Integration and Perception of Tablet PC Software in Elementary Mathematics Education

Senior Honors Thesis

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Chapter 1

Abstract

The tablet PC provides a unique tool for education in that it allows students to write naturally in digital ink, making it possible for both normal and enhanced educational material and curricula to be easily transferred to a digital environment. There are many tools currently available for the tablet PC that are very useful to teachers, but there is very little software geared toward students—especially younger students. Younger students, however, may find a tablet PC particularly helpful because many of them have not yet developed typing skills. The Tablet Math System was developed in order to enhance children's learning of simple mathematics and at the same time decrease teacher workload. The main goals of this study were to understand the ability of teachers to integrate the Tablet Math System in their classroom and to understand the perceptions of students and teachers regarding the software. Pilot studies in three fourth-grade classrooms indicate that the Tablet Math System was successfully integrated into classroom activities. Students completed almost 20,000 problems over 18 weeks on six tablet PCs rotated between three classes. Students had highly favorable perceptions of the Tablet Math System. They greatly preferred the tablet pc to paper, and were even eager to do math. The biggest complaint among students was that it was difficult to get on the system (as each class only had 6 tablets). The students also believed they did better on math presented on the tablet PC than on paper. Teachers found little change in their teaching pedagogies and had some problems integrating the system into their curriculum. These factors point to the importance of teacher training and professional development for the specific software environment. The findings also show that a tablet PC lab may be more advantageous for students, teachers and schools

than a rotational model.

Chapter 2

Introduction

2.1 The Tablet PC

Tablet PCs provide a unique mode of computer interaction in that the primary method of interaction is a pen. Tablet PCs currently run Windows XP Tablet PC Edition, a fully-functional operating system with the addition of enhanced handwriting and speech recognition. There are two main types of tablet PCs: slate and convertible. The main difference is that slate tablets have no attached keyboard, while convertible tablets include an attached keyboard. Tablet PCs are fully capable of running any Windows XP software. Tablet PCs come with the Windows Journal software, which allows users to take notes in digital ink and later save those notes or convert them to text. Tablet PCs are also generally smaller and lighter than regular laptop computers, enhancing their portability.

2.2 Related Literature on Tablet PCs in Education

Tablet PCs have begun to catch on in education. Teachers are finding that the ability to write during lectures and save their handwriting online is beneficial for themselves and their students. Timmons [1] attests to the benefits of using the tablet PC as a substitute blackboard. Timmons finds that teachers are able to easily adjust their teaching on the fly using the digital ink-but retain the benefits of archiving and retention in the digital environment. The benefit of tablets to teachers is readily apparent, but the benefit to students is slightly more ambiguous. Simons et. al. [2] used the tablet PC with both students and teachers, allowing interaction through the Classroom Presenter software [3]. Classroom Presenter allows students to write questions anonymously to the instructor, who can review and answer these questions in front of the entire class. Koile & Singer [4] found that Classroom Presenter was able to increase student focus and attentiveness, increase student satisfaction, and provide instructors and students immediate feedback on student misconceptions in an introductory computer science course at MIT. Current research has focused much on presentation tools [2, 4] such as Classroom Presenter or DyKnow, or the general tablet PC software use [1, 5] such as Microsoft Journal and Microsoft OneNote.

2.3 Related Literature on Elementary Mathematics

Understanding of elementary mathematics is crucial for students to successfully move to more advanced mathematics. Extensive research by Siegler [6] has shown the importance of allowing children to choose their own strategy to solve basic mathematics problems. These strategies may be as simple as using fingers to count, or as complex as problem abstraction and differentiation. Children also adopt multiple strategies, and use these strategies based on the problem at hand. As children grow and intellectually develop, these strategies become increasingly advanced, and their ability to choose the correct strategy increases. The implications of this in mathematics learning are basic: do not force children to use a specific strategy. Another key factor in learning is immediate feedback. Brosvic et.al [7] points out that immediate feedback facilities the learning and retention of all four basic arithmetic operations. This feedback is key to stop students from forming misunderstandings that are often difficult to correct. The immediate feedback is also crucial in promoting the accuracy of the initial learning, which Augustyniak et. al. [8] shows is paramount to successful practice and retrieval. Augustyniak et. al. [8] also shows that basic facts and operations are based on a well organized neural network, which is reinforced through practice and enriched through associated concepts.

2.4 Tablet PC In Comparison to Other Interfaces

There are many ways to interact with computers. The most common way of interacting with a computer is through the use of a keyboard and mouse. Though this method is effective for typing or web browsing, it is not the most appropriate method for doing mathematics. Kimura [9] points this out nicely:

> When a child in a third-grade classroom is learning how to add two multidigit numbers, traditional GUI-based computer software offers little help. Through mouse-keyboard operations a computer can check the correctness of the answer, but cannot obtain much more information on the child's skill at addition ...the main merit of a prosodic user interface is the ability to capture additional information from a single user action. Requiring two steps to enter one number is too intrusive for the child who mainly wants to enter the correct answer in a timely fashion.

The pen provides a clear advantage because of its ability to convey *how* the student was incorrect. This information is vital because it helps teachers adjust their teaching to incongruities in student knowledge. The pen also allows the student to continue working though their problem set, uninterrupted by the technology unless intervention is required. This enhances efficiency by allowing students to fly through problems they are comfortable with, reinforcing their knowledge, and slow down when they are having difficulty with problems. This allows them to attempt the problem, and obtain immediate, corrective feedback when they are incorrect. Oviatt, Arthur and Cohen [10] concluded that the goal of any interface is to reduce cognitive load. Their study focused on comparing various interfaces for geometry in high school mathematics. They concluded that students did best with paper, second-best with tablet PCs, and worst with a graphical tablet. They did not, however, use specialized software. Specialized software can display problems and accept scratch work directly on the screen without forcing users to switch between various problems and thus reduces their cognitive load.

2.5 Objectives

This study will analyze the ability to integrate the Tablet Math System in three elementary school classrooms. This is important because integration in the classroom will provide models for future tablet PC software implementation in education. The study will also analyze the perceptions of the teachers and students regarding use and effectiveness of the system. The perceptions of the teachers and students will provide an indirect measure of the success of the Tablet Math System. The students' perception of using the Tablet Math System can reflect a change in their attitude toward practicing math, thus improving their motivation to practice math. This can result in an improvement in learning. The teachers' perception of the Tablet Math System will provide information to improve the model of tablet PC software integration.

Chapter 3

Methods

3.1 Participants

The study was conducted at Glendale Elementary School in the Glendale school district in Flinton, Pennsylvania. Flinton is a very rural and low-income community. The Glendale Elementary School has approximately 450 students. The Glendale school district has been a leader in engaging technology in the classroom. Technologies such as smart boards, laptops, curriculum on wheels (projector and curriculum all-in-one) abound in the elementary school. Three fourth grade classes, with a total of 60 students, participated in this study. Of these 60 students, 29 were male and 31 were female.

3.2 Hardware

The study used six HP 1100 tablet PCs. All tablets were in ”slate” mode throughout the study. The tablet PCs were set up in the back of each classroom and were connected to the wireless school network. The hardware configuration of the machines is shown in Table 3.1.

3.3 Tablet Math System Objectives

The tablet math system was developed at Carnegie Mellon University to address several problems in elementary mathematics. The first problem is the

HP 1100 Specifications	
Processor	Intel Pentium M 1 Ghz Processor
RAM	512 MB DDR SDRAM
Display	10.4 in. XGA TFT LCD (with Wacom digitizer)
Operating System	Microsoft Windows XP Tablet PC Edition
Graphics Card	NVIDIA GeForce 4 Go 420
Hard Drive	40GB IDE
Display Resolution	1024x768
Max Viewing Angle	100 degrees
Wireless	Integrated Intel 2100 802.11b WLAN

Table 3.1: HP 1100 Tablet PC Specifications

ratio of teachers to students in schools. Elementary math classes routinely have 20-25 students and one teacher. This creates a time delay between student's practice and feedback on their work. This is a problem because immediate feedback is crucial for student's learning and retention of basic math facts. The Tablet Math System provides this immediate feedback to students. The second problem is that it is difficult for teachers to understand the incongruities in student knowledge and modify their teaching to address those problems. The Tablet Math System provides teachers with the ability to view how students attempt problems, as well as general statistics on class performance. This provides teachers with an opportunity to dynamically adjust their teaching in real-time to focus in on students' problems. The third problem is that students do not find math fun. It is very difficult for teachers to motivate students to do math and sustain this motivation through the necessary practice.

3.4 Tablet Math System Details

The Tablet Math System is made of two complementing applications. The first is a thin client application installed on the tablet PCs. This application is used exclusively by students to solve math problems. The second is the web application. The web application is used by teachers to assign exercises and view student results. Along with the applications, a server is used to host the web application and run the central database. The server for the Glendale study resided at Carnegie Mellon University. If the tablet is online, each problem is submitted to the database when it is completed. If the tablet is offline, the problems are saved in a local database and submitted to the central database the next time the thin-client is started online. Teachers can login to the web interface at any time to obtain information about student and class performance. The thin client was designed to be easy to use for students. Students simply write their name and birthday on the screen using digital ink to login to the system. Once they are logged in, they are either prompted to complete an exercise or allowed to practice in self-study mode. The exercises are assigned by teachers to either their entire class or to individual students within their class. Each exercise has a set of criteria which allows teachers to customize the type of problem, time limit and problem limit. This lets teachers align the problems students receive from the system to their current instruction. The problems for each exercise are created randomly by the program. An example of this assignment is shown in Figure 3.1.

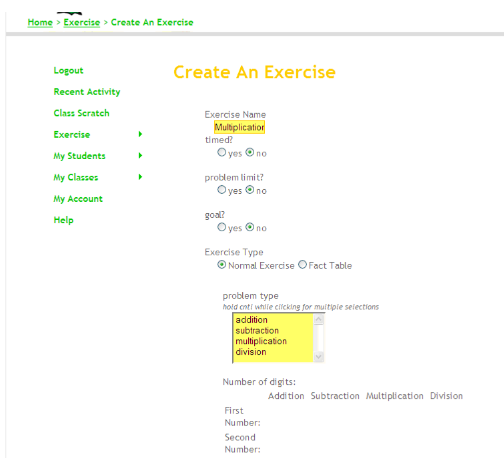

Figure 3.1: This is the teacher interface for creating exercises. Once exercises are created, all students assigned that exercise will be prompted (forced) to complete it. The interface can be accessed through any web browser.

The options for teachers include time limit, problem limit, percent correct goal, addition, subtraction, multiplication, division, and number of digits for each operation. Students can access these same options when practicing problems in self-study mode. The interface where students complete problems is shown in Figure 3.2.

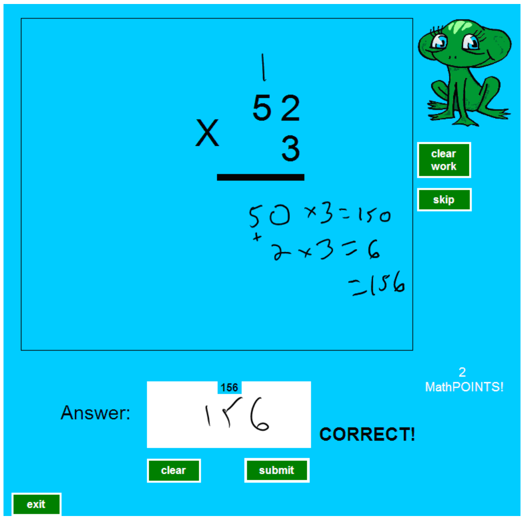

Figure 3.2: This is the student problem interface. The interface has two areas for scratch work. The problem is displayed in the center of the screen, and the answer area is directly below. Note: MathPoints is a new feature, and was not in the program during the period of the study.

Students have two areas in which they can write. The top area is used for scratch work. The scratch work for each problem is saved for teachers to later investigate. The bottom area is for the answer. This area is immediately converted into text. Gunawardena and Petty [11] point out the importance of real-time recognition to increase student accuracy while practicing math. Thus, while students are writing on the tablets, the computer recognition of their handwriting is displayed in real-time directly above their answer. Immediate feedback is provided to students directly next to the answer input area by the submit button. This helps students see the feedback before continuing on to the next problem. After an exercise or self-study session is completed students are presented with a results page. The results page, displayed in Figure 3.3, shows students details on their performance during this exercise.

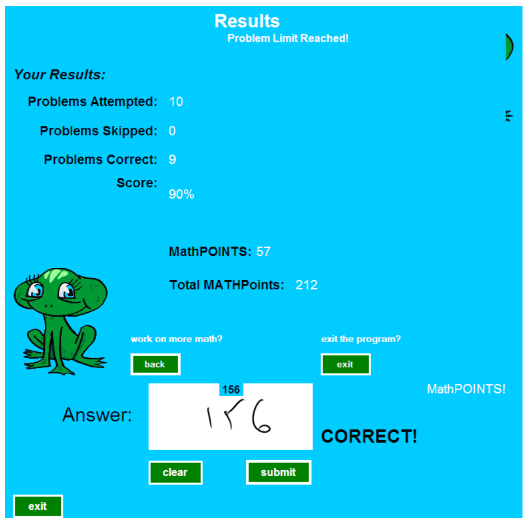

Figure 3.3: This results page is displayed after a student completes and exercise or exits self-study mode. The page includes problems attempted, problems skipped, problems correct and the percentage score. Note: MathPoints is a new feature, and was not in the program during the period of the study.

The teachers can also view student results for a particular exercise through the web interface. In addition to a particular exercise, teachers can view lists including class exercise and self-study exercises. The listing of exercises, displayed in Figure 3.4, also allows teachers to obtain more specific information.

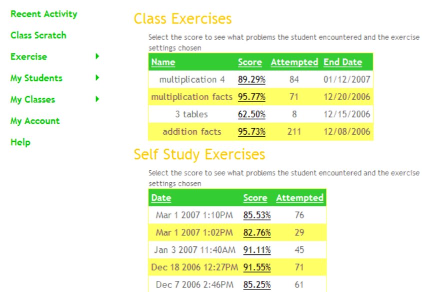

Figure 3.4: This page displays a summary of student activities. Each exercise and self-study result is displayed. The name, score, attempted number of problems and end date of each class exercise is displayed. For self-study exercises, the date, score and attempted number of problems is displayed.

The individual view of an exercise provides a teacher with all problems completed in that exercise. For each problem, the system stores and displays the first number, second number, operation, student response, correctness and the student scratch work. An example of student scratch work is shown in Figure 3.5.

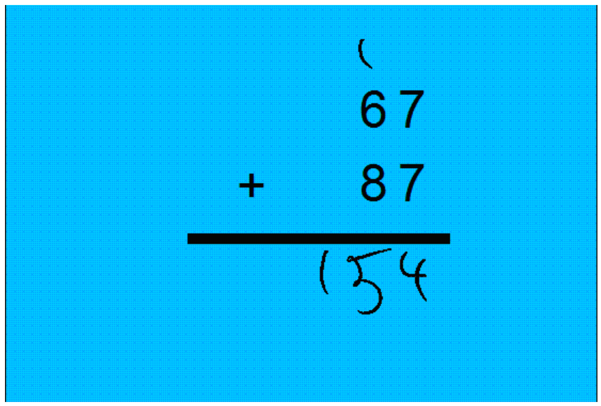

Figure 3.5: Student scratch work on a class exercise.

3.5 Procedure

Three fourth-grade classes participated in the study. Each classroom had six tablet PCs with the Tablet Math System located in the back of the classroom. Each teacher also had a desktop computer in the front of her classroom. The teachers received approximately one hour of training before using the Tablet Math System. The students had no training, but received help from their teacher when necessary. Students rotated using the tablet PCs in their classroom, with about 4-6 students using the system per day. The teachers were instructed to assign an exercise per week to correlate to their current instruction. The students had approximately 20-30 minutes each day to work on the Tablet Math System. Thus, throughout the week all students would have time to finish the teacher assigned exercise and possibly time to practice using self-study mode. After each class used the Tablet Math System, students and teachers were given a survey to assess their perception on using the system.

Chapter 4

Results

4.1 Classroom Integration

The Tablet Math System was used successfully for six weeks. Teachers assigned a total of 15 exercises over a period of 18 weeks. This is very close to the target goal of one exercise per week. Teachers had difficulty integrating the system directly into their curriculum because of the demands of the Saxon[1]curriculum, and thus used free time to allow students to use the Tablet Math System. Each teacher took a slightly different approach to integrating the system into her curriculum. Some teachers focused on reviewing material, while other teachers focused on new material. Table 4.1 provides details on the exercises assigned by each of the teachers.

In addition to all the class exercises, students completed a total of 338 self-study exercises. These exercises varied greatly in amount of problem and difficulty. Throughout both self-study and class exercises students completed a total of 18,992 problems. This shows that the Tablet Math System was successfully integrated into the classroom. The breakdown of problems by class and operator type is shown in Table 4.2.

[1]The Saxon curriculum is an all-in-one curriculum. It provides teachers with in-class activities, worksheets, assignments, and tests for the entire year. This is the math curriculum used by Glendale Elementary School.

Teacher Assigned Exercises			
	Class 1	**Class 2**	**Class 3**
Exercise 1	Addition (2x2) 15 Minutes 20 Problems No Regrouping	Multiplication (1x2) 3 Minutes 100 Problems	Addition (2x2) Regrouping
Exercise 2	Subtraction (2x2) 15 Minutes 25 Problems Regrouping	Addition (2x2) and Subtraction (2x2) 10 Minutes Regrouping	Addition (1x1)
Exercise 3	Addition (2x2) 15 Minutes 20 Problems Regrouping	Subtraction (3x3) 15 Minutes Regrouping	Multiplication (1x2) Regrouping
Exercise 4	Subtraction (2x2) 15 Minutes 20 Problems Regrouping	Multiplication (1x2) 4 Minutes 100 Problems	Multiplication (1x2)
Exercise 5	N/A	Multiplication (2x2) 4 Minutes 100 Problems	Multiplication (1x2)
Exercise 6	N/A	Multiplication (2x2) 4 Minutes 100 Problems	N/A

Table 4.1: This table shows details on each exercise assigned by teachers. The first part shows the operator and digit limits. Multiplication (1x2) means the operator was multiplication and the digits were 1 maximum in the first number and 2 maximum in the second number. Three minutes and 100 problems refer to the limits of the exercise. The exercise ends whenever either condition is true. Regrouping is a condition of addition/subtraction and refers to either carrying or borrowing.

Student Problem Completion					
Class	**Addition**	**Subtraction**	**Multiplication**	**Division**	*Total*
Class 1	1646(310)	1126(427)	542(107)	113(34)	3427(878)
Class 2	6014(1049)	1978(957)	2584(578)	95(11)	10671(2565)
Class 3	3283(271)	25(1)	3797(752)	0(0)	7105(1024)
Total	10943(1630)	3129(1385)	6923(1407)	208(45)	21203(4467)

Table 4.2: Student data; Incorrect/skipped responses in (parentheses); 2211 problems were skipped

Although teachers felt the Tablet Math System was beneficial as a learning aid, their overall perceptions of the system were fairly neutral. Teachers liked the fact that students were able to drill their math skills, and enjoyed the fact that students were motivated to do math. However, the teachers had problems with time management, as well as some difficulty with using the technology. Because only six tablet PCs were used a time, teachers felt burdened to keep the rest of the class busy. Teachers also made little use of the online tools available to them. Teachers often did not have the time to investigate student performance online or view individual problem scratch work.

4.2 Student Perception

Student reaction to the system was quite positive. Students believed that they did better at math using the tablet PC than using paper. Students were also more motivated to use the Tablet Math System to practice math than to use paper. They viewed the Tablet Math System as fun, and generally found it easier to use than traditional paper-based math practice. When students were asked ”On a scale of 1-5, how much fun did you have using the Tablet Math System,” 25 of the 49 students surveyed selected 5, the highest level of fun. Figure 4.1 shows a detailed breakdown of the results from this question.

Students were not only having fun, but they thought they were performing better. When asked, "On a scale of 1-5, do you think you did better at math on the tablet PC or on paper?" 25 students selected 5, that they did

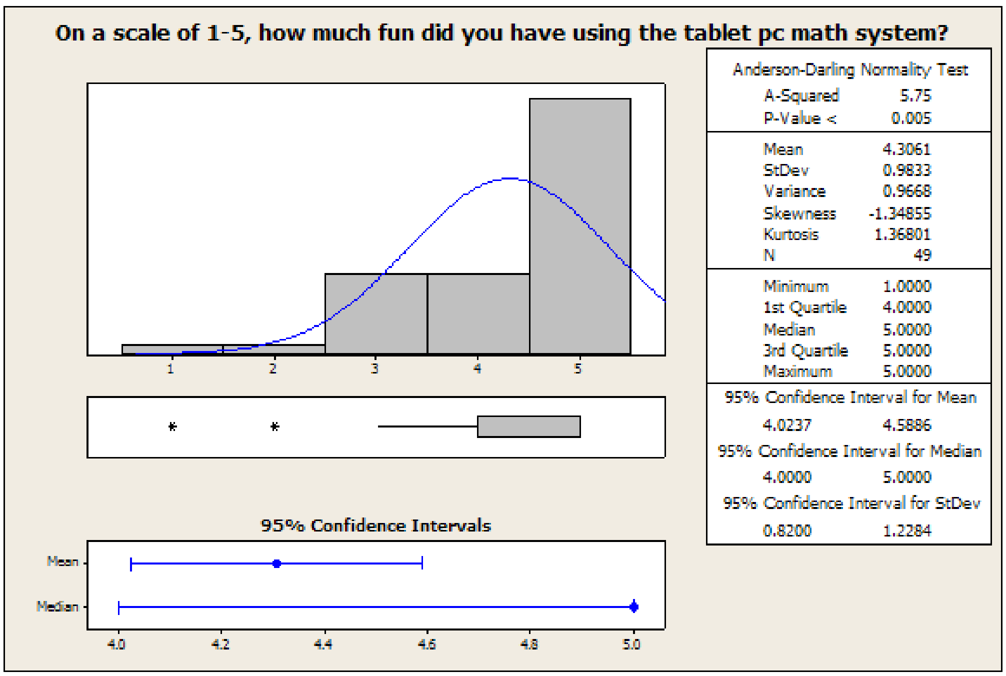

Figure 4.1: This is the student response to the first survey question,"On a scale of 1-5, how much fun did you have using the Tablet Math System." Five was "highly enjoyed" while one was "hated."

best at math on the tablet PC. Detailed results of this question are shown in Figure 4.2.

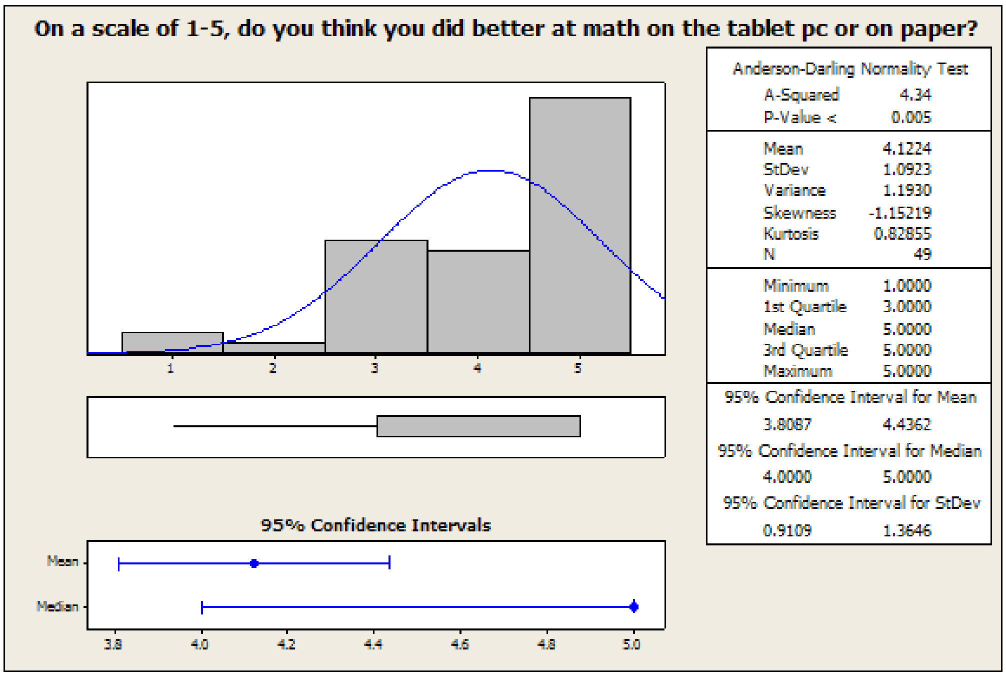

Figure 4.2: This is the student response to the second survey question,"On a scale of 1-5, do you think you did better at math on the tablet PC or on paper?" Five was "tablet PC" while one was "paper."

Chapter 5

Discussion

This study showed the potential value of the Tablet Math System in the elementary school classroom while also pointing out some of the challenges of integrating it into existing classroom curriculum. In addition, students seemed to embrace the technology more rapidly than did teachers, suggesting the need for more thorough teacher training on using the system.

5.1 Student Reactions

Students clearly enjoyed the Tablet Math System and believed they were doing better at math as a result of using it. This finding is significant because student perception and self-confidence are vital to learning basic mathematics. Improving student perception may very well lead to increased learning and retention, as per the self-fulfilling prophecy. The immediate feedback that the Tablet Math System provided is a clear advantage over traditional paper-based methods. Allowing students to write - rather than type - also has several distinct advantages over other existing mathematics software. Typing increases student cognitive load and is an unnatural and unintuitive input method. Allowing students to write their scratch work and ideas allows a smooth transition between their work and answer without interruption. Based on student comments and use, future tablet-based elementary math software should contain three key elements.

Immediate Feedback must be provided to students to increase learning and recognition.

Easy to Use is key for students to maintain interest and prefer the tablet PC platform.

Display of Problems must occur quickly and in a familiar format for students.

Future tablet based educational software should also strive to reduce the impact of negative traits:

Handwriting Recognition must be provided instantly and correctly.

Simultaneous Work for students helps teacher manage their classroom activities.

Pen "Clicking" should be kept to a minimal to help students complete problems quickly.

5.2 Teachers Reactions

Teacher perception was middle of the road, with few strong feelings, either positive or negative, about the Tablet Math System. Most teacher concerns appeared to be focused on the technical aspects of using the system, the difficulties of rotating a limited number of tablets among all students and the challenges of integrating this system with existing math curriculum. Teachers found it difficult to obtain both general and specific information with ease. Future software systems must incorporate elements of artificial intelligence, or intelligent tutors, to provide teachers with an easy way to obtain information on class and student misconceptions. This will help teachers adjust their teaching more easily. Some of their technical problems and the difficulty teachers had in obtaining the information they were seeking was likely due to the limited training on how to use the system. This points to the importance of professional development and training for specific software packages to help teachers use the technology effectively. Teachers ' difficulty in managing their classroom's time may be reduced by a different dispersion of tablet PCs. A tablet PC lab, where 20-25 tablets are in a single room would allow an entire classroom to work on the same software at once. This would ease the burden of time management on teachers and let all students practice at the same time. The study also showed the difficulty of integrating the Tablet Math System directly with classroom curriculum. The wide range of available curricula makes it difficult to create a system that corresponds directly to any one specific curriculum. This suggests that the most effective use of the Tablet Math System may be as a learning aid. Used in this way, the technology allows teachers to use the system to enhance their teaching and curriculum, instead of altering or replacing it. The use of the technology in the classroom is very teacher dependent–and the ability of teachers to manage their class time and their understanding of technology play key roles in successful classroom integration of the Tablet Math System. In addition to specific training in using this system, teachers may benefit from additional training in technology integration skills.

Bibliography

[1] Timmins, S. J., Tablet pc: blackboard to the web, in *SIGUCCS '04: Proceedings of the 32nd annual ACM SIGUCCS conference on User services*, pages 296–300, New York, NY, USA, 2004, ACM Press.

[2] Simon, B., Anderson, R., Hoyer, C., and Su, J., Preliminary experiences with a tablet pc based system to support active learning in computer science courses, in *ITiCSE '04: Proceedings of the 9th annual SIGCSE conference on Innovation and technology in computer science education*, pages 213–217, New York, NY, USA, 2004, ACM Press.

[3] Anderson, R., Classroom presenter.

[4] Koile, K. and Singer, D., Improving learning in cs1 via tablet-pc-based in-class assessment, in *ICER '06: Proceedings of the 2006 international workshop on Computing education research*, pages 119–126, New York, NY, USA, 2006, ACM Press.

[5] Anderson, R. et al., Experiences with a tablet pc based lecture presentation system in computer science courses, in *SIGCSE '04: Proceedings of the 35th SIGCSE technical symposium on Computer science education*, pages 56–60, New York, NY, USA, 2004, ACM Press.

[6] Siegler, R., *Implications of cognitive science research for mathematics education*, pages 219–233, National Council of Teachers of Mathmatics, Reston, VA, USA, 2003.

[7] Brosvic, G. M., Dihoff, R. E., Epstein, M. L., and Cook, M. L., The Psychological Record **56.1** (2006).

[8] Augustyniak, K., Murphy, J., and Phillips, D. K., Journal of Instructional Psychology **32.4** (2005).

[9] Kimura, T. D., IEEE MultiMedia **03** (1996) 48.

[10] Oviatt, S., Arthur, A., and Cohen, J., Quiet interfaces that help students think, in *UIST '06: Proceedings of the 19th annual ACM symposium on User interface software and technology*, pages 191–200, New York, NY, USA, 2006, ACM Press.

[11] Gunawardena, A. and Petty, D., Use of tablet pcs in early mathematics education, in *Workshop on the Impact of Pen-based Technology on Education*, 2007.

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