Active Learning in Mathematics via Tablet PCs, Web-Based Software, Podcasts, and Interactive Homework Systems

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Abstract: *The Department of Mathematical Sciences at Clemson University has supported several technology innovations (in addition to new classroom design) to improve student outcomes in its Calculus courses. With 2006/2007 grants from Hewlett-Packard, HP Tablet-PCs with web-based software were placed in several STEM classrooms to enhance interaction. Digital homework systems (MyMathLab, WebAssign) and podcasts are used to provide students with new forms of communication to enable them to take control of their own learning more effectively. Blackboard has been used extensively to improve coordination of and communication within large-enrollment, multi-section courses, taught by a mixture of faculty and graduate TAs. We will address student performance and perceptions in the context of these innovations.*

Keywords: *Active Learning, Tablet PCs, Podcasts, Online Homework Systems, Blackboard Workgroups, Pen-based Learning, Web-based Software.*

Active learning, in and out of the classroom, conveys images of students working on problems and communicating with each other and the instructor. Instructors of Mathematics who promote active learning find ways to move beyond a classroom of long lectures and static homework assignments. They find ways to achieve new levels of communication in their content-heavy discipline that has little time to spare and often large class sizes. This is where technology (and new instructional design) has been employed and why we present below a summary of recent applications of technology used at Clemson University to promote active learning in our Science/Engineering and Business Calculus sequences.

Part One: Pen-Based Technology

As a result of a 2007 Hewlett-Packard Leadership Grant, we have placed HP Tablet PCs into Clemson University's new multi-disciplinary Teaching-with-Technology Experimental Classroom. Our Math, Engineering, and Computer Science Departments use this equipment in order to build on the results of an earlier 2006 HP Technology-for - Teaching Grant awarded to the Department of Mathematics. All participating instructors are committed to active learning in the classroom, to reaching out to weak students, and to sharing their teaching experiences.

Technology Implementation: Students in MTHSC 106 (Science/Engineering Calculus) use the HP Tablet PCs with the web-based software packages, *Ubiquitous Presenter* and *Messagegrid*. Short lectures are punctuated with highly symbolic, graphical, and often anonymous, online submissions of their work from students. From these submissions, a few are chosen for their mistakes-of-interest and are then projected, discussed, and annotated in class by the instructor. All are saved for later reference. Group work is submitted via the Tablet PCs for grading. Students, as well as the instructors, use the

tablets to create short 2-3 minute audio-video recordings of frequently-missed exam questions from earlier semesters. These recordings are made available on the web, organized by topic, as .swf files (or as .mp4s which are downloadable as podcasts), and utilized for exam preparation.

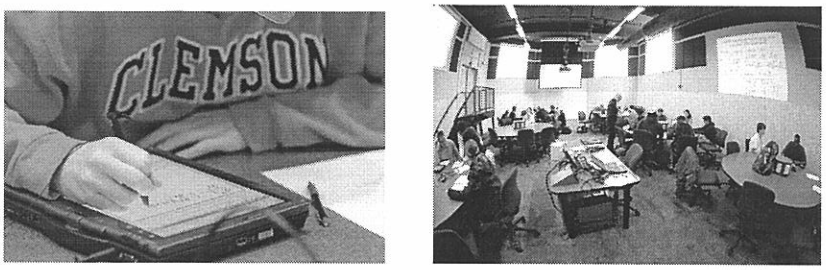


Figure 1. *HP Tablet PCs and New Technology Classroom*

Impact on Student Learning: Using the HP Tablet PCs in class was one of several changes made in our calculus courses to promote active learning. Statistics reported earlier from instructors teaching both Tablet and non-Tablet sections suggested that at-risk students benefited from the frequent anonymous submissions. (See M. Reba and B. Weaver. "Tablet-PC Enabled Active Learning in Mathematics: A First Study." *Proceedings of the International Conference on Pen-Based Learning.* Catania, Italy: 2007.)

It may be that an important part of learning occurs when students "go public" with their work because they are involved, alert, and demonstrating what they know and don't know. Most students are in agreement with the following student comment: "I learned more from seeing you correct other student's mistakes, than from the lecture or reading the text." By correcting mistakes in this public forum, we review earlier concepts while teaching new ones.

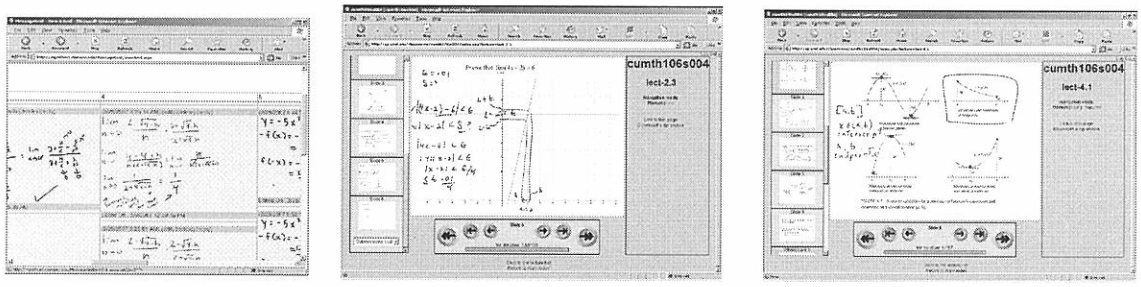


Figure 2. Student Submissions on *Messagegrid* and *Ubiquitous Presenter*

Impact on Teaching: Instructors are able to teach a new concept in an interactive, spontaneous context while monitoring student understanding and offering personal feedback. The speed at which information is exchanged between instructor and students allows the same amount of material to be covered in class. The necessary pace is maintained. A year from now we will have more data concerning the effectiveness of this technology in the classroom. Instructors continue to gather statistics from different sections of their classes--taught with and without the Tablet PCs. Researchers will look closely at class profiles, at DFW rates, and compare mean scores on common exams.

Student satisfaction will be examined through surveys and interviews and observation of student behavior in the classroom, such as participation and attendance. Faculty will collect "best practices," post discipline-specific activities on a public website, and suggest features that might be added to the current software.

Part 2: Coordination, Active Learning Activities, and Online Homework

Coordination and Active Learning: Five large enrollment multi-section courses at Clemson University are coordinated. These courses are: Science/Engineering Calculus (MthSc 106 and 108), Liberal Arts/Business Calculus (MthSc 102 and 207), and Liberal Arts Math (MthSc 101). Instructors of coordinated courses include tenured faculty, non-tenure track faculty, and graduate students. Some courses have more than 30 sections. These courses use a common syllabus, employ common testing, and common grading. **SCALE-UP** (Student-Centered Approach to Large Enrollment Undergraduate Programs), adapted from North Carolina State where it was developed by R. Beichner for use in Introductory Physics courses, was introduced with the aim of increasing student success in Science/Engineering Calculus. The table below indicates the initial improvement in student success before and after changes were made to the teaching approach in that course:

Pre Scale-Up					Post Scale-Up	
2001 *844 total*	2002 *688 total*	2003 *723 total*	2004 *735 total*	2005 *786 total*	2006 *672 total*	2007 *540 total*
DFW 42%	DFW 37%	DFW 37%	DFW 45%	DFW 44%	DFW 23%	DFW 19%
W 11%	W 11%	W 13%	W 13%	W 8%	W 4%	W 5%

Figure 3. DFW Rates for Beginning Calculus (Science/Engineering)

Instructor communication was important in implementing the new approach. In addition to a weekly discussion meeting of all instructors, a Blackboard workgroup was used to post and share materials. Here, instructors can post and share ideas, group activities, drafts of exams, and grading guidelines. Pages from the workgroup are copied below to illustrate types of entries:

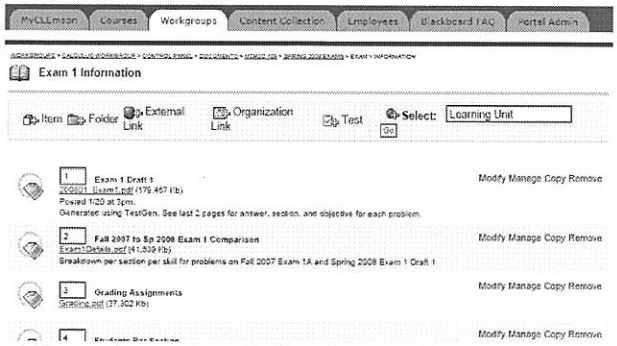
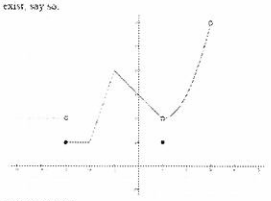


Figure 4. A Sample Workgroup Page

An important part of course coordination is common testing and grading. The workgroup page and weekly meeting are used to communicate thoughts about testing and grading guidelines. Below is example of a grading guidelines page for one problem on finding limits on a given graph:

1. (10 pts.) Find the following limits, if they exist, for the function, $g(x)$, graphed here. If a limit does not exist, say so.



(Each part a – j is worth 1 point.)

a. $\lim_{x \to -3^-} g(x)$ b. $\lim_{x \to -3^+} g(x)$ c. $\lim_{x \to -3} g(x)$

d. $\lim_{x \to -1^-} g(x)$ e. $\lim_{x \to 1^+} g(x)$ f. $\lim_{x \to 1} g(x)$

g. $\lim_{x \to 1^-} g(x)$ h. $\lim_{x \to 4^-} g(x)$ i. $\lim_{x \to 4} g(x)$

j. $\lim_{x \to 5^+} g(x)$

2. (3 pts.) Say whether the function is even, odd, or neither. Give algebraic reasons for your answer.

$f(x) = -x^3 + x$

MthSc 106 **Exam 1** Spring 2008
Calculus of One Variable I **Grading Guidelines**

Problem 1 (10 points)

Parts a – j (1 points each):

Work on Problem	Points Awarded
Correctly evaluate the limit or say that it does not exist.	1 pt. per limit
Notes: • Subtract 1 point for bad notation after 2 or more notation errors occur. (EX: missing "=", "= DNE")	

Problem 2 (3 points)

Work on Problem	Points Awarded
Evaluate $f(-x)$.	1
Determine that $f(-x) = -f(x)$.	1
State that f is odd.	1
Notes: • Subtract ½ point for poor notation. • Subtract ½ point for plugging in a specific a value. Need to be more general. • Subtract ½ point for stating odd because $f(-x) = -f(x)$ without showing what $-f(x)$ is.	

Figure 5. A Sample Problem and Grading Guidelines

An additional feature of the Blackboard workgroup is the ability to include instructors from other universities in the Clemson workgroup. A colleague from another university selected an activity worksheet from among those posted and commented as follows, "My overall reaction was one of enjoying the animation, interaction, and general activity of learning and solving a problem going on in the classroom.... I feel it was a positive exercise and it reinforces that the more student involvement during class the more active learning is going on... It's more work for the teacher but draws teacher and class together in a productive way. Down with passivity!"

Statistics showing improved success rates from the Liberal Arts/Business Calculus course are presented in the following table:

Fall	A	B	C	D.W.F
2005	106	221	190	126
793 total	13.40%	27.70%	24.00%	34.80%
2006	132	205	156	213
706 total	18.70%	29.00%	22.10%	30.20%
2007*	139	223	171	197
730 total	19.00%	30.50%	23.40%	27.00%

**Active Learning was widely used beginning in 2007.*

Figure 6. Grades for Beginning Calculus (Business)

Online Homework: Several online homework systems have been used as a part of coordinated courses. The specific online homework systems used currently are MyMathLab which is used in Engineering/Science Calculus and WebAssign which is being tested for use in Business Calculus. The advantages of online homework for students are the instant feedback, the help features which individualize instruction similar to what might be provided by an instructor responding to a student question during office hours. Instructors benefit from the automatic grading and recording of grades. Online homework usage continues to create frustration for everyone when correct answers are not recognized and when students have no feedback as to why their answers were not accepted. Some students have difficulty with the equation editors. Traditional homework is still being used to supplement online homework in most classes because evaluating intermediary steps is important. Advances in technology should improve this situation.

Conclusions:

Technology (Digital ink, Projectors, and the Web-based Software), in conjunction with new instructional models, can provide frequent, effective, detailed (and even anonymous) communication between students and their instructor in large, content-heavy classrooms. Technology (Class Management Systems and Workgroups) allows for multiple-section courses to be coordinated so that active learning can be promoted and developed even in sections led by busy or reticent faculty and graduate teaching-assistants. Finally, technology (Podcasts and Online Homework Systems) allows students to receive personalized instruction even outside the classroom.