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HOW IPADS CAN BE USED IN THE MATH CLASSROOM TO IMPROVE STUDENT LEARNING

by

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STATEMENT BY THE AUTHOR

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HOW IPADS CAN BE USED IN THE MATH CLASSROOM TO IMPROVE STUDENT LEARNING

Katie Ann Garrity Smieja

This study explores how iPads can be used to enhance student learning in the math classroom. The author reviews current literature to determine how iPads are being used to facilitate communication, formative assessment, and promising practices in math education such as discovery learning and use of spreadsheets, graphing calculators, and manipulatives. Additionally, challenges and drawbacks to using iPads in the classroom are examined. Research supports the use of iPads to provide students access to digital content including online discussion boards and practice activities with instant feedback. iPads can also be used as student response systems to engage students in instruction and provide feedback to students and the instructor. Research supports the use of iPads for exploring and manipulating digital content. Since iPads are new to education, more research is needed to determine the best ways to utilize iPads in the math classroom. The author describes an instructional model for incorporating promising practices with iPads in the math classroom.

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Chapter 1: Introduction

Statement of the Problem

This morning, the alarm on my cell phone woke me up. When I got to the kitchen, I found a pot of coffee that had already been brewed automatically. As I got ready for work, a calendar event notification on my phone reminded me about the meetings I scheduled for today. I checked the weather forecast and used my GPS to determine the time I had to leave to make it to my destination on time. I posted a notification online for my students to remind them of an upcoming deadline and replied to an e-mail from a colleague, all before I left my house for the day.

All of these things would have been possible in some way without technology, but with the incredible advancements in technology that are available today, many activities become easier, more organized, and automated. With tools like Smartphones and GPS applications, I save time, stay organized, and stay connected to my students and colleagues (and the rest of the outside world) easily. It seems likely that technology could do the same thing for learning and our classrooms. As our world becomes immersed in technology, it seems inevitable that the classroom will as well. How can we take these tools and put them to work for students in the classroom?

Using technology to enhance student learning is not a new idea. Students have reaped the benefits of exploration software such as Geometer's Sketchpad and Tinkerplots for years. Content management systems like Desire2Learn (D2L) and Blackboard allow students to access and submit assignments, videos, and other learning tools electronically. Interactive whiteboards like SMARTBoards make it easy for instructors to save classroom notes and display and manipulate software and websites for the class. Student response systems and polling sites that allow students to text in responses with their cell phones can gather information from students for instant feedback on what they know and can do. Graphing and computer algebra system calculators are changing the way students solve problems with functions. These technologies and many more are changing the way we teach mathematics and the way that students access information.

While all of these tools benefit students and enhance learning, all of them come with challenges. Activities that use Geometer's Sketchpad are only useful at schools that have purchased this software and have access to computers during class time. Students who miss class for illness or school activities cannot make up the type of learning that occurs using exploration software if they do not have access at home. If each student provides his own calculator, he may buy one that the teacher does not know how to use, making the tool much less useful. SMARTBoards are great if students can interact with them, but only one person can write on it at a time. Blackboard or Desire2Learn are only useful if students have access to the internet at home.

With such a difference in the accessibility of technological resources, it is difficult to find a way to incorporate these tools into the classroom on a regular basis. While the benefits probably outweigh the challenges, incorporating any one of these in the classroom involves the teacher learning how to use it effectively, teaching students how to use it, addressing access issues, and finding funds to purchase and maintain the equipment or software. Students carry portable gaming systems and cell phones with them everywhere they go, but they rarely (if ever) have a graphing calculator or a laptop with dynamic geometry software on it with them. Teachers have an unprecedented opportunity to reach students with mathematics in the same way Facebook, texting, and online gaming have captured their attention if they can find a tool that is easy and fun to use, valuable to them, and useful in the classroom. If teachers could find an affordable, user-friendly, unobtrusive learning device that could do even some of the things above in the classroom, it would be easier to make these practices part of the classroom on a regular basis.

Today, the education community is buzzing about the next big thing in technology: Apple's new tablet computer, the iPad. Some classroom technologies took years to creep into classrooms, but since its introduction in 2010, the iPad is exploding into classrooms across the country. The iPad is a handheld tablet computer about the size of a notebook that connects to the internet through wifi or 3G (in the same way a cell phone can access the internet). Instead of a mouse or a touch pad, the iPad has a touch screen that allows users to click by tapping on the screen and scroll or move objects by sliding a finger across the screen. It is a compact, portable computing device that very young children, non-tech-savvy senior citizens, and students with special needs can operate intuitively (Melhuish & Falloon, 2010). This exciting new tool has great potential to make a positive impact on student learning in the math classroom. While I am skeptical that iPads could ever fully replace all other technologies that have been proven to be successful in the classroom, I seek to learn how the iPad can help students learn by facilitating some of these objectives and helping to remove barriers to student learning.

Whether technology will be a part of the math classroom is no longer the question. If these tools are available, how can I use them to improve student learning? I believe whole-heartedly in the need to move from traditional formats of lecturing and drill and practice homework to concept-building, collaborative, student-centered learning. I am looking for something that allows students to collaborate, to use internet resources at home and in the classroom, to explore, to communicate with me and each other, and to make it easy for them to write mathematical notation on computers without having to type out equations in cumbersome programs. While I know that there is no magic bullet for facilitating all of these practices, I am intrigued by the iPad's potential for facilitating communication about math, allowing for instant formative assessment, and using explorations and discovery applications. The iPad may not be the answer to all of our problems in the math classroom, but it may be the answer to some of them. This paper proposes to explore how the iPad can (and cannot) be used to improve student learning.

Significance of Problem

Using technology to enhance learning in mathematics classrooms is not a novel idea. In 2000, the National Council of Teachers of Mathematics (NCTM) listed technology as one of six main principles for effective mathematics instruction. Their publication *Principles and Standards for School Mathematics* states,

> Technology is essential in teaching and learning mathematics; it influences the mathematics that is taught and enhances students' learning." It goes on to explain that calculators and computers can allow students to explore relationships so that "students can focus on decision making, reflection, reasoning, and problem solving; (National Council of Teachers of Mathematics [NCTM], 2000, p.24)

The Minnesota Department of Education (2007) lists using technology to explore mathematical relationships and test conjectures as a benchmark in the state's Academic Standards for High School Mathematics (Geometry and Measurement 9.3.2.5, revised in

2007). Since iPads came out in 2010, years after these entities published their principles and standards, iPads and other tablet computing devices are not mentioned in either document. However, both include recommendations for discovering mathematics with dynamic exploration software. Can iPads be used to support NCTM's and the Minnesota Department of Education's technology standards?

As news of iPads in the classroom spreads, excitement – and skepticism – are mounting. A quick Google search yields hundreds (if not thousands) of articles about schools adopting iPads at varying degrees of implementation all across the country. Some schools are making iPads available to check out from a media center or library; others are creating iPad labs or providing classroom sets on carts for classroom use only. The most ambitious programs are 1:1 initiatives in which one iPad is provided for each student and faculty member for use at school and at home. Eric Lai, a blogger for ZDNet Ubermobile and Sybase and Jim Siegl, a technical architect in the education industry, maintain an online spreadsheet titled "iPad and iPad 2 Deployments" that summarizes the schools, companies, and agencies that are implementing some sort of iPad initiatives and links to the websites that describe each program. As of December 2011, their site lists at least forty schools from all over the world who are piloting one-to-one iPad initiatives. More than two hundred other schools are also listed as incorporating iPads by giving them to faculty, using them as textbooks, or piloting on a smaller scale such as a single- or multiple-course pilot (ipadpilots.k12cloudlearning.com). It is unlikely this list is exhaustive, so many more schools could be implementing (or planning to implement) iPad initiatives as well.

Critics cite the limitations of the iPad, the most significant of which seems to be that iPads do not have Flash, so they cannot run Java applets that power many learning websites, making some well-known effective learning tools such as the National Library of Virtual Manipulatives or the National Council of Teachers of Mathematics (NCTM) Illuminations website inaccessible on the iPad. The cost of iPad initiatives can also be prohibitive. Since the devices are so new, their educational benefits have not been fully studied yet. "There is very little evidence that kids learn more, faster, or better by using these machines," claims Larry Cuban, a professor emeritus of education at Stanford University (as cited in Hu, 2011, p. 16). Cuban contends the money spent on iPads could be better spent on recruiting, training, and retaining high quality teachers. But even with these (and other) challenges, some educators are observing positive changes in their classrooms. There is a need to determine whether the limitations of this device can be overcome or outweighed by potential benefits or if they prevent it from being a valuable instructional tool.

Research Questions

1. How can the iPad improve student achievement in the math classroom? Specifically, how can the iPad improve student achievement in the math classroom by supporting or facilitating the following practices in math education:
    a. Communication in the math classroom (including collaboration, writing about math, and communicating between students and the instructor)
    b. Formative assessment in the classroom (specifically in the form of student response systems or clickers with iPads)

c. Use of student exploration tools (such as Geometer's Sketchpad and spreadsheets) for experiencing and discovering mathematical relationships and concepts

2. What are the challenges and limitations of using an iPad in the math classroom?

Limitations

When studying the effects of iPads in the classroom, I will limit my research to one-to-one iPad initiatives in which every student has an iPad that s/he can take home. I will be primarily studying the iPad since this is the tool my institution is currently considering implementing. I may include some research of the functions of other tools (*e.g.* iPods, Smartphones, Kindle, Nook, and netbooks) that have similar capabilities, but the focus will be on the iPad in particular. I will not study primary grades; instead, I will focus on 7th grade through college.

Of all of the best practices in math pedagogy, I will limit this paper to the study of student exploration tools (such as Geometer's Sketchpad and spreadsheets), formative assessment (specifically in the form of student response systems or clickers), and communication (including collaboration, writing about math, and communicating between students and the instructor).

I will limit this research to general functions of the iPad that can be used to enhance instruction. While I may highlight some apps specifically if they have been shown to improve learning, this paper will not be an all-encompassing review of all possible apps available.

Assumptions

Although not universally implemented in math classrooms, the best practices listed above have been studied extensively by many in the field and have been shown to increase student achievement and performance. Instead of duplicating the extensive research of many others before me, I will assume that a small number of sources on each of the best practice topics above represent a larger body of evidence that supports these practices in the math classroom. I will also assume that information regarding improving student learning (or failing to do so) using the iPad in classrooms for subjects other than math will be applicable to the math classroom in some way (if not directly transferable to the math classroom). Since the iPad is new, some of the practices I am investigating have not been studied with the iPad in particular. For the purpose of this research, I will assume that if a function or practice has been proven to be successful in increasing student learning, and if that function or practice is practically achievable on the iPad, then the iPad can be used in this way to increase student learning. I will also assume that if a function is shown to be effective on another tool (*e.g.*an iPod, Smartphone, or other tablet device) and the same function can be done in a similar way on the iPad, that the function will be effective on the iPad as well. Differences between the capabilities of the iPad and the tool studied will be noted.

Definition of Terms

- **Smartphone**: a cellular telephone capable of running applications and connecting to the internet
- **Student response systems** (also called "clickers"): devices that allow students to submit a response electronically to a software program instantly

- **app**: an application that has been created for a mobile device such as a Smartphone or tablet computer
- **3G/4G**: when the internet comes from a service provider through the device itself (without the need for wifi or cords)
- **Flash** (also called Adobe Flash): media platform that allows websites to contain animation, videos, or interactive elements
- **Java applets** – computer programs that can run through a browser with the use of Flash
- **NCTM**: National Council of Teachers of Mathematics
- **MDE**: Minnesota Department of Education

Chapter 2: Review of Literature

Why are Schools Choosing iPads for Classroom Instruction?

While there is no shortage of options for personal computing devices, many schools are selecting Apple iPads as their tablet of choice because of its portable design, intuitive touch screen, and engaging ability for manipulation. Portability makes mobile devices like Smartphones, laptops, netbooks, and tablets ideal for education because students can access them and stay connected to others all the time through wifi or 3G (or 4G) networks (Melhuish & Falloon, 2010). Weighing in around one pound, the iPad is slightly smaller than a notebook, making it uniquely portable and convenient to carry. Its eight- to ten-hour battery life and short startup time (Quillen, 2011) along with its irresistible touch screen make many of the functions of a laptop available with the mobility of Smartphones (Eichenlaub, Gabel, Jakubek, McCarthy, & Wang, 2011; Melhuish & Falloon, 2010). Its flat design makes it unobtrusive, allowing students to maintain eye contact with the teacher in the classroom (Hu, 2011) and pass the device easily around a group (Melhuish & Falloon, 2010). Its size makes it easier to read with, watch videos on, and type on than Smartphones (Ireland & Woollerton, 2010; Quillen, 2011). With an LED backlit display with lighting that adjusts to the environment (Valstad, 2010) and a screen resolution of 1024 x 768, the quality of graphics on iPads is incredible (Johnston & Stoll, 2011). The devices are relatively sturdy and can be protected with durable cases, so schools do not need to worry about iPads being broken easily (Shah, 2011). Apple's secure circuit provides a virus-free environment and minimizes technology glitches (Shroff, 2011).

The iPad's touch screen and single home button make it easy to use. To open an application (app), the user simply taps the app. Scrolling, manipulating images, flipping through pages, and zooming in and out can all be accomplished by tapping, sliding, or using different numbers of fingers on the touch screen (Valstad, 2010). Some schools also like that iPads accommodate some of their special needs students because the touch screen is intuitive to use (Shah, 2011). In an iPad lending program at the University of Cincinnati, instructors from many disciplines submitted requests for using iPads in the classroom, but 80% of the pilot programs selected to use iPads in the classroom were STEM courses because the instructors saw potential value in students engaging with and manipulating content such as graphs and graphics of cell diagrams (Johnston & Stoll, 2011). While iPads can be used in part as an e-reader (Shroff, 2011), their usefulness is enhanced now that many publishers are not only making textbooks available in a digital format but also creating interactive, dynamic books with active links to multimedia, animations, and interactive activities. Software is currently available that makes it easy to create digital, dynamic books for use on mobile devices such as iPads (Ireland & Woollerton, 2010).

While all of these features make the iPad a useful portable computing device, Johnston and Stoll (2011) contend that the apps provide the biggest benefit because they allow manipulation and direct interaction with content. More than 5400 educational apps are available for the iPad, of which approximately 1000 are free (Hu, 2011). Apple regulates the quality and number of apps available in its App Store, so users can be assured that the apps will work as intended (Johnston & Stoll, 2011). Houghton Mifflin Harcourt developed an iPad-only Algebra course that includes an interactive multimedia textbook, and Pearson is currently adding features for iPads and developing iPad-specific versions of its course materials (Hu, 2011). As tablets become more popular, more apps will be created to support learning (Johnston & Stoll, 2011), so many educators believe that any gaps that currently exist in app availability and function will soon be filled by new or upgraded apps (Hu, 2011).

The cost of iPads makes them an attractive option for the classrooms. In Roslyn, NY, one school paid $750 per tablet to replace costly textbooks and consumable materials. Apple offers a 10% educational discount. Students used to show up without textbooks, notebooks, or writing utensils, but students like their iPads so much that they keep them with them all the time, taking away excuses for not being able to work (Hu, 2011). According to Valstad (2010), schools can get up to 50% off of apps when they purchase in bulk. When fully implemented in a school or district, schools may save money by using less paper and copy materials, offsetting some of the costs of the devices (Hu, 2011).

Part of the reason schools are choosing iPads in the classroom could be the excitement surrounding the tablet. Ireland and Woollerton (2010) claim, "Whether people like them or not, Apple's products are considered to be 'cool' and therefore can confer 'cool' on the institution" (p. 48). Mobile devices are part of students' daily lives, capturing their attention for regular activities (Melhuish & Falloon, 2010). Schools are trying to capitalize on the engaging features of the iPads to enhance learning. Schools that do not join the mobile education revolution may be left behind (Ireland & Woollerton, 2010).

In nearby Little Falls, MN, more than 1400 iPads were distributed to students in grades 5 - 12 for the 2011-2012 school year with the goal of increasing students' engagement in learning. Superintendent Curt Tryggestad claims that the district chose to implement iPads because they are portable, engaging, and accessible to students 24/7. While increasing test scores would be a welcome result, the main reason the one-to-one iPad initiative was implemented was to ensure students would have access to digital content at home, extending the potential for learning beyond the school day. District officials hope that providing students with the portable tool will help them learn to be better students, which could lead to improved academic performance (Thiessen, 2011).

Current iPad Uses in Schools

Since iPads are so new, a lot of the ways schools are using them are the result of trial and error (Quillen, 2011). Some schools are using iPads to replace other technologies and learning materials such as planners, laptops, paper worksheets, student response systems, and textbooks, while others provide iPads to facilitate communication among students and between students and the teacher. Johnston and Stoll (2011) emphasize that the focus of iPads in the classroom should be on supporting high-impact pedagogical practices, not on the device itself.

Communication and note-taking with iPads. Initially, many schools used iPads in the same way that laptops can be used (Johnston & Stoll, 2011). Graduate students piloting iPad use at Ryerson University found the organizational tools useful for keeping track of school work. Students enjoyed using calendar options that can be synced to web-based calendars. Teachers can use web-based calendars to post assignment due dates and push the information to students' devices to ensure students have the information they need. The DisplayPad app turns an iPad into an interactive second monitor for any computer, expanding the viewing screen and making it easier to have many files or pages open on one computer. In an anecdotal report after the pilot, one student reported that the apps kept her focused and productive because they prevented her from multitasking since she could only work in one app at a time (Eichenlaub et al., 2011).

As long as the campus has wifi, students with iPads can access web-based content at school. Many sites have developed mobile versions compatible with iPads and Smartphones, but desktop versions of these sites are usually available as well. Students who do not have access to the internet outside of school can download files to iBooks or use the Read It Later app to save webpages for offline viewing. However, this app restricts offline access to viewing pages, not interacting with them (Eichenlaub et al., 2011). NCTM's Equity Principle calls for high expectations and support for all students regardless of special needs, readiness levels, or opportunities. Their publication *Principles and Standards for School Mathematics* further states, "Technology can assist in achieving equity and must be accessible to all students" (NCTM, 2000, p.24). The iPad and some of its apps can make digital content accessible to students with iPads, potentially leveling the playing field with regard to access.

However, iPads differ from laptops in the organization of files. iPads do not have a file structure, so documents and files must remain inside apps or be uploaded to web-based file structures (Quillen, 2011). With no USB or CD drive and no file structure, students are unable to download or pass around inappropriate materials (Shroff, 2011). Graduate students at Ryerson University found that they were nearly able to go paperless by using apps like Dropbox, which allows files to be stored in an online file system that can be accessed from multiple devices. Marzano, Pickering, and Pollock (2001) contend that summarizing, note-taking, and creating graphic organizers can aid in student learning. Students at Ryerson University used the iPad to take class notes with apps like iAnnotate, an app that allows users to write on pdf files with a stylus or finger, and iBrainstorm, an app the combines typed text with hand-drawn images (Eichenlaub et al., 2011). Valstad (2010) suggests three other possible apps for classroom use: AudioNote, NoteTaker HD, and the Complete Class Organizer. AudioNote can record sound while taking notes, but it has some formatting limitations. NoteTaker HD is the most like taking notes with paper and pencil. The Complete Class Organizer can record and playback audio that corresponds to notes as they were written, track assignments, and organize content by course (Valstad, 2010). In addition, the iWork suite of applications includes Pages (a word processor), Numbers (a spreadsheet), and Keynote (a presentation app) which could be used to type notes and information (Ireland & Woollerton, 2010). Some apps even make it possible for students to take notes and highlight on virtual textbook pages (Johnston & Stoll, 2011).

A great deal of research supports the use of small-group cooperative learning in the classroom (Marzano, Pickering, & Pollock, 2001). Grouws and Cebulla (2000) claim that there is overwhelming evidence that small-group work on activities, problems, and assignments increases achievement. Johnston and Stoll (2011) suggest the instructor carry the iPad with her as she moves through the room facilitating group work so that she can provide just-in-time support and instruction on the device as needed. Using internet applications like Google Docs, students can create, edit, and share their work online from anywhere they have an internet connection (Johnston & Stoll, 2011).

NCTM's Communication Standard describes the importance of students explaining their thinking and writing about mathematics (NCTM, 2000). Gardner (2004) agrees that student presentations involving technology can be valuable for students to learn and review math concepts. Using a VGA adapter, a student can connect her iPad to a projector so that she can present her ideas and problem-solving processes to the class using a familiar device without transferring files (Valstad, 2010). The Splashtop app allows an iPad to remotely access and operate a laptop or computer, allowing the teacher or a student to present from anywhere in the classroom (Johnston & Stoll, 2011).

Communication about math can also be facilitated through discussion boards on classroom web sites like Blackboard or D2L that provide opportunities for students to post and respond to questions in a less intimidating forum (Gardner, 2004). Johnston and Stoll (2011) suggest teachers set up a backchannel Twitter feed for questions and feedback during class so that students can post questions and responses immediately in a less threatening environment (Johnston & Stoll, 2011). Grouws and Cebulla (2000) report that having students work together on math problems, share their results, and explain their methods or ideas lead to increased student achievement.

Similar recommendations resulted from Project K-nect, an initiative that began with three districts in North Carolina in 2007 in which students used Smartphones to help them learn math. Students used the phones for internet access, recording videos, and instant messaging, but the text and talk capabilities of the phones were disabled. Animated video math problems created by mathematicians at Drexel University in

Philadelphia provided supplemental math instruction, and students were encouraged to use instant messaging for help and the online textbook as a resource. Soon the project evolved as students took control of the technology, creating blogs for giving and receiving help, posting videos of themselves working out math problems, and even creating movies and rap songs about the math content. The role of the teacher soon changed from the presenter of information to the facilitator of learning. Students reported they were spending more than an hour each day on math because they had increased access to instructional materials and learning support. Surveys indicate an increase in students' confidence about their math abilities, and teachers reported that students were explaining their thinking more than they ever had before. In 2007, all of the ninth-grade Algebra I classes using Smartphones in class performed better on the final exam and course grades than the same classes taught by the same teachers the same school year who were not using Smartphones (Davis, 2010).

Assessment with iPads. According to the Assessment Principle in NCTM's *Principles and Standards for School Mathematics*, classroom assessment is valuable for showing students what is important, providing feedback, and adjusting instruction based on results. Collecting information about student progress frequently can build a clear case for what students know and can do and can spark discussions about the content along the way (NCTM, 2000). Using questioning strategies and allowing appropriate wait time for students to respond are essential components in a successful classroom (Marzano et al., 2001). One way schools are implementing questioning strategies and providing opportunities for all students to think and respond is through the use of student response systems, or "clickers." Clickers provide opportunities for instructors to ask questions or pose problems to an entire class and collect instant responses as a form of formative assessment. The results can be collected into reports for teachers to adjust instruction, or they can be displayed graphically for the class to stimulate discussion (Kaleta & Joosten, 2007). Clickers typically allow students to answer true and false and multiple-choice questions or to enter numerical data using the digits zero through nine, a decimal point, and a negative sign (Koppel & Berenson, 2009).

In a study of the use of clickers in a Business Statistics course at Montclair State University in New Jersey, student response systems were shown to be an effective tool for increasing engagement in the classroom and providing feedback to students and teachers (Koppel & Berenson, 2009). In a similar study at the University of Wisconsin, students and faculty largely reported that engagement, participation, and classroom interactions increased significantly. Students felt more comfortable responding to questions anonymously instead of out loud in front of their classmates, and they liked the instant feedback to see if they were on track. Students also reported paying more attention to class activities because they knew they would have to respond to questions throughout the class period. As a result, students in the clicker courses performed statistically significantly higher than the students in the same courses taught by the same instructors without clickers (Kaleta & Joosten, 2007). Use of clickers did not come without challenges, however. Teachers found the time it takes to prepare for lessons that incorporate clickers was somewhat burdensome, and students sometimes forgot to bring their clickers to class (Koppel & Berenson, 2009). While the iPad is not a student response system itself, it can operate like one with web-based polling systems like Poll Everywhere or Socrative (Eisele-Dyrli, 2011). These programs turn Smartphones, iPads, or other mobile devices into student response systems that are not restricted to multiple-choice or simple numeric answers.

iPads as instructional tools. Marzano et al. (2001) include providing opportunities for practice and receiving corrective, timely, specific feedback as important strategies for supporting student learning. Online math assignments can provide students with immediate feedback specific to each student's needs based on the response entered into the program (Gardner, 2004). Studies have shown a positive correlation between the amount of instructional time spent on math and student performance (Grouws & Cebulla, 2000). Grouws and Cebulla (2000) further conclude that supporting learning at home and providing access to more instructional opportunities at home can aid student achievement. Some teachers are providing access to instructional materials by providing students with iPads and "flipping" the classroom structure.

A flipped classroom incorporates instructional videos (created by the teacher or assigned from places like YouTube, iTunes, or Khan Academy) that students watch as their homework so that they can spend class time on activities, group work, and homework problems. The teacher becomes the facilitator of learning in the classroom, and students can watch the presentation (or parts of it) as many times as needed. Stacy Roshan, an Advanced Placement (AP) Calculus teacher at Bullis School near Washington, D.C., reports that she gets through more content since she flipped her classroom. She used to barely get through all of the material, but by flipping her classroom, she has a full month left before the AP exam to review. Roshan has seen an increase in the number of students who score a five on the exam (the highest possible score). Critics of the flipped classroom point out that lecture is not always the best teaching strategy, but students might find success with flipped classrooms when class time is used for pedagogically sound teaching methods (Greg, 2011).

Perhaps one of the simplest ways to use iPads in the classroom is to turn them into an e-reader for textbooks with apps like iBooks, CourseSmarts, and KindleApp (Johnston & Stoll, 2011). In their “Beyond Textbooks” initiative, the Virginia Department of Education is providing students with iPads so that they can use games, assessments, and e-texts through the publisher. Pearson, the publisher working with the Beyond Textbooks initiative, claims they will adjust their course materials based on the results of pilots like this one (Quillen, 2011).

A promising study conducted by a third-party research firm in Riverside, CA incorporated the use of iPads equipped with an interactive Houghton Mifflin Harcourt (HMH) Algebra I textbook app called *HMH Fuse* in eighth-grade algebra classrooms (Houghton Mifflin Harcourt [HMH], n.d.). The app is much more than a typical e-book with its interactive lessons, video tutorials, and note-taking capabilities (Takahashi, 2011), allowing teachers to flip the classroom (HMH, n.d.). The textbook includes interactive links to the glossary, step-by-step examples, explorations, and homework assignments and tests that can provide instant feedback. Jeanette Mitchell, a teacher involved in a similar HMH pilot in a San Francisco middle school, stresses that students use the videos to supplement instruction, not as the instruction itself. She still expects students to write on paper (partially due to the limitations of the app’s sketch area), and she feels the feedback she collects with the instant response system is more genuine than she would have gotten from asking for students to raise their hands to respond (Barseghian, 2011). Throughout the pilot, teachers contacted HMH frequently to provide feedback about the product so that adjustments could be made to the app (Barseghian, 2011).

HMH reports increased student engagement in class as well as more reading and homework completion outside of class (HMH, n.d.). Mitchell claims that students with iPads and the *HMH Fuse* app frequently reported watching videos multiple times until they 'got it,' but students with textbooks never said they read the book multiple times to understand (Barseghian, 2011). Parents rated the app favorably because the features allowed them to help students with homework at home. Teachers reported that some students came to class with homework done after missing a day of school because they were able to learn the material on their own. In Riverside, CA, two teachers each taught one class using *HMH Fuse* and another class just using the textbook during the 2010-2011 school year. The average score on the district's algebra test was 10% higher for students using *HMH Fuse* than students who had not used the app. On California's standardized state test, 78% of students using the app scored either as proficient or advanced, while 59% of students at the school scored in these ranges (HMH, n.d.).

At Pepperdine University, instructors studied the impact of utilizing Numbers, a spreadsheet application, and GraphingCalc HD, a graphing calculator app, on iPads in a Business Calculus class. In the control group, students used laptops with Excel and a Java graphing applet. While both classroom situations incorporated technology and group-work for problem-solving, the researchers found that students in the iPad classroom stayed on task more than students in the laptop classrooms. Researchers hypothesized that the physical barriers formed by the upright screens of laptops (as opposed to the flat design of the iPad, which can lay flat on a table) made students feel disconnected from the classroom and therefore more likely to stray to social networking sites in class. Since all students used a uniform device, students could help each other with technology use. Overall, students with iPads were more likely to incorporate graphs and spreadsheets into their solutions. Students with laptops were reluctant to use the technology and only did so when the problems were too difficult to solve by hand (Fisher & Lucas, 2011).

Pedagogical uses of iPads. The iPad is helping to facilitate learning through engagement, access to the internet, and opportunities for communicating about math, but early adopters caution that use of the device should not be limited to these features. “It’s so engaging, we want to make sure we’re capitalizing on the functionality—not just the engagement,” said Brian M. Engle, executive director for education technology for Glenview District 34 in Illinois (as cited in Shah, 2011, p. 17). The device is a tool for enabling quality education, but the teacher must be implementing sound teaching practices in order for the iPad to work (Eisele-Dyrli, 2011). The iPad itself will not change education, but the pedagogy that the iPad can facilitate could change education if students use the devices to experience and manipulate content with educational apps (Johnston & Stoll, 2011). What is best practice for pedagogy in the math classroom?

According to the Trends in International Mathematics and Science Study (TIMSS), students in the United States are being outperformed by students in Japan. Students in U.S. classrooms spend approximately 90% of their instructional time in math practicing routine procedures. Students in Japan, on the other hand, spend about 40% of their time on practice, 15% on applying knowledge to new situations, and 45% of their time on inventing new procedures and analyzing new situations. Thus researchers conclude that discovering math and inventing procedures lead to a stronger conceptual understanding than practice alone. In fact, studies show that students who learn in a concept-focused environment perform just as well as their counterparts on procedure-based skills, but they do much better on concept-based content than students who are taught with traditional skill practice methods. Studies also suggest that too much drill on isolated skills can make it difficult to incorporate the conceptual piece later (Grouws & Cebulla, 2000). Marzano et al. (2001) emphasize the importance of students generating and testing hypotheses through discovery learning, problem-solving, and experimenting. Valstad (2010) and Gardner (2004) concur that quality pedagogy includes collaborating, analyzing math concepts, engaging in problem-solving, discovering relationships, connecting concepts to real-world situations, and experimenting. Grouws and Cebulla (2000) emphasize that hands-on manipulation (not just observing demonstrations) increases the effectiveness of discovery explorations.

Technology can support these practices by making visual models accessible and allowing students to explore and investigate mathematics with dynamic software. "When technological tools are available, students can focus on decision-making, reflection, reasoning, and problem solving" (NCTM, 2000, p. 24). Spreadsheets can be used to make calculations and explore algebraic concepts. Investigating with dynamic geometry software allows students to discover mathematical relationships and take ownership of abstract concepts. Exploring virtual manipulatives and graphing functions with technology facilitate the exploration of mathematical concepts and graph features (NCTM, 2000). Use of technology can make data collection take less time so that students can spend more time on analyzing the data (Gardner, 2004). Studies show that students who use graphing calculators are better problem solvers, develop better graphing ability, and show greater understanding of graphs and relationships (Grouws & Cebulla, 2000).

Johnston and Stoll (2011) seek to find ways for the iPad to change *how* mathematics is taught by having students using them to manipulate images and explore relationships in activity-based and learner-centered classrooms. Valstad (2010) emphasizes that choosing the appropriate app is essential for using iPads in this way. However, neither of their articles described specific pedagogical uses that support discovery learning.

Challenges and Drawbacks to iPads in the Classroom

The potential benefits of iPads in the classroom do not come without challenges. Critics of the iPad cite its cost, lack of file structure, and inability to run Java applets as major drawbacks of the device. Apple refuses to allow Flash on its iPhone, iPod, and iPad (Unrein, 2011). According to Gardner (2004), NCTM's free Illuminations activities are a valuable learning resource for exploring mathematics through the interaction with virtual manipulatives and discovery activities. However, since the Illuminations site contains Java applets, and iPads don't have Flash to run Java applets, these activities cannot be used on an iPad. Other valuable sites like the National Library of Virtual Manipulatives and countless others are not accessible on iPads. However, a new programming language called HTML 5 that operates similar to Flash without the need for plug-ins is becoming more common in websites. While there are currently not many e-learning tools using HTML 5, HTML publishing will soon become commonplace (Unrein, 2011).

Others criticize the limitations of specific apps. All apps must be downloaded through the app store on the iPad or through Apple's iTunes software, so students do not have choices about from whom to purchase their apps. Some people are concerned that access to apps may be limited by Apple's screening process (Melhuish & Falloon, 2010). Gaps exist between the availability of quality educational apps and the needs of educators. Ireland and Woollerton (2010) contend that large publishing companies will develop more quality apps for educational use to stay competitive. If an app is not currently available to meet an educational need, it is likely that one will be created in the near future (Ireland & Woollerton, 2010).

The iPad's lack of USB port and internal file structure pose some challenges to users of the device. There is no USB port, so jump drives cannot be used to transfer data among devices without sending files through the internet. Apple's solution to file management is cloud-based computing in which files are stored online to be accessed by multiple devices (Melhuish & Falloon, 2010). Data is stored within each app, not inside a set of folders. The Dropbox app can be used to store documents and files and can even allow an iPad to open documents without being connected to the internet. However, it is somewhat cumbersome to use because the user must email the file back to the dropbox in order to save any changes (Valstad, 2010).

Some question whether iPads are worth their costs. Las Vegas Public Schools, for example, spent $790,050 on their one-to-one iPad initiative to participate in the HMH Fuse pilot in the hopes of increasing student achievement. With a $56 million budget shortfall, skeptics question whether this is the best use of district funds (Takahashi, 2011). Since the devices are relatively costly, it is important for students to take care of them. Some schools have students or parents buy insurance plans or sign agreements regarding their financial responsibility in case the iPad is lost or stolen. Since students like and use their iPads so much, very few issues have come up so far (Barseghian, 2011). Hu (2011) questions whether other less expensive options are being ignored. Smartphones, netbooks, and other tablets can do a lot of the same things as iPads at a lower cost. In a survey of over 350,000 K-12 students, parents, and administrators including 5757 schools and 1215 districts, 78% of students in grades 6 – 12 prefer to use their own devices over classroom-issued technologies (Eisele-Dyrli, 2011).

As with any new technology, there is a learning curve for using iPads. Eichenlaub, Gabel, Jakubek, McCarthy, and Wang (2011) recommend more studies be done for extended periods of time so that the effects of iPads can be measured after students and teachers are used to them. Schools may not be set up for widespread iPad use if wireless networks and technology policies are not in place. Teachers and students must be trained on how to use both the device and helpful educational apps. Students must also be trained on appropriate use of technology in the classroom and safe web navigation skills (Davis, 2010). Teachers may not be comfortable with their new role as facilitator of learning without training in the importance of new pedagogy (Melhuish & Falloon, 2010). Creating learning opportunities, lessons, and activities that use the iPads effectively takes a lot of time out of teachers' already limited preparation time (Quillen, 2011).

iPads have many potential benefits in the classroom, and almost as many potential drawbacks. Eisele-Dyrli (2011) emphasizes that the focus of any classroom change should be on the teaching. The iPad is the current device educators are buzzing about, but mobile learning, not the iPad itself, is really the next big thing. Elliot Soloway, co-founder of the mobile-learning developing company GoKnow, describes the future of mobile learning:

> People are used to focusing on devices, applications or Web sites in education, but that's not the future with mobile. The future is 'device agnostic.' It will be an integrated learning environment we haven't seen before, an educational operating system not yet developed that will work across every device. (Eisele-Dyrli, 2011, "Device Agnostic Future," para. 2)

Chapter 3: Results

Using iPads to Improve Student Achievement in the Math Classroom

Schools are using iPads in many different ways to engage students in learning. Apps for interactive textbooks, online math discussion boards and blogs, and multimedia math tools are providing students access to learning resources that were out of reach before iPads entered the classroom. Surprisingly, there was very little overlap in the ways schools report using iPads in the classroom. This may indicate that although some promising practices are emerging, no best practices have been proven yet. As more research becomes available, it is likely that schools will begin to share ideas and learn what works from each other, potentially increasing the opportunities for student success.

Facilitating communication with iPads. Can iPads support communication in the math classroom (including collaboration, writing about math, and communicating between students and the instructor)? The research indicates that iPads can facilitate communication about mathematics through the use of note-taking apps, online blogs and discussion boards, and class presentations about mathematics. Davis's 2010 study of Smartphones in an Algebra I classroom resulted in increased student engagement and achievement as a result of students communicating with each other about math on classroom blogs. This study is directly applicable to iPads, which can accomplish the same objectives as Smartphones on a larger screen that is easier to read on and type on. Students used their mobile devices to explain their thinking in writing and on videos.

Schools also experienced success with facilitating group work with iPads. Students worked together in groups on activities or problems, using their iPads for graphs, spreadsheets, or note-taking. The teacher became the facilitator, circulating throughout the room and providing help and support as needed. Students prepared presentations using iPads and shared their results with the class by connecting an iPad to a projector.

The iPad can also support communication by providing students with access to digital materials outside of the classroom with wifi capabilities and apps like iBooks or Read It Later which allow students to save documents and web sites to access offline. Some teachers use iPads to flip their classrooms, providing videos for students to watch outside of class to free up class time for group work, problem-solving, and other learning activities.

Schools could take the power of the iPad one step further by combining digital note-taking capabilities with the ability to share activities and assignments with students electronically. Students could download activities the teacher provides and use note-taking apps to write on them and complete paperless submissions. Using iPads in this way can expand computerized assignments from the typical drill and practice problem sets by allowing students to write math expressions and equations on activities and assignments with a stylus or finger without the need for complicated software like Math Type. Students can share their mathematical steps electronically without a scanner. Students can write about math, share ideas with each other, and show what they know in ways they never could have before – and without the use of hardware like scanners or expensive software.

Formative assessment with iPads. How can the iPad facilitate formative assessment in the classroom, particularly in the form of student response systems or clickers? Research supports the use of student response systems to provide instant feedback, increase engagement in learning activities, and to monitor student understanding. Several options for using iPads in this way were discussed: web-based polling sites such as Poll Everywhere or Socrative can turn any mobile device with internet access into a student response system. Other apps like *HMH Fuse* or individual clicker apps can be used as student response systems to assess students instantaneously. Students can also receive instant feedback from online math assignments through publishers' websites or apps designed to supplement curriculum. Using iPads only as clickers for formative assessment would not be cost effective. However, when used in conjunction with other effective practices, the use of iPads as student response systems can be valuable in the math classroom.

Exploring mathematical relationships with iPads. How can the iPad facilitate learning through the use of student exploration tools (such as Geometer's Sketchpad and spreadsheets) for experiencing and discovering mathematical relationships and concepts? The research was lacking in this area. Research clearly supported problem-solving, discovery activities, and exploring mathematical relationships as high-impact practices in the math classroom. Several sources advocated for sound pedagogical practices that allowed students to explore and manipulate content on iPads, but unfortunately, few schools reported specific examples for using iPads in this way. The *HMH Fuse* app includes a graphing calculator feature, virtual manipulatives, and exploration activities. Spreadsheets and graphing calculator apps supported learning in Business Calculus at Pepperdine University. Multiple other learning apps are (or will soon be) available for students to explore mathematical relationships.

Key Curriculum Press created Sketchpad Explorer, a free app that allows students to interact with Geometer's Sketchpad files. The app does not allow users to create new sketches, but activities and templates are available all over the web. Sketches can also be created on computers and shared with iPads using iTunes. Even with these limitations, however, this app brings many of the benefits of dynamic geometry software like Geometer's Sketchpad to the user-friendly touch screen of the iPad.

Challenges and Limitations of iPads in the Classroom

What are the challenges and limitations of using an iPad in the math classroom? Any device comes with drawbacks, and the iPad is no exception. While some schools found that iPads defrayed printing and textbook costs, the cost of the tablet can be prohibitive for some schools. If the iPad is only being used as a computing device, the cost may not be worth the benefits. However, if schools use iPads to replace several other costly learning tools like textbooks, workbooks, student response systems, computers, scanners, and learning software, the benefits may be worth the money. Some other devices may provide similar educational benefits with a lower price tag.

Some educators have not found apps to fill their students' learning needs. Although the iPad was not designed specifically for educational use, now that it has become a part of so many classrooms across the country, textbook publishers and software designers will not ignore this market. They are already hard at work at creating iPad-compatible learning materials. Researchers agree that more and better apps are coming.

The lack of file structure and a USB port force iPad users to use email and cloud-based apps and sites to save and organize files. While it may be slightly inconvenient to email files before uploading them to virtual dropboxes, the device does allow users to access and share documents and files wirelessly.

Perhaps the biggest drawback of iPads is the lack of Flash, which prevents iPads from running Java applets. The National Library of Virtual Manipulatives and NCTM's Illuminations activities cannot be used on iPads without remotely accessing another computer with apps like Splashtop. This researcher is hopeful that the growing popularity of HTML 5 will make this challenge irrelevant in the near future. Until then, there are many other ways in which the iPad can be used to facilitate learning that do not involve Flash. If not having Flash is a deal-breaker for school districts, they could choose to adopt a tablet that has Flash instead.

Many of the high schools piloting iPad initiatives purchased the devices for their students. At the post-secondary level, however, who should pay for iPads if they are going to be used in the classroom? What infrastructure would need to be set up to support iPads in a post-secondary institution? If students are required to provide their own iPad, will the cost be prohibitive? If students cannot afford to purchase their own iPad, the accessibility the iPads are intended to provide is irrelevant. Research supports the use of a uniform device in the classroom so that students can help each other use them in the classroom and teachers can create learning materials with device-specific instructions. Therefore schools should select one tablet to provide or require students to obtain for effective classroom use.

Chapter 4: Conclusions

Problems with the Research

The research indicated several promising practices for using iPads in the classroom to enhance learning. However, the research was far from conclusive on the results on student achievement in mathematics. Very little scientific, statistically sound research has been conducted on the effects of iPad use on student achievement. Most of the reports of iPad use in the classroom included teacher perceptions and anecdotal evidence that were not confirmed with data. Some of the suggestions in this paper are mere speculation based on logical applications of tablets to support best practices in math education. Since iPads are so new, best practices for incorporating the devices into the classroom have not been developed or confirmed yet. More research is needed to determine the effects of iPads in the classroom.

The Houghton Mifflin Harcourt study on the effects of the *HMH Fuse* app on student achievement reported impressive results: an average test score of 10% higher for iPad users than for students who had not used the app. The report also boasts higher scores on California's standardized state test: 78% proficient and advanced rate for iPad users compared to 59% of non-iPad users scoring in these same categories (HMH, n.d.). The comparison on the results of the district test between students taking the same class from the same teachers during the same semester is valid, and makes a strong case for using *HMH Fuse* to improve student achievement. However, it is not clear from the report whether all of the non-iPad users who took California's state test had taken Algebra I at all. In Minnesota, students take the state standardized tests in a specific grade, but not all students have completed the same courses. One would expect that the results of any class that aligns with standards on the state test would perform better than the population at large if the population includes students who never had access to the test's contents in their courses. It would not be fair to compare a group of students who had taken Algebra I with the *HMH Fuse* app to the rest of the student population if they did not all take some form of an Algebra I course.

In Greg's article (2011), AP Calculus teacher Stacy Roshan reported an increase in the number of students who earned a five on the AP Calculus exam. However, the article does not indicate how many more students achieved this result. How can one conclude that the difference is statistically significant? It is unclear whether an actual difference is being made or if the teacher is reporting her perception of gains in achievement. More information is needed to be sure.

Suggestions for Further Research

iPads are still so new that we may have only scratched the surface of their potential. Schools using iPads are connecting with their students in their own technological language, making the process of learning more like their daily lives. On the other hand, schools may still be in the honeymoon period in which iPads are new and exciting, and therefore engaging enough to keep students interested in learning. What will happen when the novelty wears off? Will iPads become more effective as students become accustomed to the technology, or will their benefits decrease when the excitement dies down? More research is needed to determine the long-term effects of iPads in the classroom.

To supplement the anecdotal evidence that is mounting in support of iPads, schools implementing iPad initiatives should collect data on student achievement, retention, persistence, and conceptual understanding. None of the sources included in this paper addressed the student populations that were most affected by iPads in the classroom. Are iPads beneficial to students at all ages, grade levels, and technological competencies? Do some students benefit from iPads more than others? More research is needed to find out.

While several sources indicated the importance of using iPads to support sound pedagogy, very few specific examples were given. More research is needed to determine how iPads can (or cannot) support some of the best practice in math teaching.

Suggestions for Implementation: An Instructional Model

While any one of the uses described in this paper could enhance learning and provide students access to learning resources in the classroom on its own, this researcher advocates for combining these methods into a holistic instructional model that can make the most of the iPad's potential benefits. When used for communication, providing access to digital learning materials, assessment, and exploration, the iPad may be a powerful tool to make best practice in teaching possible in the math classroom. The following instructional model combines the practices found in research with other potential uses of the iPad to make the most of iPads in the classroom.

Every student should have an iPad that he or she can take home with them so that access to the iPad's benefits is not restricted to the school day. Teachers should teach students how to use apps that allow them to access content when they are connected to the internet. To further narrow the gap in access to technology, options for 4G iPads should be available to students without internet access or wifi at home.

In the classroom, iPads can be used to take notes and complete activities without the need for paper. The instructor can post blank SMARTBoard or PowerPoint presentations to Google Docs or D2L so that students can take class notes on the templates. Absent students can also access these notes. Perhaps students could collaborate or take turns posting their completed notes to a class website for students to refer to later (and to help students who are absent). Similarly, students can complete activities and assignments posted on D2L or Google Docs and save their results electronically. The teacher should set expectations for students communicating about mathematics and explaining their processes for problem-solving. Concept maps and graphic organizers can become a part of the classroom routine without expensive software, and students can write about their thinking as individual assignments, collaborative group projects, or online postings. Students' presentations can become multimedia presentations because every student has access to the necessary tools.

When practice is assigned, students can complete problems on the textbook publisher's web site or math app to receive instant feedback. Teachers can track students' progress on these programs, freeing up more time for creating activities and monitoring achievement. When rich real-world applications are assigned, students can work in groups or on their own, writing on the iPads and submitting their completed assignments electronically. Students can help each other by posting questions and answers on math help discussion boards on D2L or a class website. The teacher can monitor these boards to provide support and adjust instruction to meet students' needs in class.

To further monitor students' understanding of the concepts, teachers can use Socrative or other student response system apps or programs to collect responses to questions instantly. The results of these polls can be displayed for the classroom, stimulating discussion on what the common errors are and how to avoid them. Student response systems could even be used for submitting journal responses or quizzes or assignments to shorten feedback time.

Perhaps most importantly, iPads can be used to facilitate discovery learning. Students can work in groups on exploration activities using spreadsheet apps, graphing calculator apps, and Sketchpad Explorer. Students can share results and give each other feedback by posting to a class blog or discussion board and commenting on each other's work. Class time can be spent on exploring mathematics and discovering relationships. Students can present their findings to each other (in class or online), and share their completed activities digitally. Classrooms can be flipped for supplemental direct instruction, review topics, or extension concepts so that class time can be used for questioning, exploring, collaborating, and working on real-world problems.

The iPad's potential for enhancing student learning is incredible. While there are many things it cannot do, the things it can do could make an enormous impact on student learning. This device can make learning materials, math help, supplemental instruction, and exploration tools accessible to every student who has one. Best practices like writing about mathematics, discovering math relationships, and adjusting instruction based on formative assessment are made much easier with iPads. If teachers use iPads in pedagogically sound ways, and if students take advantage of the resources available to them on these devices, then iPads could change math classrooms for the better.

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