# The Use of Tablet PCs in Early Mathematics Education


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## 1. ABSTRACT

The tablet PC provides many avenues to enhance education by allowing students to interact with "intelligent paper." Pen input may be particularly useful for younger students because of the similarities it bears to their normal workflow enhanced by the benefits of a digital environment. The Tablet Math System was developed in order to enhance children's learning of simple mathematics, decrease teacher grading workload and to enhance access to handwritten work so teachers can develop effective course pedagogies. This paper will focus on the deployment of the Tablet Math System at Glendale School district in rural Pennsylvania. The study consisted of three classes of 4th graders. Six tablet PCs rotated every six weeks between the classes. The tablets were placed in the back of the classroom, and children rotated daily to work on the tablets for thirty minutes. The study clearly illustrates the ability to blend traditional education with tablet-based education—in that without much direction or contact, teachers were able to utilize the system. In total, students completed 18,992 problems through the three classes. Of the total 16,736 were correct, while 2211 were skipped and 2256 problems were incorrect. Through the three rotations, the average of each class was, respectively, 74.38%, 75.96%, 85.59%. The interface was adjusted to give immediate response to student writing (using real-time ink recognition) between the second and third rotations. This greatly increased student accuracy, and thus, correct problems. Future tablet and ink-based tools must provide this type of information immediately to students to ensure the students understand how their ink is being recognized.


## 2. PROBLEM STATEMENT AND CONTEXT

Tablet PCs provide a unique mode of computer interaction using a digital pen. The pen provides a natural input medium and allows previous workflows centered on paper to continue uninterrupted. The computer becomes "intelligent paper," capturing the benefits of the digital environment and traditional paper. This was quickly realized by instructors and professors, because of their ability to markup PowerPoint presentations, archive class notes and replace the outdated chalk in their classrooms. In turn, it has prompted a large amount of research on how teachers use tablet PCs to enhance their teaching. Research by Timmons [1], Simon [2], and Koile [3] attest to the benefits of the tablet PC for both teachers and students when used as a substitute blackboard. The University of Washington went one step further and developed

“Classroom Presenter” a collaborative presentation software for instructors [4]. This software allows students to send questions to their teachers on a tablet PC anonymously, and for teachers to answer the questions on students’ virtual blackboards. Current research however does not address the benefits of student writing in a digital ink environment.

In comparing pen and paper with tablet PCs for high school mathematics education, Oviatt et.al concluded that the goal of any interface is to reduce cognitive load [5]. Their study concluded that better students did slightly better with the tablet PC, while worse students did significantly worse (even though worse students perceived they did better). Their study was, however, fundamentally flawed. The students worked next to the problem given in Windows Journal, and they also tested students only in one session. Thus, our hypothesis is that to full integrate tablet PCs into the classroom, students must use a program customized to their activity. Students must also be provided handwriting feedback where appropriate, and the program should also strive to provide all the benefits of the digital environment (ie.. immediate feedback, digital archiving, etc.).

## 3. SOLUTION EMPLOYED

The Tablet Math System was designed specifically for children to practice simple math facts on the tablet PC. In almost all schools, there are far too many students and far too few teachers. This leads to situations where students receive feedback long after they completed their problems. In studies by Brosvic et.al, immediate feedback facilitates the learning and retention of all four basic arithmetic operations [6]. Thus, the Tablet Math System was designed to provide immediate feedback to students to enhance their ability to learn and retain facts—while at the same time providing them with a comfortable and natural environment. The system was aimed at basic mathematics because the learning of basic math facts is crucial in order for students to succeed at more advanced math.

The Tablet Math System is made up of two main components. The first is a thin-client installed on tablet PCs. The thin-client is used by students to practice various math problems. The second main component is the web application. The web application is used exclusively by teachers to perform administrative and analytical operations. Figure 1 illustrates the thin client, while Figure 2 illustrates the web application. The thin client has space for scratch work, as well as an answer area.

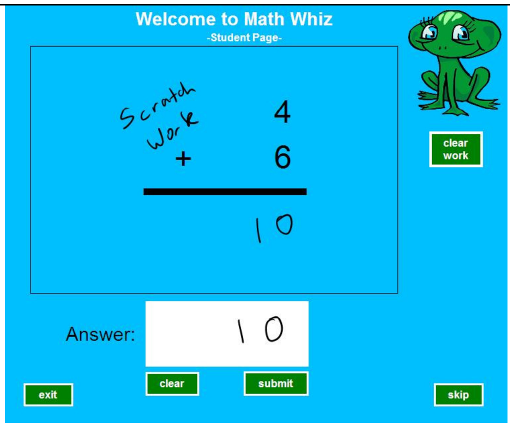


**Figure 1:Thin Client Interface**

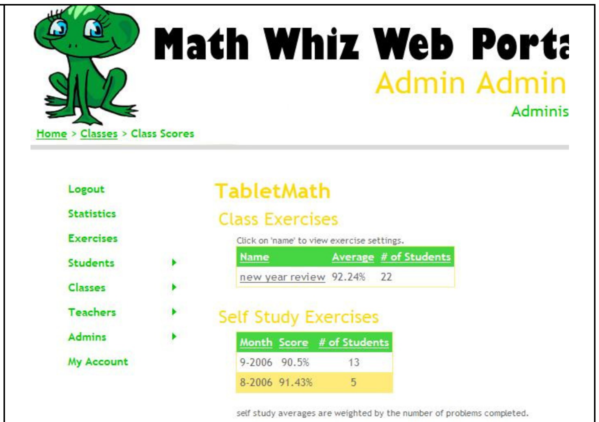


**Figure 2: Web Interface**

Teachers used the Tablet Math System in two ways. The first way was to assign class exercises. The class exercises force each student to practice a particular set of problems in a limited amount of time or number of problems (optional). The teacher is also able to set the operation (addition, subtraction, division, multiplication) along with the number of digits for each operation. The teacher can also control if addition/subtraction problems require borrowing/carrying. Teachers also have the ability to assign exercises to individual students. The second way is to allow students to work in "self-study" mode. This mode allows students to choose all the criteria that teachers choose in class exercises.

Teachers can review the results of student work online. Each exercise has information about the class average and the students who have completed it. Teachers can also view the scratch work online in near real time. This allows teachers to pinpoint incongruities in student knowledge, by examining *how* they attempt to solve problems.

## 4. EVALUATION

The study was conducted at Glendale Elementary School, at the Glendale School District in Flinton, Pennsylvania. The participants were three classes of 4$^{th}$ graders, with a total of 60 Students participating. Class A has 22 participating students, Class B has 19 participating students, and Class C has 19 participating students (A, B, and C are aligned with the classes place in the rotation). The breakdown of classes by gender is explained in Table 1.

| **Class** | **Male** | **Female** | ***Total*** |
|---|---|---|---|
| **A** | 12 | 10 | 22 |
| **B** | 8 | 11 | 19 |
| **C** | 9 | 10 | 19 |
| ***Total*** | 29 | 31 | 60 |

**Table 1: Breakdown of Classes by Gender**

The target goal was one teacher-assigned exercise given per week. Overall, 15 exercises were completed over 18 weeks. Class A completed 4 exercises, Class B completed 6 exercises, while Class C completed 5 class exercises. The breakdown of the exercises is shown in Table 2. Teachers tended to assign operator based exercises, aligning to their point in the Saxon curriculum.

| Class | Addition | Subtraction | Multiplication |
|---|---|---|---|
| **A** | 2 | 2 | 0 |
| **B** | 1 | 1 | 4 |
| **C** | .5 | .5 | 4 |
| ***Total*** | 3.5 | 3.5 | 8 |

**Table 2: Assigned Exercises; .5 is Assigned for the Mixed Exercise**

Through exercises and self study, the classes completed 18,992 problems. The details of the problems completed are in Table 3.

| Class | Addition | Subtraction | Multiplication | Division | *Total* |
|---|---|---|---|---|---|
| **A** | 1646(310) | 1126(427) | 542(107) | 113(34) | 3427(878) |
| **B** | 6014(1049) | 1978(957) | 2584(548) | 95(11) | 10671(2565) |
| **C** | 3283(271) | 25(1) | 3797(752) | 0(0) | 7105(1024) |
| ***Total*** | 10943(1630) | 3129(1385) | 6923(1407) | 208(45) | 21203(4467) |

**Table 3: Student Data; Incorrect/Skipped Responses in (Parentheses); 2211 Problems were Skipped**

The students had greater success in Class C where real-time ink recognition helped students ensure the program understood their input. Through the three rotations, the average of each class was, respectively, 74.38%, 75.96%, 85.59%.

The system showed that teachers were willing to teach new concepts and immediately practice them on the Tablet Math System. Of all the exercises, only one contained multiple operations—showing teacher tendency to focus on the concept at hand without too much review. This also shows that the system took the place of an extra worksheet or practice problems. This is the goal of the new technology---provide an improved, simplified, natural environment without causing disruption in the classroom.

The data can also provide insight into the mathematics level of the students. The best predictors of problem correctness for Class A were: second number (number on bottom), regrouping (borrowing or carrying), first number, and start date (in this order). These four factors were able to explain about 10% of the variance in if the problem was correct ($R^2$=9.9, Mallows Cp=5.0). For Class B, they were: regrouping, first number, second number (in this order). These factors explain about 7% of the variance in if the problem was correct ($R^2$=7.4, Mallows Cp=3.1). For Class C, they are: start date, first number and second number. These factors explain about 4% of the variance in if the problem was correct ($R^2$=3.7, Mallows Cp=4.5). The change in importance of factors is mostly likely due to variance between the individual classes. Teacher styles, utilization of the system, instruction and knowledge of technology are all factors that could contribute to the change. The deviation among students also decreased as the study progressed (and greatly between Class B and C where the real-time recognition was introduced): Class A was .4366, Class B was .4273 and Class C was .3512.

Real-time ink recognition and customized software is key to incorporating the tablet PC into the classroom. The benefits from the immediate feedback from computers and intelligent tutors have been proven time and time again. Coupling this with software that is easily integrated with student and teacher workflow provides a compelling educational solution. The pen allows software to transcend the computer and fuse into education.

## 5. FUTURE WORK

This study was able to incorporate data on software components and integration of the tablet PC in the classroom, but because of logistical challenges was unable to orchestrate control groups and testing over such an extended period of time. Future studies should work with schools to plan curriculum around the tablet PC to ensure teachers are able to work the tablet PC as a normal part of their day. The increase in student performance and student perception while implied by the results of this study must also be validated by future studies.

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