and people move on. We plan to record the ideas from our program and others on our website, and then learn from and build on them as we encourage our colleagues to adopt and adapt our implementation. We hope these efforts will be considered valid and useful by other academies, colleges, and the scholarly community.