Tablet PCs and Web-based Interaction in the Mathematics Classroom

Dr. M. Reba
Department of Mathematical Sciences, Clemson University, Clemson, SC 29634 USA
mreba@clemson.edu

Abstract
Bringing Tablet PCs and a projector, obtained through a 2006 Hewlett-Packard Teaching-for-Technology Grant, into multiple sections of two large-enrollment freshman courses--Calculus and Liberal Arts Math, allows students to use the pen/digital-ink feature to submit solutions anonymously via web-based classroom-interaction software, *MessageGrid* or *Ubiquitous Presenter*. The instructor projects, annotates, and saves these submissions. Communication now occurs with students reluctant to participate, and active learning is enabled in the classroom because all students are primed for instructor feedback. Weaker students benefit from the modeling of alternative problem-solving strategies and the review of prerequisite concepts, both of which regularly occur when discussing student submissions. Class profiles (GPA, class rank, and math placement scores) and performance results on common exams are compared with those of the traditional sections. All sections of each course are closely coordinated, with the same text, topics, and exams. Student and faculty perceptions are gathered in a systematic way (3 times throughout the course).

Introduction

Much research has focused on the importance of success in the first college math course, not only with its correlation with retention rates in STEM fields [2], but also with retention rates in the university [5]. Today most mathematics educators embrace active learning as a desirable classroom pedagogical style where the instructor minimizes lecture time and engages the students in problem-solving. Active learning demands that a student take charge of his own learning, identify what he doesn't fully understand, seek remedies, and interact with his instructor.

We wanted to use Tablet PCs and Pen-Technology to make active learning a reality in the classroom while maintaining the necessary pace of the course. Tablet PCs achieve active learning in the classroom because an instructor is able to teach a new concept in a context that has meaning for all the students—e.g., every student, working on his own or with others, shares his work with the class and receives immediate feedback from the instructor. The goal is not to replace face-to-face tutorial sections or labs, but rather to maximize the instructor's valuable time with the students in front of the classroom.

Project Design

By means of a 2006 Hewlett-Packard "Teaching for Technology" Grant, we inserted HP Tablet PCs and projectors into twelve sections of both freshman Calculus and Liberal Arts Math. Back to back Tablet PC sections were scheduled in the same two classrooms. Tablets were set out in the morning and returned to a locked cabinet in the afternoon. With this implementation, individual students or groups of students now submit problem solutions anonymously via electronic ink to the instructor at various points throughout the class which are then projected, discussed, annotated, and saved. This classroom interaction takes place via special web-based software, either *MessageGrid* or *Ubiquitous Presenter.*

In Fall 2006 the Department of Mathematical Sciences at Clemson University implemented a new classroom model in all 27 sections of freshman Calculus to address its long-standing, unacceptably- high DFW rates in this course. This model is a version of SCALE-UP (Student-Centered Activities for Large-Enrollment Undergraduate Programs) which was a 2001 innovation from North Carolina State University's physics classrooms.[1] SCALE-UP involves redesigning classrooms with round tables to facilitate group work on graded activity sheets, as the instructor and student assistants move about the tables answering questions. At Clemson University, the traditional offering of Calculus I (MthSc106) is a 15-week, 4-hour course that meets 4 times a week. Our SCALE-UP Calculus classrooms have a maximum of 45 students, include a short lecture (10-15 min) preceding the group work, and have one graduate Teaching Assistant and one undergraduate SI leader (Supplemental Instruction [11]) to grade homework journals in addition to answering student questions.

In Spring 2007 we experimented with HP Tablet PCs in 4 sections of SCALE-UP Calculus. Each group of 2-3 students in each classroom has a Tablet PC and "inks" solutions to submit to the instructor via classroom interaction software, *MessageGrid* or *Ubiquitous Presenter*. Both the Tablet PC sections and non-Tablet PC sections take common exams. The final grade is calculated the same way in all sections.

The traditional offering of MthSc101 (Mathematics for Liberal Arts) is a 15-week course that meets twice a week for a 75-minute lecture (19 students per graduate instructor; up to 35 per full-time instructor) The regular course has no computer component. Each instructor assigns weekly credit homework and quizzes. There are three common exams and a comprehensive common final exam. In Fall 2006, there were 5 HP Tablet PC-based sections of MthSc101, containing only 19 students each, with a Tablet PC for each student. In Spring 2006, there were 4 sections with approximately 35 students each.

Instructors in both the traditional and Tablet PC sections are encouraged to lecture for no more than 15 minutes on new material before they allow students to try problems. In the Tablet PC sections, students are asked to work problems that appear on their screens and submit solutions which then appear on the instructor's PC which the instructor can highlight and discuss. To make the two versions of the courses as comparable as possible, experienced instructors and first-time graduate instructors taught both Tablet PC and non- Tablet PC sections. There are common exams and the final grades are calculated the same way in all sections. Attendance is taken in all sections. All sections have access to a course website that posts course materials.

Software

The web-based software program, *MessageGrid*, was developed at Clemson University in 2004 [7]. It enables classroom interaction by allowing students to ink their submissions into a large grid, where the questions might be in columns, and the student responses in rows. Images (such as the logic circuits in Figure 1) can be imported into the grid. The instructor can then scroll down a column, enlarge a particular submission, and annotate someone's correct or incorrect approach to the problem. *MessageGrid* is easy to learn and involves no registration procedure. An instructor simply copies a list of his students' University Userids to a list of Grid Users. Students can access all the grids for their class using the internet from any computer.

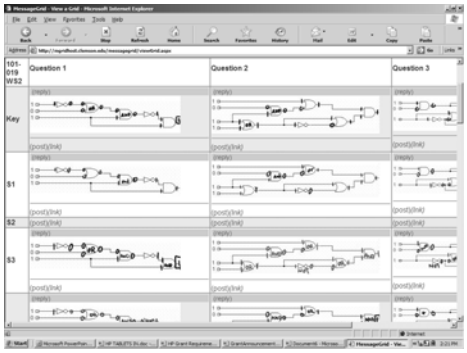

Figure 1. *MessageGrid* Submissions

Ubiquitous Presenter (UP) was developed in 2005 at the University of San Diego as an outgrowth of University of Washington's *Classroom Presenter* (CP).[10] It uses Tablet PC ink to allow instructors to annotate pre-prepared Powerpoint slides and upload them to a location on the web where students can then create submissions for in-class activities. The instructor sees a list of student submissions to the left of his screen and can enlarge any one of them:

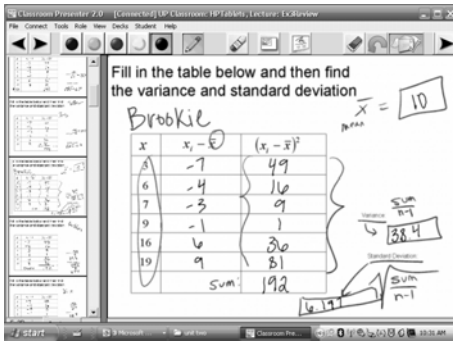

Figure 2. *Ubiquitous Presenter* Submissions

Performance

Performance results are given only for MthSc101 (Fall 2006), since the results for MthSc106 (Spring 2007) are still being calculated. Results on the Common Exams for the 5 Tablet PC sections are compared with the 21 non-tablet sections. The mean scores in the Tablet PC sections were consistently 2-3 percentage points higher than in the traditional sections (using a one-tailed t-test for independent samples with unequal variances; See Table 1).

This is surprising for two reasons: (1) More than one week of classes was spent on acclimating faculty and students to the new hardware and software. Time was lost on teaching the course material. (2) The class profile was almost identical for the Tablet PC and the Traditional sections (see Table 2). The average scores on the CMPT (Clemson Mathematics Placement Test), the average GPAs (Grade Point Averages), and the number of freshmen did not confer any advantage. There is a correlation between GPA and Final Grade (r = .853).

Table 1. Performance on Common Exams.

Variable	Descriptive Statistics	Tablet PC MthSc101 N=97	Traditional MthSc101 N=437
Exam 1 (%)	Mean S.D.	88.37 10.30	85.54 12.32
Exam 2 (%)	Mean S.D.	77.13 18.73	75.32 18.29
Exam 3 (%)	Mean S.D.	80.95 10.54	77.58 14.41
Final Exam (%)	Mean S.D. t df p	79.01 12.76 2.298 135 <0.012	75.46 15.01
Final Grade (%)	Mean S.D.	83.11 11.75	80.58 13.38

Table 2. Class Profiles

Variable	Tablet PC MthSc101 N=97	Traditional MthSc101 N=437
CMPT (Total possible = 50)	28.78	29.2
GPA (Total possible= 4.00)	2.96	3.03
Class Standing Freshman (%)	76.66	77.80

Two instructors taught both Tablet PC section and traditional sections of MthSc101 in Fall 2006 and had mean scores on their final grades that were 6-11 percentage points higher in their Tablet PC sections, given similar class profiles. (See Table 3.)

Table 3. Same Instructor/ Different Sections

Variable	S. Samson		M. Reba	
	Tablet PC MthSc101 N=19	Traditional MthSc101 N=19	Tablet PC MthSc101 N=19	Traditional MthSc101 N=32
Final Grade Mean S.D.	 81.21 11.15	 75.95 16.55	 84.63 9.54	 73.54 15.4
CMPT Mean S.D.	 30.13 .73	 28.94 .94	 27.69 .99	 28.26 .77
GPA Mean S.D.	 1.94 3.12	 2.47 2.41	 2.94 1.84	 2.74 1.82

One of Reba's traditional classes (in Table 3) had more students which is a variable that affects these results, and in Spring 07 we are looking at the impact of Tablet PCs in larger sections. The DFW rate (Poor-Failing-Withdraw) in all sections of MthSc101 was 19% in 2005-06 and dropped to 13% in Fall 2006. Though the DFW in the tablet PC sections was slightly lower (12%), since the reduction in the DFW rate was seen across several undergraduate courses, it might be explained by a freshman class with higher academic qualifications than in the previous year.

Behavior and Satisfaction

The 27 sections of MthSc101 in Fall 2006 had approximately 70% freshman from majors not requiring Calculus, such as Education, Nursing, Communication, Psychology, English, and Political Science. In a first-week survey, one-fourth of all the students enrolled in MthSc101 indicated their belief that this would be a very difficult course and two-thirds described themselves as rarely or never speaking up in class. Two–thirds cited their primary/secondary learning sources as text/lecture, with the remaining students almost equally split between worksheets/text and lecture/homework. By the midterm survey in the Tablet PC sections, 89% were describing themselves as actively participating in class and citing their primary learning source as the pen-based/ in-class activity sheets (projected via MessageGrid or Ubiquitous Presenter). At the end of the term, for the Tablet PC sections, these new numbers were up to 95%. This is consistent with the goal of active learning in the classroom in the Tablet PC sections. Other pen-based experiments have also shown dramatic increases in participation . [4]

It was not unusual for students in the Tablet PC sections to comment that, even though the same material was covered and approximately the same number of homework problems assigned, "having immediate feedback on my work during class puts the material in my head, really reducing the amount of outside study-time." Anonymous student evaluations were looked at for the two instructors who taught both a traditional section and a Tablet PC section in Fall 2006. Ratings were significantly higher in the Tablet PC sections on questions involving "clear communication" and "feedback," but not on overall ratings of the instructor or course.

Full-time instructors teaching the traditional sections have about 2 1/2 times as many students as the Fall 2006 Tablet PC sections, but the grading of homework is done by teaching assistants, and exams are graded by teams. So smaller class size has negligible benefits for full-time instructors teaching the Tablet PC courses. Perceptions by instructors teaching the Tablet PC sections were that they had to spend more time developing materials and lecture content (in conjunction with the new software), and interacting with students outside of class (especially during the first several weeks). Instructors also spent time on grant-related formalities and extra meetings to discuss experiences with other faculty. Despite this, everyone teaching with the Tablet PCs opted to do so for another semester (Spring 2007). Instructors can assess student understanding as they teach. The interactive software delivers detailed student work (unlike clickers) that directs and enhances the lecture.

Future

We plan cross-disciplinary collaboration to further explore Tablet PC/pen-based technology. Given the current environment where most students do not have their own Tablet PCs, we are

promoting a special classroom where Tablet PCs are available for students to use during class and where multiple STEM disciplines can schedule courses.

References

[1] Beichner, R. Student-Centered Activities for Large-Enrollment University Physics (SCALE-UP). NSF Award 9981107.

[2] Budny, D., and W. LeBold, "Is When as Important as What?," *ASEE Annual Conference Proceedings,* 1985, pp. 1-10.

[3] Davidson, N. A. Cooperative Learning in Mathematics: A Handbook for Teachers. Addison-Wesley Publishing Co., Inc., 1990.

[4] Griswold, W.G., Shanahan, W. Brown, R, Ratto,M, Shapiro, R., and Truong, T. Active Campus Experiments in Community-Oriented Ubiquitous Computing, *IEEE Computer,* October 2004.

[5] National Science Board. *Undergraduate Science, Mathematics and Engineering Education: Role for the National Science Foundation and Recommendations for Action by Other Sectors to Strengthen Collegiate Education and Pursue Excellence in the Next Generation of U.S. Leadership in Science and Technology. Report of the Task Committee on Undergraduate Science and Engineering Education,* Neal, H.J., Chair., Washington DC.

[6] Ohland, M. W. and B. Still. Identifying and Removing a Calculus Pre-Requisite as a Bottleneck in Clemson's General Engineering Curriculum, *Journal of Engineering Education,* 2004, 253-57.

[7] Pargas, R., and Austin, J. Work in Progress: Providing Interactivity in a Technology-rich Classroom. *Proceedings of the ASEE/IEEE Frontiers in Education Conference,* April 2005, 13-15.

[8] Seymour, E. and N. Hewitt. Talking About Leaving: Why Undergraduates Leaving the Sciences. Westview Press, Boulder, CO, 1997.

[9] Denning, T., Griswold, W., Simon, B., and Wilkerson, M. Multimodal Communication in the Classroom: What does it mean for us? *Proceedings of the 37th SIGCSE Technical Symposium on Computer Science Education,* March 1-5, 2006, 239-223.

[10] Simon, Beth, Anderson, R., Hoyer, C. and Su, Jonathan. Preliminary Experiences with a Tablet PC Based System to Support Active Learning in Computer Science Courses. *Proceedings of ITICSE,* June 2004, 213-217.

[11] Widmar, G.E. "Supplemental Instruction: From Small Beginnings to a National Program" in D. C. Martin and D. R. Arendale (Eds.), *Supplemental Instruction: Increasing Achievement and Retention,* Jossey-Bass, 1994, 3-10.