

**Analysis of effects of tablet PC technology  
in mathematical education of future teachers**

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**Abstract.** *This paper presents description of authors' current and proposed work using Tablet PCs mobile computer lab in future teachers' preparation classes. Faculty from the Colleges of Education and Science at the University of Texas at El Paso worked together to study the effects of incorporating Tablet PC technology in pre-service teachers' math education. We assessed the significance of the technology by evaluating and comparing students' final project and course grades. We did a statistical comparison of two groups: the treatment group where students extensively used Tablet PCs to work on mathematical investigations and lesson plans and the control group where students worked on identical math investigations and created lesson plans without utilizing any technology. The outcome shows a greater improvement in the treatment group's mathematical content knowledge versus that of the control group's. Current and future work involves evaluation of the change in acquiring mathematical pedagogical knowledge by pre-service teachers. Future teachers (in both groups) are asked to create original math lessons using unique manipulatives and hands-on activities. Students in the treatment group are required to use Tablet PCs to create hands-on activities. Groups' pedagogical knowledge will be compared using pre/post tests, questionnaires and knowledge and attitude surveys.*

**Introduction**

The concept of a “digital divide” separating those with access to computers and communications technology from those without is simplistic.

Research (Peslak, 2005) shows that computers per students and total number of computers in a school significantly effects student learning, but surprisingly there is a negative impact of this metric on standardized reading and math scores.

Another study (Warschauer, 2005) shows that kindergarten through 12th grade students from a higher socioeconomic status are more likely to use computers for experimentation, research and critical inquiry; students from a lower socioeconomic status usually engage in less challenging drills and exercises that do not fully utilize the advantages of computer technology.

To benefit from computers teachers should have access to good educational software and be familiar with the available software. Ideally teachers should be able to use appropriate software to create math activities that guide students to higher order thinking. Pre-service (future) teachers should be confident and knowledgeable about effective instructional strategies that incorporate variety of digital technologies.

Located on the Rio Grande River in the far western edge of Texas along the borders of Mexico, New Mexico and Texas, El Paso is a bustling urban area of 700,000 people, more than 74% of whom are Mexican in origin. Widely known as a major passageway for land travel through the mountains from Mexico to the U.S., El Paso sits in close proximity to the Mexican City of Juarez, with a population of more than 1.2 million; together El Paso and Juarez represent the largest metropolitan along the 2,000- mile U. S. /Mexico border. Generations of Mexicans and Mexican-Americans view El Paso as a place where they can pursue their hopes, aspirations, and dreams. Almost a quarter of El Paso's population is foreign born, and more than 50% of El Paso's households speak Spanish as the language of preference. The University of Texas at El Paso prepares a large number of bilingual educators to work with the growing Hispanic population.

In the beginning of 2004 the team of researchers from the College of Education and College of Engineering received a grant from Hewlett Packard that allowed UTEP to organize a mobile Tablet PC lab. This lab was readily available for use in the math and math methods classes taught in a field-based environment. It was this HP grant which provided us the necessary technology for this study.

In this paper we present the study on the effects of Tablet PC technology on mathematical content knowledge of pre-service teachers. We also in the process of collecting data and evaluating students' math pedagogy, attitudes toward digital wireless technologies, and effects of this technology on collaborative learning of mathematics. Thus, the scope of this paper addresses the following research questions (from Discussion Document <http://www.math.msu.edu/~nathsinc/ICMI/>): roles of different technologies in teaching and learning mathematics, assessing learning of mathematics using digital technologies, and how can technology-integrated environments be design so as to capture significant moments of learning.

The significance of Tablet PCs: recently, at Technology Review's Emerging Technologies Conference held at MIT, Nicholas Negroponte, a founder of MIT's Media Lab, showed off a laptop design he hopes can be sold for just \$100. These small laptops work similarly to Tablet PCs, using "digital ink" thus providing students the opportunity to write on the screen using a specially

designed stylus pen. With the affordability of these computers, schools will be able to provide every child with a computer.

### **The Study**

In spring semester of 2005, 38 pre-service elementary teachers were enrolled in math content and math methods courses. These students were also enrolled in internships at local elementary schools. The students' internships and class placement was random. Our study focused on two groups of students. The treatment group consisted of 15 students that regularly met in a professional development school where they were provided with 14 Tablet PCs for use in their math and math method classes. The control group consisted of 23 students who were enrolled in the same courses with the same instructor but met at different times and location. In this control group Tablet PCs were not used.

All math and math methods classes were team taught using a series of rich math investigations, in-depth discussions on topics in the methods textbook (Van de Walle, 2004) and group lesson preparations and implementations. Specifically, math and math methods course were designed to foster conceptual understanding of mathematics and pedagogy in the following major strands: rational numbers, geometry, algebra, number theory, and functions. All projects were designed to include open-ended problems that required thorough investigations to achieve successful solutions. Instructors utilized collaborative learning and inquiry based methodology while students worked in small groups.

The treatment group used Tablet PCs to explore the investigations or projects. This technology allowed students to explore each activity fully without being limited to paper and pencil drawings. The real time feedback in the various programs and websites used gave students a good evaluation tool of their problem solving methods. In addition, the ability to iterate calculations allowed students to focus on the "big" picture without getting bogged down with repetitive calculations.

Besides the rich investigations, students from both groups planned individual/group lessons and implemented them in local elementary schools. Students created these lesson plans by applying the concepts investigated in their math and math methods courses. Students in the treatment group successfully implemented Tablet PCs in their individual and group teachings allowing pupils to engage in meaningful technology based activities.

By the end of the four month period both groups had completed and presented several investigations. The students' final exam was an oral presentation covering the functions and algebra investigation. The students' final grade was

a cumulative grade indicative of the students' performances in each investigation, presentation, teaching and methods review.

### **Implementing the Tablet PCs in a technology-enhanced classroom**

Tablet PC's are fully functional PC's running an enhanced version of Windows XP Professional. One of their most interesting feature is the "digital ink" that allows a user to write on the screen using a stylus pen. The same pen is also used as a mouse. The handwriting recognition software allows the written text to be converted to digital text in Microsoft Word. Traditional keyboard and mouse are also available. Tablet PC's also have built-in wireless connectivity, so they can communicate with each other even if there is no internet connection present (ad hoc mode). They can also wirelessly connect to the internet. In newer Tablet PCs battery life can be up to six hours, however in our case our Tablets only have a battery life of three hours.

Students had the opportunity to utilize the Tablet PC during their presentations by connecting the Tablets to a data projector. In addition since we had 14 Tablets and 15 students, then students were able to work with the Tablet PCs individually or in small groups. Faculty used special software to communicate with the students. First, using VNC software (<http://www.realvnc.com/what.html>) and internal wireless capability, faculty could connect to any of the students' Tablet PCs and check their work, help them and project their successful solution on the screen. Second, Discourse software ([www.ets.org/discourse](http://www.ets.org/discourse)) was used for assessment. Using this software, faculty is able to ask various types of questions including open-ended or multiple-choice questions. Each question can be accompanied by an image guiding students to explore this particular question. In addition to images, faculty can guide students to a specific internet site relevant to the question. Students can answer their questions concurrently or on their own pace.

The faculty is also able to simultaneously monitor each student's answer in real time. Some of the students prefer typing the answers; others can open a writing pad, and record their answer on the pad. This writing pad automatically converts it to digital text. Also, students can have discussions using the "chat" option (that can be disabled by faculty).

Pre-service teachers employed the Tablet PCs in their university courses and during their internship teaching in a number of ways. The most popular program was a program called Microsoft Journal, which comes free on Tablets and is used as an electronic whiteboard. The Power Point program was extensively used for presentations and for the creation of animated virtual manipulatives. The students were very successful in creating virtual

manipulatives for solving word problems, place value tasks, fractions, and geometrical designs. Similarly, Kidspiration and Inspiration software was used for the creation of math activities and games. Students also used this software to create concept or mind maps.

Variety of specialized free software was also used. One of the most interesting software is Java Bars

(<http://tt.uga.edu/tt/jwilson.coe.uga.edu/olive/welcome.html>) that provides a creative workspace to explore fractions. Another software used extensively was the Tangram editor that will no longer be available for free. Excel was used in mathematical projects by utilizing the different spreadsheet capabilities such as graphing and formula calculator. Another interactive site used for fractions was Cynthia Lainus' website from Rice University where students could explore fractions with pattern blocks. Students also used a variety of internet sites such as the National Library of Virtual Manipulatives, NCTM Illuminations, Math Playground and InterMath Investigations. Preservice teachers used a WebCT portal provided to all students by the university to submit their work for grading and discussion as well as for submitting questions outside of class time.

### **Results, Conclusions and Future Work**

We statistically compared the effectiveness of our technology enhanced method for mathematics, using the Tablet PC, to the standard inquiry based method. This comparison is based on the results of two distinct items. The first is the students' Final Exam given at the end of a 4 month learning period. The second is the students' Final Grades which is a cumulative grade based on all the investigations throughout the semester. Of a random sample of 38 students, 15 were taught by the technology enhanced method and were considered our treatment group. The other 23 students were taught by the standard inquiry-based method and were considered out control group. All 38 students were taught by the same qualified instructors under similar conditions.

We computed students' grade point average (GPA) using only their previous mathematics courses. The average math GPA for the treatment group is 2.99 while the average math GPA for the control group is 2.98. This indicates that both groups had approximately the same mathematical background and content knowledge prior to the study. We developed descriptive statistics for both samples and both teaching methods see (Table 1).

Group	Final Exam				Final Grade			
	n	Mean $\bar{X}$	Var $\sigma^2$	St.Dev.	n	Mean $\bar{X}$	Var $\sigma^2$	St.Dev.
Treatment	15	90.8	14.31	3.78	15	93.04	8.95	2.99
Control	23	84.9	77.55	8.81	23	87.70	42.49	6.52

Table 1: Sample's Descriptive Statistics

Based on our observations during the previous semesters, we expected that the new teaching method is more effective. If we can show a statistically significant difference between these groups, we can conclude this observation to be valid. To do this, we set up a null hypothesis that the two sample means are the same (or the two groups come from the same population), and attempt to reject that hypothesis.

The standard approach for this situation is to use the small-sample t-test. The first theoretical assumption about the independency of observations is satisfied, based on the information provided about the sampling procedure. The second assumption is about Normality (the histograms of all four distributions are bell-shaped and approximately symmetric). To verify the Normality in more rigorous way, we used the  $\chi^2$  – test for the Final Exam and Final Grades for both groups. The results of four tests are represented in (Table 2).

The test shows that for all four distributions the calculated value chi-square is less than the critical value for the indicated degrees of freedom and  $\alpha$ . There is insufficient evidence to reject the null-hypothesis about the Normal distribution for given samples. Consequently, each sample data set appears to come from a population that is approximately Normal. Moreover, as we know, the t-test is robust to moderate departures from Normality.

The third and weaker assumption is that the two samples come from distributions with approximately the same variance.

For our samples we can see that the ratio of the larger to smaller standard deviation is greater than two, so the unequal variance test should be used. In the case where the sample sizes and variances are different ( $n_1 \neq n_2$  and  $\sigma_1^2 \neq \sigma_2^2$ ), an approximate small-sample test can be obtained by modifying the standard deviation and the degrees of freedom associated with the t-distribution.

Final Exam					
Group	n	$\chi^2$	df	$\alpha$	$\chi^2_{critical}$
Treatment	15	3.53	1	0.05	3.84
Control	23	4.37	1	0.025	5.02
Final Grade					
Group	n	$\chi^2$	df	$\alpha$	$\chi^2_{critical}$
Treatment	15	1.52	1	0.05	3.84
Control	23	0.78	2	0.05	5.99

Table 2: The Results for  $\chi^2$  – test for Final Exam and Final Grades

We used the Approximate Small-Size Procedure (McClave, Sincich, 2003, p.390, J.Devore, 2004, p.373) when  $\sigma_1^2 \neq \sigma_2^2$ . We let  $\mu_1$  and  $\mu_2$  represent the population mean for the Final Grade of the treatment and control groups, respectively. The null hypothesis  $H_0: (\mu_1 - \mu_2) = 0$  signifies that samples do not differ significantly. The alternative hypothesis is  $H_1: (\mu_1 - \mu_2) > 0$ .

Test statistic  $t = \frac{\bar{X}_1 - \bar{X}_2}{\sqrt{s_1^2/n_1 + s_2^2/n_2}}$  where t is based on degrees of freedom

equal to

$$df = \frac{(s_1^2/n_1 + s_2^2/n_2)^2}{\frac{(s_1^2/n_1)^2}{n_1 - 1} + \frac{(s_2^2/n_2)^2}{n_2 - 1}}$$

Table 3 (test results) shows that the t-values for both tests are much bigger than the critical value of the t-test with the 5% Type I Error. The table of t-distribution (J.Devore, 2004, p.747) shows that the area under the 32 degrees of freedom t-curve to the right of 2.851 for the Final Exam test is 0.0035. So the p-value for the upper-tailed test is also 0.0035, that corresponds to the probability 0.35%. For the Final Grade test the p-value is only 0.001 or 0.1%.

	t	df	$\alpha$	t <sub>critical</sub>	Confidence Interval	
					Lower limit	Upper limit
<b>Final Exam</b>	2.851	32	0.05	1.694	2.40	9.45
<b>Final Grade</b>	3.418	33	0.05	1.693	2.70	8.00

Table 3: The results of the Small-Size t-test

With a confidence level 0.95, we estimate the difference in the mean of the Final Exam scores between treatment group and the control group to fall in the interval (2.40, 9.45). This means that with 95% confidence we estimate the mean Final Exam score for the new method to be anywhere from 2.40 to 9.45 points more than the mean of the Final Exam score for the standard inquiry-based method.

The 95% confidence interval for the Final Grade is (2.70, 8.00), so we estimate the mean of the Final Grade for the new method to be anywhere from 2.70 to 8.00 points more than the mean of the Final Grade for the standard inquiry-based method. In other words, the new method is associated with higher mean scores.

Therefore there is enough evidence to indicate that  $(\mu_1 - \mu_2)$  differs from zero and that  $(\mu_1 - \mu_2) > 0$ . Using a significance level of 0.05, we can reject the null hypothesis that the two sample means are the same in a favor of the alternative hypothesis which states that the treatment group mean is significantly bigger than the control group mean for the both the Final Exam and the Final Grade.

Consequently, the statistical analysis of the data collected shows that the technology enhanced group achieved significantly higher mean scores than the control group. These higher mean scores obtained by the treatment group translates into the treatment group having a greater understanding of math content when compared to the control group. This greater understanding can be directly contributed to the effective implementation of the Tablet PC technology in the math and math methods courses. Thus, we simultaneously achieved two goals. We increased students' math education software literacy and math content knowledge.

This study was conducted in math and math methods classes. The natural extension of our work is to evaluate the change in acquiring mathematical pedagogical knowledge by pre-service teachers. Future teachers (in both groups) are asked to create original math lessons using manipulatives and hands-on activities. Students in the treatment group are required to use Tablet PCs to create hands-on activities and virtual manipulatives. Groups' pedagogical knowledge will be compared using pre/post tests, questionnaires and knowledge and attitude surveys. Preliminary observations show that even students who did not improve significantly their math content knowledge benefit from using Tablet PCs in terms of mathematical pedagogy. They become more creative in developing hands-on activities, become very confident in searching the Internet and develop good skills to critically analyze existing mathematical activities posted on the Internet.

Another important aspect that will be studied is how well the collaboration helps pre-service teachers to learn mathematics and pedagogy. Collaboration is

recognized as an important forum for learning (Bransford, J. D., Brown, A. L., Cocking, R. R., Eds., 2000.), and research has demonstrated its potential for improving students' problem-solving and learning (Slavin, R. E, pp. 145-173, 1992, Johnson, D. W. and Johnson, R. T., pp. 23-37, 1990). In both treatment and control groups students are working in teams. However in the treatment group Discourse software is extensively used for teaching, learning and assessment by both faculty and students. Important feature for collaboration evaluation is "chat" option. Students are encouraged to chat only on the topics discussed in the class session. These chats can be saved in the archive file and then be analyzed to evaluate the level of cooperation, team members' participation in collaborative work on the project as well as level and complexities of content questions asked.

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