THE IPAD: NOVELTY OR BREAKTHROUGH FOR SCIENCE EDUCATION?

by

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ABSTRACT

This research is focused on the impact of the Apple iPad upon student learning, student motivation, and student/teacher attitudes towards technology use in a middle school science classroom. Three eighth-grade science classes used iPads for three alternating weeks for their study of astronomy. During intervening weeks, the classes reverted to more traditional instructional practices. Quantitative data included comparison of daily quiz scores between treatment and non-treatment weeks. Another source of quantitative data included results from numeric responses from pre and post-treatment surveys. Qualitative data included open-ended student responses on survey forms, interviews, teacher field notes, and student work artifacts. Quantitative data showed small improvements in student achievement, student motivation, and student attitudes toward technology use in their learning. However, all qualitative data sources suggested the iPad had a much larger impact in all three areas. Moreover, results suggested the iPad had a larger positive impact on student motivation and student attitudes towards technology with the lowest-achieving students. The results of this study suggested the Apple iPad is indeed a breakthrough technology for student science learning. The effect is so powerful that school districts should consider allowing student access to their personal hand-held media devices in class, if adequate numbers of iPads are not available.

INTRODUCTION AND BACKGROUND

I am completing my fifth year of teaching eighth-grade earth science at Lewis & Clark Middle School in Bellevue, Nebraska. Lewis & Clark is part of the Bellevue Public School district. The city of Bellevue, with a population of around 50,000, is located approximately ten miles south of Omaha, Nebraska. While most students in our school are from middle class households, 21% of the students are eligible for free/reduced lunches from the National School Lunch Program. Like many school districts across the nation, my district has recently piloted efforts at technological innovation. Increasingly, these efforts involve use of hand-held media devices.

Since the mid-1990s, desktop computers and Internet access have become widely available in K-12 schools. However, correlating increased student achievement to desktop technology use has often proved elusive. More recently, a new generation of computing technology has emerged, in the form of hand-held media devices. These devices offer instantaneous access to the Internet, and offer robust authoring capabilities for users. Coincidentally, K-12 educators in virtually all content areas are seeking ways to make subject matter relevant to their students' lives. Connecting subject matter more directly with students' lives holds the promise of increased student learning, as well as increased student motivation towards learning. Since hand-held media devices are nearly ubiquitous in the world of today's adolescents, integerating these new devices into classrooms becomes important to teachers, students, parents, and administrators.

My action research (AR) topic examined the impact of one hand-held media device upon learning in the middle school science classroom. Hand-held media devices come in several forms, including: music players, smart phones, and electronic tablets. Apple's

iPad contains most hand-held capabilities in one device, with a robust screen display. The iPad also has the most educational applications (apps) available. But questions remain whether the iPad truly affects student learning, or appeals mainly to students because of its engaging technological features. Using the iPad in a middle-school science classroom was the focus of my AR investigation.

Since my intervention utilized one hand-held media device (the Apple iPad), my primary research question became: *How does the iPad impact student learning in a middle-school science classroom?*

Two secondary research questions were answerable, based on measurement instruments addressed later. Secondary question #1 may be expressed as: *How does the iPad impact student motivation towards learning in a middle-school science classroom?* Secondary question #2 may be expressed as: *How does the iPad impact student & teacher attitudes towards technology use in a middle-school science classroom?*

This study was important for at least five reasons. First, it directly influenced my teaching strategies in a middle school science classroom, and led to new approaches on how to increase student learning. Since I teach eighth grade earth science, several units (astronomy, meteorology, oceanography) are not always amenable to classical laboratory-based learning approaches (such as chemistry and biology). The iPad provides a vehicle for more authentic learning through Internet access, along with multi-media production and editing capabilities. Moreover, the iPad can utilize thousands of quality applications, called apps, already developed for educational use. Second, while I believe the promise of the iPad to increase student learning is strong, it can also increase student *motivation* towards learning in the middle school science classroom. Third, the iPad

positively changed teacher and student *attitudes* towards technology use in our school district. Fourth, results of my research may help justify additional district acquisition of iPads. Fifth, few peer-reviewed articles discuss the relationship of hand-held media devices to learning and motivation in a middle school science classroom, although some have documented impact at other grade levels and in other subjects. As a result, my AR results may benefit other teachers outside my school district.

Fortunately, I had a talented support team to offer constructive feedback along the way. The first person on my support team was my wife (Lisa). A first grade teacher at a local Catholic school, she made sure my writing was clear and concise. As a reading specialist, she was a source of ideas on how to improve grammar and sentence structure.

The second person on my support team was Elissa Wolf. She is a fourth grade teacher in a local K-8 Catholic school, and also her school's science representative to the State of Nebraska's "Science Matters" Committee. She is very knowledgable of our state's K-8 science curriculum. She offered insight on my research based from a broad science education background. While Elissa works in a different school, I easily sent electronic drafts for her review.

The third member of my support team was Jenny Krzystowczyk. Jenny is a technology trainer for our district. She was the person who not only encouraged me to pursue this project, but also arranged the use my project's iPads. An expert in Apple devices and associated applications, she provided an insightful technology perspective. Since Jenny works at my school, she was always available to review drafts of this paper. Other research work laid the precedent for my research; this previous research is discussed next.

CONCEPTUAL FRAMEWORK

A Look At Previous Research

Previous work providing direction for my research topic evolved over time, much as the technology in hand-held media devices has evolved. It is worthwhile to briefly explain the hand-held technology evolution chronologically, before citing specific literature.

Apple's original iPod was introduced in 2001, and was an immediate success as a music, voice, and text storage/playback device. Variations of the iPod were unveiled before the ground-breaking iPhone was released in 2007. The iPhone's touch-screen technology was subsequently incorporated into the iPod Touch, which was also released in 2007. The iPod Touch has the original iPod capabilities, along with the touch-screen and "smart device" technology of the iPhone (although the iPod Touch lacks phone service capability). Finally, Apple introduced the iPad in 2010. The iPad is essentially a large iPod Touch in the form of an electronic tablet, and has already been produced in four versions. The term "hand-held media device" in this paper includes the iPod, iPod Touch, iPhone, and iPad. It is also important to note the iPhone, iPod Touch, and iPad currently run the same operating system. iOS 6.1 was installed on the iPads used in this study. All three devices can use over 250,000 applications (apps) developed for this operating system. An application developed for one device essentially operates on the other two, although some apps are designed only for the iPad.

Early recognition of the value of hand-held technology in education was documented by Lacina (2008). He found iPods were valuable tools in language

acquisition in elementary and middle schools. In previously conducted studies, Lacina found improvement in writing skills and vocabulary development, with “a significant increase in comprehension skills” (p. 247). Additionally, podcasts allowed the opportunity for students to “publish, or record, their writing in a technological format” (p. 247). Lacina also documented the use of iPods in a Dallas area sixth-grade English Language Learners (ELL) classroom. The ELL teacher integrated iPods “into classroom instruction, and for individualized homework instruction” (p. 248). Lacina’s work was significant because it provided early research results documenting the role of a hand-held media device in learning, which is my primary question’s focus. Although the primary focus of Lacina’s work was an ELL classroom, the language and writing skill improvement is directly relatable to a science classroom. Indeed, Lacina noted the use of podcasting in another Dallas area school was “most noticeable in language arts and science classrooms” (p. 248).

While Lacina’s work centered on the iPod, a later work by Banister (2010) offered a view of the potential of the more technologically advanced iPod Touch. Surveying the iPod Touch’s impact upon primary and secondary education, Bannister identified the emergence of the iPod Touch as a “pocket computer with multiple K-12 classroom possibilities” (p.122). Banister highlighted the iPod Touch’s robust media capabilities including storage/playback of audio, image, video, and text files. Almost as importantly, he noted the iPod Touch offers instant access to the Internet. Banister (2010) found the iPod Touch media capabilities make accessible a “plethora of pre-made educational media…available for K-12 classroom use” (p.123). He stated a powerful

capability of the iPod Touch is its ability to use teacher and student-created content, "customizing learning content to specific curricular needs" (p.123).

Banister (2010) briefly surveyed basic applications (apps) that are useable in the middle-school science classroom. These included a notetaking app, which is useful for class notes, field notes, and creative writing. Banister also surveyed apps applicable to earth science curricula including a weather app to monitor weather at selected cities, and an electronic flash card app for storing content-related review material. Nearly as important, Banister also found "Web applications in the scientific fields are plentiful and diverse" (p.128).

Although the iPad is a relatively recent arrival (2010), it has already proved popular with the public, and has generated considerable interest with K-12 educators. Fewer studies documenting the iPad impact in a K-12 classroom have been published, although it is reasonable to presume previously documented results from iPod and iPod Touch also apply to the iPad. Hutchinson, Beschorner, and Schmidt-Crawford (2012) used a case study to examine the utility of the iPad in literacy instruction. Citing their case study from a fourth-grade classroom, the authors found the iPad strongly supported literacy instruction. They additionally noted "…students were also highly engaged and able to demonstrate unique and creative ways of responding to text using a technology tool that offers some unique affordance to users" (p. 23).

Early research efforts cited in this section were important synopses of the iPod, iPod Touch, and iPad's ability to promote learning in primary and secondary classrooms. They were critical to my research effort because they provided early conveyance of a

critical finding: the use of hand-held media devices in the classroom is not merely a novelty, but a demonstrated way to enhance student learning.

Theoretical Foundation

Keengwe and Onchwari (2011) examined the role of technology integration in support of constructivist pedagogy. Their work provided a theoretical foundation behind the investigation of my primary and secondary AR questions. While Keengwe and Onchwari used the term “technology” as a general umbrella for many devices, the phrase “iPad” could just as easily have been substituted throughout the article.

“Piaget's notion of constructivism theory assumes that learners have to construct their own knowledge, individually, and collectively” (Keengwe & Onchwari, 2011, p.1). This was consistent with my instructional goals of using the iPad for students to construct their own knowledge of earth science, both individually and collaboratively. This contrasts with more traditional “teacher-centric” direct-instruction methodologies. Additionally, constructivism “embraces the understanding that learning requires active engagement on the part of the learner” (Jenkins, 2000) as cited in Keengwe and Onchwari, 2011, p. 2. Active engagement was precisely my goal with the introduction of iPads into my science classes. If students are actively engaged learners, then the instructor becomes more of a facilitator in the learning process, helping “learners scaffold the zone of proximal development for individual construction of knowledge and meaningful learning” (Novak, 1998) as cited in Keengwe and Onchwari, 2011, p. 2.

Keengwe and Onchwari (2011) summarized three basic tenets of a constructivist approach to instruction: learners independently form representations of knowledge,

learning should occur through active engagement and exploration, and learning occurs best within a social context. The link of constructivism to technology is presented as constructivist pedagogy incorporating active learning with technology, with teachers acting as guiding partners.

"Constructivist teachers ask questions, oversee activities, and mediate class discussions; the instructional process is viewed as supporting construction rather than exchanging information" (Keenwge & Onchwari, 2011, p. 3). Keenwge and Onchari also believe the more constructivist a teacher's approach, the more likely this teacher would integrate technology into classroom learning. Keenwge and Onchari cited a compelling statement from O'Dwyer, Russell, and Bebell (2004): "The strongest positive indicator of whether a teacher will use technology to deliver instruction, have their students use technology during class and have their students create products is a teacher's belief about the positive impacts of technology integration" (p.15).

I was encouraged to discover Keenwge's and Onchari's work confirmed the fact that my AR topic was connected to constructivist theory. Using iPads in a science classroom allowed my students to independently construct knowledge, ensure active engagement by each student, and provide a social context for learning. Their article ensured my research was not based merely on measuring the popularity of the iPad in learning, but rather on measuring the effect upon learning (the primary research question), student motivation (a secondary research question), and student attitudes towards technology (a secondary research question).

METHODOLOGY

Treatment

During each of the three treatment weeks, students in each of my three science classes had access to a classroom set of a second-generation Apple iPads. Treatments started on the first day of our third quarter, 1/7/13. This date was selected because it marks the start of our astronomy unit, which is the longest teaching unit of the year. Numerous web-based applications and specific iPad apps have been developed for the study of astronomy. A matrix correlating application use to each treatment week (TW) is shown in Table 1.

Table 1
Applications Used Each Treatment Week

Application	Use	TW
Apple TV	Projects iPad displays to large screen	1
Safari	Web browser	1-3
Astronomy Picture of the Day	Displays daily astronomical images	1-3
Socrative	Electronic quiz taking	1
NASA HD	Planetary information	1
Quia	Server hosting of chapter tests	1, 3
Apple iTunes University	Video clips on solar system moons	2
Pages	Word processing	2
Moon Globe	Imagery/features of lunar surface	2
AudioNote Lite	Produces audio podcasts	3
Popplet Lite	Produce graphic organizers	3
iPhoto	Stores/edits image files	3

The first treatment week began with our study of our solar system, and introduced students to *iPad functional capabilities*. We started with an examination of the inner and outer planets. For each group of planets, students explored planetary characteristics by primarily using websites and the NASA HD iPad app.

During the first treatment week, students completed paper worksheets, paper graphic organizers, and paper charts as they investigated planets with the iPads. The exploration of the inner planets and outer planets began with students completing a paper graphic organizer on general planetary characteristics on each group of planets. To complete the inner planets graphic organizer, students accessed an on-line version of their textbook. After completing the inner planets graphic organizer, students used a website to complete a more detailed worksheet on each of the inner planet's characteristics. Examination of the outer planets proceeded in a similar way, starting with students completing a graphic organizer. But instead of using the on-line version of the textbook, students used the NASA HD iPad app to investigate the outer planets. As will be discussed later, students strongly preferred this approach vis-a-vis the online textbook. After completing the outer planets graphic organizer, students used an astronomy website to complete a more detailed worksheet on each of the outer planet's primary characteristics.

Although I did provide feedback to students on the quality of their graphic organizers and planetary worksheets, the primary formative assessment during the first treatment week was the daily quiz. The daily quiz consisted of five objective questions from content investigated in the previous day's instruction. Each daily quiz was administered at the start of class, with questions projected in PowerPoint format on a large projection screen. Daily quizzes provided an important data source to assess progress in student learning. By the end of the first treatment week, the iPads had essentially replaced student textbooks.

After a non-treatment week (when students reverted to textbooks and more traditional instruction methods), the second treatment week began on 2/22/13. The second treatment week introduced students to *iPad authoring capabilities*. At this point in our astronomy unit, students began studying the Moon. Similar to their study of planets, students explored lunar characteristics using iTunes University media, a word-processing application, and other iPad-specific apps. However instead of relying upon paper worksheets and other paper handouts used in the first treatment week, students used their iPads to author their own learning aids. To accomplish this, students learned to use a suite of iPad multimedia applications. This included Apple's Pages word processing application to take notes, and other applications as shown in Table 1.

Treatment Week Two started by taking a chapter test over the planets. Students used Apple's web browser (Safari) to access the planets chapter test from my electronic test bank. My chapter tests are hosted by a subscription service called Quia. Students logged into Quia and successfully took the chapter test on the iPads. As will be discussed later in this paper, students strongly preferred taking electronic tests on the iPad vs. a traditional "paper and pencil" mode. The next day we began our study of our Moon. We began with a short video clip on lunar exploration. This video clip was available free of charge from London's Open University through Apple's iTunes University. Jenny Krzystowczyk, from our district's technology training office, provided each class about a ten-minute tutorial on using Pages. Although none of my students had previous experience using the Pages application, students quickly grasped how to use this application to author documents on their iPads.

Students then used Pages to author a one-paragraph reflective essay about a special time when they recalled a particularly memorable viewing of the Moon. This activity was designed to allow students to develop a personal, and sometimes emotional, connection to their science subject matter. Here is an excerpt from one 8th grade student's essay:

> It was a late summer night and I was outside with my mom, dad, and brother. My dad and brother were fishing in the lake and me and my mom were talking. About an hour later I realized there was a full moon in the sky. I will never forget how bright and white the moon looked. It was as if there was a second moon right below the surface of the water in the lake. The way the moon lit up the whole lake amazed me! I will never forget the way the moon looked on this…summer night.

The next day we continued our study of the Moon by introducing new vocabulary words related to the lunar surface. Students used a few pages from their textbook to define approximately ten terms. Their notes including these definitions were typed using the Pages application. Files from different classes were segregated by last name, topic, and class period. For instance, notes from a student with last name of "Smith" from seventh period would save their notes as "SmithNotesp7." This file-naming convention worked well, with no major problems for students locating their previous day's work on their iPad. I continuously monitored student progress in note taking, and observed no difficulties as notes were authored using the Pages application.

The crowning achievement during the second treatment occurred on the last day. Working cooperatively in pairs, students explored the lunar surface using high-resolution imagery provided from the Moon Globe app. Moon Globe empowered students to

discover detailed facts about maria, craters, and rilles by simply tapping a particular feature on their iPad screen. While one student explored the lunar surface, the other recorded details in an electronic journal, made with the Pages application. After about fifteen minutes, students reversed roles, so each could explore and each make journal entries. Students were truly learning cooperatively, since not even my most advanced students were aware that each lunar mare and crater have individual names! One student's response from my Period 6 class typified the thoughts of most students: "Before today, I thought it was just the Moon!" Student journals were detailed, and an example journal entry is shown at Appendix A. By the end of the second treatment week, the iPads replaced the student textbooks *and* school computers.

Figure 1. Exploring the lunar surface with iPads.

Another non-treatment week ensued, when students reverted to textbooks and more traditional instruction methods. Then came the third, and final, treatment week. This third treatment week introduced students to *iPad collaborating capabilities*. At this point in our astronomy unit, students began a study of asteroids, comets, meteoroids/meteors/meteorites and the Oort Cloud. Students worked in cooperative pairs to explore one of the four sub-topics just mentioned. Students were given the freedom to investigate these solar system features using websites, apps, and iTunes University media. Instead of typing up their research information in a word processing application, students used an app named AudioNote Lite to create an audio podcast of their informal research findings. Students then used the text from their AudioNote Lite podcast to organize their information graphically, using an iPad app called Popplet Lite.

Popplet Lite allows students to create graphic organizers (called Popplets), which can include color, creative design features, and photos. Popple Lite fostered collaboration, because it allowed students to e-mail their Popplets to their peers, and to me. One Popplet graphically explaining details of the Oort Cloud was e-mailed to me, and is shown in Figure 3 later in this paper. The last day of treatment week three ended with a chapter test taken on the iPads via my Quia subscription. By the end of the third treatment week, the iPads had not only replaced student textbooks and school computers, but also provided students with authentic learning experiences. These experiences would have been nearly impossible to create using standard textbooks, conventional instruction, and desktop computers.

School Demographics

At the start of the 2012-2013 school year, Lewis and Clark Middle School's enrollment was near 550 students for grades seven and eight. Ethnic backgrounds show some degree of diversity, with 78% of students classified as white, and 13% as African-American. Hispanic students comprised 5% of the student population, while Asian students comprised 3%. Students classified as either American Indian or Pacific Island comprised approximately 1% of student enrollment. Approximately 21% of Lewis and Clark students are eligible for free/reduced price lunches from the National School Lunch Program.

Study Participants

I teach 64 eighth-grade students in three sections of earth science, with an average class size of 21 students. Of the 64 students, 38 are male and 26 are female. The average student age is 13.8 years. Demographically, the study participants showed a fair amount of diversity, as depicted in Table 2. While there are no special education students in any of my classes, I do have five students on 504 plans. My students' previous K-6 instruction in astronomy was limited to an introductory study of the planets.

Table 2
Student Demographic Data

	Caucasian	African-American	Hispanic	Asian	Total
# of Students	51	10	2	1	64
% of Students	79.7	15.6	3.1	1.6	100

Data Collection Strategy

My research used a mix of qualitative and quantitative data sources. Two teaching colleagues reviewed my data collection instruments for validity before I collected data. As shown in Table 3, my AR project used five measurement instruments: interviews, surveys, field notes, student artifacts, and daily quiz scores. A schedule of when each instrument was used is included in the research project timeline, found in Appendix B.

Table 3
Data Triangulation Matrix

Questions	**Data Source 1**	**Data Source 2**	**Data Source 3**	**Data Source 4**
How does the iPad impact student learning in a middle-school science classroom? (Primary)	Post-treatment student interviews	Teacher field notes	Student artifacts (podcasts, concept maps, etc.)	Daily quiz scores
How does the iPad impact student motivation towards learning in a middle-school science classroom? (Secondary #1)	Pre and post-treatment surveys	Post-treatment student interviews	Teacher field notes	
How does the iPad impact student & teacher attitudes towards technology use in a middle-school science classroom? (Secondary #2)	Pre and post-treatment surveys	Post-treatment student & teacher interviews	Teacher field notes	

Qualitative Instruments

Post-treatment interviews were conducted after the end of the intervention weeks in mid-February 2013. This provided a valuable stream of qualitative data to help validate results from quantitative instruments. I selected four students from each of my three science classes for interviews, for a total of 12 students. From each class I selected one high-performing student, one average-performing student, and one low-performing student. The fourth student from each class was selected using a random selection. This yielded a student sample rate of approximately 20%.

Additionally, I interviewed three teachers from my school after completion of the third treatment week. One was technically a teacher candidate, completing a 100-hour practicum course. Since she worked in one of my science classes during her practicum, she provided an objective view on the iPad research. The second teacher interviewed was a seventh-grade special education teacher. She had recently used iPads with her special education students during a co-taught math class. Her views were important because she observed the iPad used in a subject other than science. The third teacher interviewed was the seventh-grade math teacher in the co-taught math classroom. She provided valuable insight from a math teacher's perspective. The interview questions are included as Appendix C. Interviews provided credible qualitative data to strengthen reliability of other data sources. Interview data is analyzed in the next section.

Since both the pre- and post-treatment surveys contained open-ended questions, answers to these questions became a source of qualitative data to identify themes suggested from the numeric Likert-scale scores. Since all students received a survey, I

achieved a sampling rate of 100%. Student responses to the open-ended questions were a valuable source of data, analyzed in the next section.

Teacher field notes were the third source of qualitative data. During each treatment week, I carefully monitored the classroom environment and observed student behavior and work quality as they used the iPads. The original field notes were recorded in a notebook, and then expanded after the end of the school day. Field notes began with the first treatment week in January 2013, and the results are included in the next section.

Student artifacts were the final source of qualitative data. As I monitored progress in student learning with the iPads, I constantly evaluated the electronic work they created. These included worksheets, text documents, audio podcasts, photos, and concept maps. Electronic artifacts were primarily examined through my daily observational rounds in the classroom. However, some artifacts of student work were e-mailed to me for review. Examples of student work included in this paper have identifying names removed.

Quantitative Instruments

To answer my primary research question, which relates iPads to student learning, a quantitative measure of student performance became essential. I used daily quiz scores to meet this need. The daily quiz consisted of five-question objective questions to start each class day. Quiz questions came from material taught in the previous day's lesson. I compared class daily quiz scores from three treatment weeks to scores from three non-treatment weeks. Since daily quiz scores have proven to be my best predictor of student performance on summative assessments, they provide a measurement of progress in student achievement over time. Since all students take daily quizzes, the sampling rate was near 100%.

The second quantitative measurement instrument I used was pre- and post-interventions surveys. Surveys were critical in answering the two secondary research questions. The first five survey questions address secondary question #1, which pertains to effects of iPads upon student motivation. The second five survey questions focus on secondary question #2, pertaining to effects of iPads upon student views towards technology use. A copy of the survey is included as Appendix D.

Pre-treatment survey data was collected in mid-December, while post-treatment data was collected in mid-February. Pre- and post-treatment surveys used questions 1-5 to assess student motivation in an eighth-grade science classroom. I used a Likert-scale survey design. Since each survey response can have a corresponding numeric value (1-5), I made quantitative comparisons between pre- and post-intervention survey responses.

Data collection ended with the end of the third non-treatment week on February 13, 2013. Data analysis then began, and results are contained in the following section. The research methodology for this project received an exemption by Montana State University's Institutional Review Board and compliance for working with human subjects was maintained. A copy of this exemption approval is at Appendix E.

DATA AND ANALYSIS

Primary Question

This research project’s primary question was to determine if the iPad had an impact upon student learning. In other words, could it be demonstrated that the use of iPads increased student understanding of astronomy when compared to more traditional teaching methods? Quantitative data revealed only a small positive impact upon student

learning from the iPad intervention. The primary quantitative data source was daily quiz scores. However, qualitative data suggested the iPad had a more significant positive impact upon student learning. Qualitative data sources included post-treatment interviews, field notes, and student artifacts.

Quantitative Data

Quantitative data to help resolve the primary question came from daily quiz scores. These five-question objective quizzes covered subject matter from the previous day's lesson. Daily quiz scores from treatment weeks were compared to those from non-treatment weeks. This approach attempted to provide a measure of the iPad's impact upon student learning. Each treatment and non-treatment week averaged four quizzes per week (24 quizzes over six weeks). Multiplied by the number of students (64) yielded a value for N of 1536. A summary of quiz score comparisons is displayed in Figure 2.

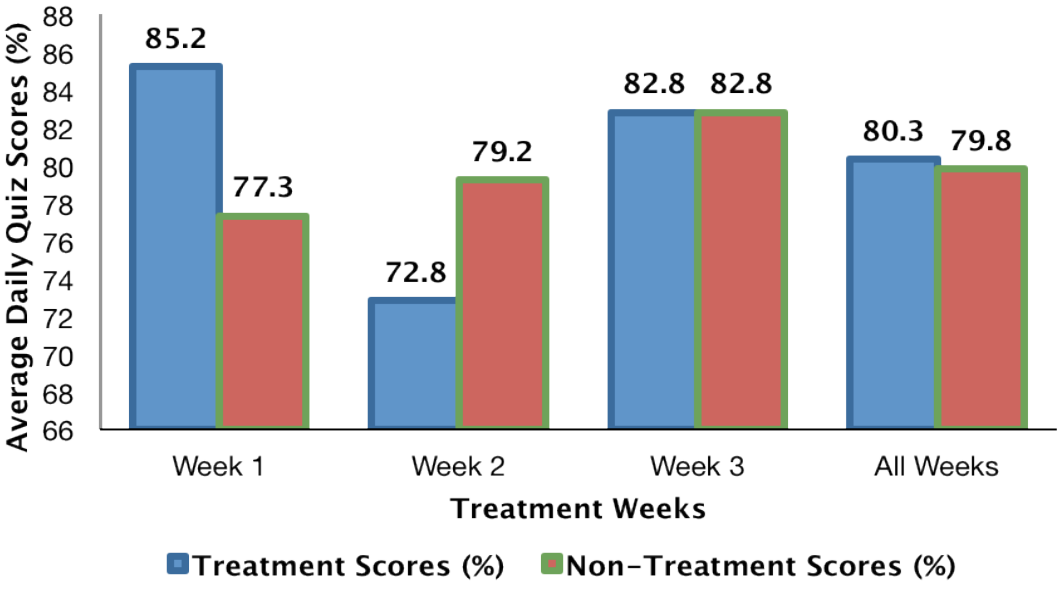

Figure 2. Daily quiz scores from treatment/non-treatment weeks, (*N*=1536).

Overall, average daily quiz scores from three treatment weeks averaged 80.3, just 0.5 points higher than average daily quiz scores from three non-treatment weeks (79.8). While lower ability students did not necessarily improve academically, their motivation and attitudes towards technology did improve (as shown later in this paper). The initial apparently strong impact of the iPads is easily seen from treatment week one's average daily score of 85.2, 6.9 points higher than the non-treatment week one average of 77.3. Figure 2 shows treatment week two average daily quiz scores were 6.4 points lower than non-treatment week two average daily quiz scores. I do not believe this is directly attributable to the effect of the iPad. During treatment week two, students' normal daily rhythm of learning was upset by a three-day weekend in honor of Dr. Martin Luther King, Jr. This may have contributed to one day of lower daily quiz scores recorded the day after our return from the three-day weekend. Both treatment week three and non-treatment week three had identical average daily quiz scores of 82.8.

Although the overall increase in treatment week average daily scores was positive, it proved much smaller than I anticipated. This result may have been a function of my study design. I believe treatment week daily quiz scores would have shown stronger gains if students had access to the iPads for a longer time period of continuous use. Instead of alternating single treatment and non-treatment weeks, perhaps I should have alternated pairs of treatment weeks and non-treatment weeks. This approach would have provided students a longer amount of time for continuous use, possibly providing more of an opportunity for the iPads to positively impact student quiz scores.

Qualitative Data

Post-treatment student and teacher interviews provided the first qualitative evidence of a strong iPad-based impact upon student learning. These results were corroborated by other qualitative data, including field notes and student artifacts.

Despite only marginal improvements in daily quiz scores, the perception of both students and teachers alike was the iPads improved student learning. Analyzing results from the first interview question revealed 100% of students and teachers interviewed (N=15) believed the iPad helped them learn our astronomy unit better, when compared to standard instruction. Three common themes emerged from student interviews.

The first theme centered on the iPad's ability to display astronomical phenomena in striking detail. Student interview comments (from three of twelve students interviewed) that typified this sentiment included phrases such as "the imagery was more engaging" and "liked the color graphics."

A second common theme discerned from student interview comments (from three of twelve students interviewed) was the iPad's strength in the ability to retrieve information rapidly. One student quote that typified this sentiment was "Internet access allowed quick answers rather than the book."

A third common theme (from all twelve students and all three teachers interviewed) that emerged from post-treatment interview comments was the belief the iPad could strengthen student learning in other subjects. One student interview response typified the value placed on learning history by stating the iPad would allow students to "see the places, use interactive maps, and see the people." Most students and teachers interviewed also believed the iPad would help with mastery of math lessons. One student

remarked that the iPad could help her “look up solutions, and I could use apps to practice.” The seventh grade math teacher I interviewed felt the same way, stating the iPad “made it easier to drill, and provided a more engaging way to reinforce basic math skills.” Students and teachers alike felt the iPad could make language arts lessons more effective. One student commented reading on an iPad was “better than reading books.” Another student felt editing writing was “easier on the iPad.” The seventh grade special education teacher I interviewed was impressed by the iPad’s ability “to read text aloud,” along with its ability “to highlight words to look up definitions.”

Moreover, all three teachers I interviewed believed the iPad helped students learn in new and transformational ways. The teacher candidate who worked in my sixth period science class during this project stated students learned better with iPads because they are “more motivated, constructing knowledge.” The special education teacher who used iPads with her students for seventh-grade math lessons believed the iPad offered something “new, different…a stimulus to the classroom.”

Field notes substantiated the interview findings. During our three treatment weeks using the iPads, students in all three classes were totally immersed in their learning. There were literally zero classroom distractions during the three treatment weeks. An excerpt of my field notes from my sixth period class on the last day of the treatment week one included: “Total silence for forty-three minutes!” Early in the treatment phase, this may have been caused by the students’ fascination with using an iPad for an entire class period. As the treatment weeks wore on, I deduced a different reason might have caused the total lack of distractions: the iPad’s self-containment of student learning tools. As we began treatment weeks two and three, students literally had no need for a textbook, paper,

or pencil. The iPad provided their electronic source for textual/graphic information, and provided the multimedia tools to create and share their knowledge. As a result, normal sources of classroom distractions (such as getting out books, sharpening pencils, etc.) were absent. This allowed students to focus all their energy and attention towards learning. An excerpt from my field notes from my sixth period class at the start of treatment week two included: “Students all quiet, completely engrossed in their work.” The seventh grade special education teacher I interviewed corroborated my field notes. She was “surprised students never found iPads boring.”

Student artifacts created during treatment weeks indicated students were not only learning, but also learning in transformational ways. During treatment week three, students had two linked assignments they completed in cooperative groups of two. The first part of the assignment required students to make a short (30-45 second) audio podcast from one of four topics: asteroids, meteoroids/meteors/meteorites, comets, or the Oort Cloud. Students used their iPads to informally research their topic, and then used an app called AudioNote Lite to create an audio podcast. This app offers the capability to type an on-screen script before students engage the “play” button on the recorder. One sample script, discussing the Oort Cloud, is shown as Appendix F. This activity involved making an audio recording for eventual playback to their peers, and students were able to focus on the most salient points of their research findings. Using AudioNote Lite seemed to energize the students because they realized their work would be “on the air” once I played the recording back to the class.

Once the podcast was developed for the student pair’s research topic, students then used an app named Popplet Lite to graphically organize and depict their knowledge.

Popplet Lite allows students to design a graphic organizer with design features of their choosing, to include text, photos, and graphics. Student interviews confirmed Popplet Lite was the favorite aspect of student use of the iPads during the three treatment weeks. Observing students create work with Popplet Lite convinced me students were finding, organizing, and creating new knowledge. One student example of a Popplet Lite graphic organizer is shown below as Figure 3. As I interacted with each student pair during class, I discussed the content of each graphic organizer. Without the need to refer to the graphic organizer, the students overall seemed knowledgeable enough about their topic to discuss it in some detail. This suggested the Popplet Lite activity helped students achieve a deeper understanding than would have been achieved by simply reading from a textbook.

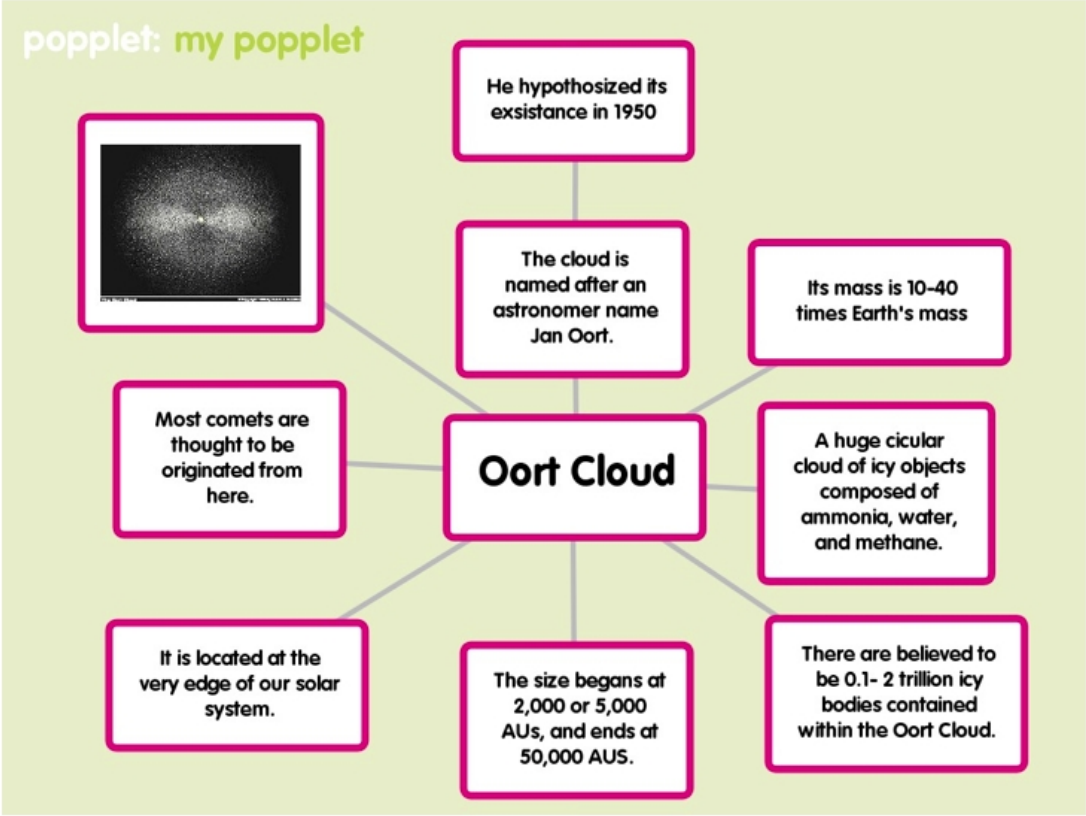

Figure 3. Sample Student Popplet Lite graphic organizer.

Secondary Question 1

This research project's first secondary question asked if the iPad had an impact upon student motivation to learn. In other words, I wanted to determine if students were more eager to attend class as a result of the iPad intervention. Quantitative data, collected from pre- and post-treatment survey ratings, suggested it did. Qualitative data also suggested the iPad had a significantly positive impact upon student learning. Qualitative data sources included post-treatment surveys, interviews, and field notes.

Quantitative Data

Pre-treatment surveys were conducted during my guided study classes during the week of Dec.10th -14th, 2012. Student survey responses to questions were numerically coded, using a Likert scale design. Strongly Disagree, or SD, received a value of 1. Disagree, or D, received a value of 2. Undecided, or U, received a value of 3. Agree, or A, received a value of 4, while Strongly Agree, or SA, received a value of 5.

Survey questions 1-5 focused on assessing student motivation to learn science. The individual average question score was computed by multiplying the number of responses in each column by their point value (1-5), summing point values across the question's row, then dividing by N (= 64).

Post-treatment surveys were taken from students in all three earth science classes (N = 64) in the same manner as the pre-treatment surveys. These surveys were conducted in my guided study classes during the week of Feb.11th-14th, 2013. Like the pre-intervention survey, the first five questions focused on student motivation to learn

science. Individual average question scores were computed in the same manner as the pre-intervention survey scores.

With scores computed from pre-intervention and post-intervention settings, the impact upon student motivation from implementation of the iPads is shown in Table 4.

Table 4
Pre and Post-Treatment Survey Scores, Questions 1-5

	Question 1 (Science is Fun)	Question 2 (Talks About Lessons At Home)	Question 3 (Wants To Learn More)	Question 4 (Motivated In Class)	Question 5 (Connects Science Lessons)	AVERAGE
PRE	4.2	3.1	3.5	4.0	3.3	3.6
POST	4.1	3.1	3.6	3.9	3.6	3.7

Note. (*N*=64).

Table 4 shows the overall motivational score nudged upward, from 3.6 from pre-treatment surveys to 3.7 in post-treatment surveys. This is an increase of 3%. Question 5, which asked if students connected science lessons to life experiences, showed a more significant increase, from 3.3 to 3.6, and represented a 9% increase. All other questions were either unchanged, or moved upward/downward by only 0.1 of a point. While I was surprised the overall motivational score increase was not higher, there may be at least two reasons why this occurred. The first reason may be the fact student motivation is largely governed by intrinsic factors. The iPads used in this project may have provided a relatively short-term increase in motivation that gradually lessened as the treatment weeks progressed. In the end, factors that determine a student's motivational level seemed barely affected by introduction of iPads into the learning environment.

The second reason may be related to my study design. I conducted the post-treatment surveys the week after treatment week three. The effect of the iPad intervention could have been dampened by this time lag. Perhaps a better study design would have included post-treatment surveys on the last day of treatment week three, to better capture the iPad's effect upon student motivation.

Table 4 shows aggregated data from all three of my classes. When individual class data was examined, one important result revealed itself. My lowest ability class (Period 8) showed a larger increase in overall student motivation than the other two classes. Period 8's overall post motivational score was 3.8, higher than the overall average of 3.7. Moreover, the score for question 5 (relating science lessons to life experiences) rose from 3.1 to 3.7, and increase of 19%. This was the second-highest percentage increase in a survey response from any class, for any question. Pre- and post-treatment survey data (questions 1-5) for Period 8 is shown in Appendix G. This data suggested the iPads had little impact on the motivational levels of high ability learners (3% increase), but a somewhat larger impact upon lower ability learners (6% increase).

Qualitative Data

Qualitative data suggested a stronger association between the iPad intervention and student motivation. The survey design provided the opportunity for open-ended comments after some questions. See Appendix D for the survey design. A second source of qualitative data was student and teacher interviews. The final source of qualitative data was my field notes.

Of the sixty-four students surveyed, fifteen explicitly mentioned the iPads as a positive force upon their classroom motivation to learn. The most frequent mention of

iPads (eight responses) came in response to follow-up question 2, which asked what recent science lessons students had talked about at home. Open-ended responses included comments such as “I tell my parents what topics are on our tests, and I have recently told them about the activities we are doing on the iPads.” Another comment stated “I talked about using the iPads to make podcasts on objects in space.” Another comment was more emphatic: “The iPads! I discussed the podcast activity!”
I was encouraged to find out that nearly 25% of my students, at a minimum, mentioned the iPad intervention with their parents.

The second highest number (five responses) of explicit references to iPads from survey remarks came in follow-up question 1, which asked students why they thought learning science was fun. Quotes from students included “Science can be fun, especially if there are iPads involved!” Another comment included: “I love science & with the iPad it’s a lot more fun.” When asked after the first question about why learning science is fun, one student explained: “The iPads make it so much better.” Another student claimed learning science is fun “…only with the iPads.” For at least a portion of my students, the iPad appears to make learning science a more enjoyable experience, thereby increasing their motivation to learn.

The third highest number (three responses) of explicit iPad survey remarks came in follow-up question 4, which asked students to explain why they were motivated to come to science class. One student stated they were motivated because “We get to use the iPads.” Another student responded by stating: “Using the iPads made me more excited to learn.”

Student and teacher interviews largely substantiated qualitative data from responses to open-ended survey questions. Of the sixteen survey respondents, fourteen (93%), believed the iPads would improve students attitudes towards learning, if used on a daily basis (interview question 3). A student response that typified these results stated she would be “Happier as you came to class; iPads are better than textbooks.” A similar response from another female student who stated, “Yes…because I don’t like textbooks.” One especially compelling comment came from a male student. If iPads were used daily, he “Would look forward to going to more classes I didn’t like.”

Comments from teacher interviews mirrored student viewpoints, but from a different perspective. The seventh grade special education teacher stated after starting the use of iPads in her co-taught math class: “Some students came to class early to work.” The seventh grade math teacher in the same co-taught classroom stated the iPads would “totally” change student attitudes towards learning. When I asked why she made such a definitive statement about the iPad’s impact on student motivation, she said it was because “My kids ask when they’re coming back!” The teacher candidate who worked with me in one class for this project believed iPads were “Short term...a plus for attitude.” However, she expressed a caveat because she felt the “Long-term impact [was] less sure…how long will the iPad be cool?”

Field notes recorded during the three treatment weeks reinforced results from the other sources of qualitative data: iPads were associated with increased student motivation levels. Some sample student comments made to me on the last day of treatment week one concerning the effect of the iPad included “It makes me want to do the work.” Another student stated the iPad makes learning “More exciting, I’m more motivated.” A third

student remarked, “It gives me more tools to learn with.” The increased levels of motivation left the students more focused on their lessons. During the three treatment weeks, I never had to redirect a student for using the iPad for anything other than our science lessons!

At the end of treatment week two, I recorded an observation that the iPad strengthened the social context within which students learned. As students worked cooperatively in groups of two or three, I observed a great deal of harmony between students as they cooperatively used their iPads. I hypothesize this was attributable to the iPads, because I did not observe such high levels harmony during cooperative learning activities earlier in the school year.

Secondary Question 2

My research project’s second secondary question asked if the iPad had an impact upon student and teacher attitudes towards technology and learning. In other words, did the iPad intervention make students feel technology use had empowered their learning? Quantitative data was primarily from pre and post-treatment survey ratings, and results suggested a positive impact. Qualitative data also suggested the iPad had a significantly positive impact upon student attitudes towards technology use and learning. Qualitative data sources included post-treatment surveys, interviews, and field notes.

Quantitative Data

As mentioned previously, pre-intervention surveys were conducted during my guided study classes during the week of Dec. 10th -14th, 2012. Questions 6-10 focused on assessing student attitudes towards the role of technology in their learning. The

individual average question score was calculated in the same fashion as for secondary question 1.

Post-intervention surveys were taken from students in all three earth science classes (N=64). These surveys were conducted in my guided study classes during the week of Feb. 11th-14th, 2013. Like the pre-intervention survey, questions 6-10 focused on student attitudes towards technology use and their learning. Individual average question scores were computed in the same manner as the pre-intervention survey scores.

With scores computed from the pre-intervention and post-intervention settings, the impact of the implementation of the iPads is shown in Table 5. The acronym "HHMDs" stands for the phrase hand-held media devices.

Table 5
Pre and Post-Treatment Survey Scores, Questions 6-10

	Question 6 (Technology Important In Learning)	Question 7 (Access to Technology)	Question 8 (Need Technology to Perform Best)	Question 9 (HHMD Preferred Over Computer)	Question 10 (HHMD As Effective As Computer)	AVERAGE
PRE	4.2	3.6	3.4	4.3	3.6	3.8
POST	4.4	4.1	3.8	4.4	4.0	4.1

Note. (*N*=64).

Table 5 indicates the overall technology attitudinal score rose 8%, from 3.8 in pre-treatment surveys to 4.1 in post-treatment surveys. Each technology attitudinal question registered a positive increase in ratings, when comparing post-treatment to pre-treatment results. Results from question 6 revealed students strongly believe technology is important for their learning, as the post-survey average response to this question was

among the highest of all post-treatment scores, at 4.4. Question 7 showed the largest increase, from 3.6 to 4.1. This 14% increase suggested students' use of iPads improved their attitude towards our district's efforts at making technology available. Results from question 8 suggested the iPad intervention convinced more students that technology was important for them to perform at their academic best. The average response score for this question rose from 3.4 to 3.8, an increase of nearly 12%.

The highest overall question rating was the 4.4 (out of a possible 5.0) from question 9. The results from this survey question indicate students strongly prefer to use hand-held media devices to computers. Moreover, most students believed this *before* the iPad intervention, as the same question received a pre-treatment survey rating of 4.3. It is important to note results for question 10 showed students became more convinced hand-held media devices were just as effective as computers in learning. The average question response score moved from 3.6 to 4.0, an increase of 11%.

Table 5 shows aggregated data from all three of my classes. When individual class data was examined, my lowest ability class (Period 8) showed a larger increase in the score to this question than the other two classes. The score for question 10 (are HHMDs as effective as computers?) rose from 3.3 to 4.1, an impressive increase of 24%. This was the highest percentage increase in a survey response from any class, for any question. Pre- and post-treatment survey data (questions 6-10) for Period 8 are in Appendix H.

Qualitative Data

Qualitative data strongly supported student's improved attitudes towards technology use and learning. Open-ended responses to questions 6-10 on pre- and post-

treatment surveys revealed four strong themes when relating attitudes towards technology and learning science.

The most dominant theme in student responses was one I had not anticipated: students believed technology (including hand-held media devices) provided them with more current scientific information. One response to survey question 6 stated: "…you need modern technology to get accurate answers." Another stated, "You don't have to waste papers and you have an unlimited library of info." A third student stated: "There's more you can do with technology and there are updated facts." Still another student believed technology was superior to textbooks because "…they are frequently updated but textbooks are old." Another student typified the sentiment of this major theme by saying "…some books are old and if we have the technology we can see new things happening." The last two quotes also typified a related, but somewhat secondary theme: a fairly prevalent student disdain for textbooks. Although several student comments expressed dislike of textbooks, the following student comment probably summarized this secondary theme best, by stating technology is "…a lot better than using the book and reading boring text."

Another theme emerging from survey comments was the student belief they learned science more effectively using technology. One student remarked, "I think it's easier to learn if you use modern technology." One female student responded, "It makes learning fun." Another secondary theme was the iPad's ability to better display of graphics. Typical comments included "Because it gives more detailed pictures/graphics than a textbook can." Another student stated: "…it shows more of a 3D effect by using different apps instead of just a book."

Another compelling theme from open-ended answers to survey questions 6-10 was the students' preference for a hand-held media device. Of the 60 students who specified their preference, 54 respondents named the iPad (or other tablet) as their first choice, closely followed by smart phones. One student named the Kindle Fire as their preference, with another naming a Nook. Clearly, tablets and smart phones were the most student-preferred electronic devices to use for science learning.

In relation to student and teacher attitudinal views of technology after the iPad intervention, interviews largely corroborated qualitative data collected from open-ended survey response questions. One student responded the iPads allowed her to "use technology" and that the iPads were "…part of my world." The seventh grade math teacher felt the iPad capabilities fostered more collaboration by allowing a student/teacher two-way communication through e-mail or shared storage devices.

Field notes recorded during the three treatment weeks reinforced results from the other sources of qualitative data: iPads were associated with improved student attitudes towards use of district technology in their science classes. At the end of treatment week one, I informally polled all three of my classes about whether they preferred using the iPad with the NASA HD app, or their textbooks. The vote was 64-0 for the iPad/NASA HD app! One student commented at the end of treatment week one that the iPads "Were less cumbersome than using books." At the start of treatment week three, another student was thrilled by the capability of the iPad when he exclaimed: "I made my first podcast!" Apparently even test taking was more palatable to students when using the iPads. After we took a chapter test on the iPads (using my Quia-hosted tests), I polled one class as to

whether they favored testing with iPads, or with paper/pencil. The results were 25-0 in favor of using the iPad.

The primary and secondary research questions were resolved by the triangulation of quantitative and qualitative data used for this research. Each of my three science classes showed consistency in results from answering the primary research question (how iPads impacted student learning). However, the lowest achieving of my three classes showed stronger gains in student motivation (secondary question 1) than the other two classes. Similarly, the lowest achieving of my three classes showed the strongest gains in their perception of how technology empowered their learning (secondary question 2). The interpretation of these results, using all available data sources, appears next.

INTERPRETATION AND CONCLUSION

This research project demonstrated iPads had a positive impact upon learning in a middle school science classroom. Even though quantitative data showed just a small increase in student academic performance between treatment weeks and non-treatment weeks (80.3 vs. 79.8), it is important to note that this may have been a function of the study design. If students had used the iPads for a longer continuous period of time, quantitative evidence of increased student achievement may have been more apparent. Every source of qualitative data indicated the iPads were a positive factor in student learning. This view came from not only students, but also from teachers. Students found the iPad's ability to deliver high-resolution graphics and quick retrieval of information helpful in their learning. Student and teachers alike believe the iPad can help a student learn in many subjects in addition to science.

During this project, I frequently noted the lack of classroom distractions when students were working with their iPads. This allowed me to become more of a facilitator in the learning process, rather than a director of it. I truly felt like the constructivist teacher described by Keenwege and Onchwari (2011). Finally, the iPads enabled students to use their creativity to construct knowledge, creating electronic artifacts instead of more traditional paper/pencil artifacts. Student energy, focus, and attention to detail became squarely directed towards their work. Quality of student work, evidenced in electronic artifacts such as podcasts and electronic graphic organizers, was truly impressive!

Quantitative data suggested the iPad intervention provided a modest overall increase in motivational scores (3.7 vs. 3.6), which may have gradually decreased as the treatment weeks progressed. Factors that determine a student's motivational level are numerous and complex. In the long term, these factors may be only marginally affected by an extrinsic factor such as the introduction of iPads into the learning environment. Another reason may again be related to my study design. I conducted the post-treatment surveys the week after treatment week three. The effect of the iPad intervention could have been dampened by this time lag. Perhaps a better study design would have included post-treatment surveys on the last day of treatment week three, to better capture the iPad's effect upon student motivation. However, when analyzing data from each of three science classes, one important outlier emerged. Period 8, my lowest achieving class, showed a much greater increase in motivational scores than my other two classes. For instance, this class's motivational score increased to 3.7 from 3.1 in regard to survey question 5 (relating science lessons to life experiences), a 19% increase. Qualitative data suggested the iPad's were a strong positive force upon overall student motivation than

quantitative data suggested. 25% of the students surveyed stated they mentioned using the iPads to their parents. Many students indicated they had a more positive attitude about coming to class during treatment weeks.

Both quantitative and qualitative data suggested the iPad intervention in this research project gave students a more positive view towards how technology use empowered their learning. Students believed the iPads were far superior to their traditional textbook. In fact, my research showed students showed a general disdain towards traditional textbooks. One major reason was students' perception the iPad provided more current scientific data than textbooks, and provided the information nearly instantaneously. The use of iPads convinced more students that modern technology was important for them perform at their academic best in science. Moreover, students preferred tablet technology as their technological choice by an overwhelming margin (54 of 60 student responses).

Today's middle school students' daily lives are very much entwined with hand-held media devices such as smart phones, iPods, and electronic tablets. Use of the iPad during the three treatment weeks provided an instant relevance to their daily lives, enhancing its impact in learning science content. The use of iPads also convinced more students that hand-held media devices were just as effective, if not more effective, than computers.

My conclusions are based on stronger signals from qualitative data than from quantitative data. If I did this study again, I would administer other forms of formative assessments to reconcile this difference more fully. Nonetheless, the conclusions were valuable because they will lead me to more carefully shape my future teaching strategies

in science instruction. Additionally, these conclusions may prove valuable to other teachers, and to my school district. The last section of this paper addresses this possible value.

VALUE

This project demonstated value not only to my teaching, but also to other classrooms, and perhaps to my school district at large. From a value perspective, I will discuss five distinct areas: the value of surveys, the value of qualitative data, the need for a curriculum to match hand-held media device capabilities, a new perspective on when these devices should become more accessible to middle school students, and how the iPad may have extra payoff for struggling learners.

First, the value of using student surveys was strongly evident during the course of this study. By keeping the surveys anonymous, I felt the overwhelming majority of students were sincere and candid with their survey responses. I can use the same type of anonymous survey approach to gather student input on other topics, such as lesson effectiveness, interest levels on different science units, etc. I could always do a better job of considering student input, and the anonymous survey is a good way to solicit such input.

Second, this project taught me the value of collecting qualitative data. Before I conducted this research, I tended to view qualitative data as unreliable and less trustworthy as quantitative data. But in my case, the qualitative data provided a much better measure of the iPad's impact in the classsroom than the quantitative data. This project taught me that properly collected and analyzed qualitative data provides very

distinct themes and insights that may not be captured by solely by quantitative data. Occasionally collecting qualitative data from my science classes would only help me see a more complete picture of the learning environment in my classes.

Third, while this project documented the potential effectiveness of the iPad in the classroom, it also demonstrated the need for a curriculum design to take full advantage of the technological capabilities of the iPad (or similar devices). Without a science curriculum designed for these devices, iPads can become relegated to merely augmenting textbooks, and the associated curriculum developed for textbooks. This approach would not take full advantage of the iPad's multi-dimensional abilities to deliver content information, and to foster student creativity. The potential learning power of the iPad is realized only when instruction is designed to take full advantage of this tablet's many capabilities.

Long-term iPad integration into the science classroom will require teachers to rethink teaching approaches in transformational ways. Since iPads appear to offer students the opportunity to construct new knowledge, effective science lessons must become more about student-centric discovery instead of teacher-centric direct instruction. iPads offer students the opportunity to collaborate with their peers as they discover new ways to demonstrate their knowledge. Teachers may need to adapt their teaching philosophy to accomodate more opportunities for cooperative learning. If iPads were made available for the next school year, I would start planning immediately for next year's instruction. Original and creative lesson planning will allow the opportunity to capitalize on the iPad's data retrieval, authoring, and collaborating capabilities.

Fourth, this project made me consider possible approaches to overcome the current lack of “1-to-1” iPad availability for each student in our school. As mentioned in the previous section, the iPad’s power is maximized when students and teachers have access to the device for a fairly substantial continuous period. One approach, taken by some districts in the U.S., is to allow students to use their personal hand-held media devices in class when an app-based lesson is implemented (Richtel, 2013). As mentioned earlier in this paper, Apple’s operating system for the iPad also runs on the iPhone and iPod Touch. Allowing students to use a personal hand-held media device when an iPad is not available should at least be considered. This would allow students to connect their learning to a personally-owned device that they believe is equal, or superior to, school-provided computers. Teachers would have to establish firm rules for proper use of personal electronic edvices in the classroom. Since many school districts discourage student use of hand-held media devices during school hours, allowing their personal use in a classroom would, in many cases, require policy changes. But such policy changes are worth considering.

Fifth, the value of this research points to the fact iPads may provide more of a motivational spark to struggling learners. This made me realize the iPad was not just a novel way to learn science, but perhaps a way to help lower-ability learners have a greater chance of academic success.

Finally, this research project showed me how to rethink my approach to classroom technology use. So far in my teaching career, I’ve used an “all or nothing” strategy towards technology integration. In other words, if computers were not available for all my classes, I didn’t reserve them. The results of my research suggested I need to

change my approach for next year. My data suggested the iPads had a stronger positive impact upon student motivation and attitudes towards technology with the lowest achieving class. Next year, if iPads are available for only my lowest ability class, I'll reserve them. I need to move away from an "all or nothing" approach for using technology resources, and instead target technology for the biggest payback in student achievement. Apparently this payback will be largest with my weakest performing class.

My research project suggested iPads have a positive impact upon student learning, student motivation, and student attitudes towards technology in suppport of their learning. In light of these encouraging results, some caveats are in order before iPads are implemented in a classroom on a consistent basis. First, a system for classroom accountability of iPads must be in place. I assigned a specific numbered iPad to each student in each of my three science classes. To hand out, and then collect, each student's iPad may take a total of five minutes per day. During a 43-minute class period, this represents about 12% of the available teaching minutes. Second, the iPads' battery levels must be monitored. Apple engineers have done a remarkable job of designing efficient iPad power management. However some devices discharge at different rates. The teacher must ensure battery charge levels are sufficient for the day's planned activities. Third, the iPad screens should be cleaned on a periodic basis. This helps maintain crisp screen displays, as well as mitigate the potential for germ spreading. Fourth, any apps chosen for a classroom activity should be thoroughly vetted by the teacher. Some apps promoted as "popular" may prove to have clumsy user interfaces, or may contain unresolved software bugs. Fifth, an adequate network bandwidth is essential to take advantage of the iPad's ability to pull in video and audio streams. With dozens of students accessing media

sources simultaneously, schools with relatively low network bandwidth may experience disrupted data flow to the iPads.

Finally, it is important to note the iPad is designed for a single user, unlike traditional desktop and laptop computers. Teachers must plan ahead to manage student-created files. If files are stored on the iPad, a file naming convention (mentioned earlier in this paper) should be established. Even with a file naming convention in place, the opportunity remains for students to inadvertently edit, or delete, another student's work. An alternative is for teachers to access cloud storage sources, such as Dropbox and Google Drive.

Despite these caveats, the iPads are indisputably a powerful, positive force in the science classroom. During this project, students quickly became proficient in most of the iPad's functional capabilities. In doing so, I saw their fascination increase not with just the iPad, but also with their learning of astronomy. The question asked most often by students arriving to class each day was: "Mr. Benson, are we using the iPads today?"

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APPENDICES

APPENDIX A

SAMPLE LUNAR EXPLORATION JOURNAL ENTRY

Lunar Exploration Journal (1/25/13)

Mare Tranquillitatis
-Diameter 873.0 km
-"Sea of Tranquility"
- Mare material within the basin consists of basalt.
- Slight bluish tint to the rest of the moon.
- Named in 1651 by Francesco Grimaldi and Giovanni Battistariccioli

Mare Imbrium
- Diameter 1123.0 km
-"Sea of Showers"
- One of the largest craters in the solar system.
- Lava flooded crater and when a massive object hit the moon.

Mare Serenitatis
- Diameter 707.0 km
- Position 28.0 N 17.5 E
- Made of basalt
- Named by Giovanni Riccioli

Manilius Crater
- Diameter 30.0 km
- Position 14.5 N 9.1 E
- 3.1 km deep
- Possesses a ray system

Sinus Medii
- Position 2.4 N 1.7 E
- "Bay of the Center"
- Almost dead center on the front side of the moon

Mare Fecunditatis
- Diameter 909.0 km
- "Sea of Fecundity"
- The basin is overlapped with the Nectaris, Tran

APPENDIX B

PROJECT SCHEDULE

PROJECT SCHEDULE

PHASE	DATES	ACTIONS
IRB Approval	11/25/12	MSU IRB exemption
Literature Review	11/1-11/30/12	Finalize literature review in draft
Preliminary draft	12/1-12/10/12	Include intro, literature review, methods in initial draft
Pre-Intervention	12/10-12/20/12	Conduct student surveys
iPad Treatment	1/7/13-1/11/13	Record daily quiz scores, record field observations, collect student artifacts
Traditional Learning	1/14/13-1/18/13	“Standard” teaching/learning modes
iPad Treatment	1/22/13-1/25/13	Record daily quiz scores, record field observations, collect student artifacts
Traditional Learning	1/28/13-2/1/13	“Standard” teaching/learning modes
iPad Treatment	2/4/13-2/8/13	Record daily quiz scores, record field observations, collect student artifacts
Traditional Learning	2/11/13-2/13/13	“Standard” teaching/learning modes
Post-Intervention	2/19-2/22/13	Conduct student surveys, student & teacher interviews
Data Analysis	2/22/13-3/15/13	Analysis of collected data
First Draft (Data)	4/1/13	Compile first draft (data analysis)
First Complete draft	5/1/13	First complete draft to committee
Finish Final Draft	6/1/13-6/30/15	Final draft edited for presentation
Capstone Symposium	7/1-7/5/12	Present Capstone results

APPENDIX C

INTERVIEW QUESTIONS

INTERVIEW QUESTIONS

Participation is voluntary, and you can choose to not answer any question that you do not want to answer, and you can stop at anytime. Your participation or non-participation will not affect your grade or class standing.

1. Did using the iPad help you learn our astronomy lessons better?

    Why or why not?

2. What aspect of using the iPads did you enjoy the most?

3. How would your attitude towards learning change if we used iPads every day?

4. Do you think the iPad would help you learn more in other subjects?

    What subjects might they be?

APPENDIX D

STUDENT SURVEY

STUDENT SCIENCE AND TECHNOLOGY SURVEY

Please answer the survey questions by circling response on the scale. "SD" means strongly disagree, "D" means disagree, "U" means undecided, "A" means agree, and "SA" means strongly agree. *Participation is voluntary, and you can choose to not answer any question that you do not want to answer, and you can stop at anytime. Your participation or non-participation will not affect your grade or class standing.*

1. Learning science is fun.

SD D U A SA

Why did you select that answer?

2. I talk about my science lessons with my family.

SD D U A SA

What recent lessons have you talked about?

3. I want to learn more about science topics outside of class.

SD D U A SA

4. I am motivated to learn when I come into science class.

SD D U A SA

Why do you say that?

5. I can connect my science lessons to my life experiences.

SD D U A SA

Can you give me an example?

6. It is important to use modern technology (computers, hand-held media devices) when learning science.

SD D U A SA

Why do you say that?

7. My school gives me frequent access to modern technology to learn science.

SD D U A SA

8. I need to use modern technology more often to perform at my very best in science.

SD D U A SA

Why do you think that?

9. I would prefer to use hand-held media devices (smart phones, tablets, music players) instead of computers to learn science.

SD D U A SA

If you agree or strongly agree, can you name a hand-held media device you prefer?

10. Hand-held media devices are just as effective as computers for learning science.

SD D U A SA

Why do you say that?

APPENDIX E

IRB EXEMPTION APPROVAL

INSTITUTIONAL REVIEW BOARD

For the Protection of Human Subjects
FWA 00000165

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Administrator:
Cheryl Johnson
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MEMORANDUM

TO: Charles Benson and Walt Woolbaugh

FROM: Mark Quinn, Chair Mark Quinn CH

DATE: November 25, 2012

RE: *"The iPad: Novelty or Breakthrough for Science Education"* [CB112512 EX]

The above research, described in your submission of November 18, 2012, is exempt from the requirement of review by the Institutional Review Board in accordance with the Code of Federal regulations, Part 46, section 101. The specific paragraph which applies to your research is:

_X_ (b) (1) Research conducted in established or commonly accepted educational settings, involving normal educational practices such as (i) research on regular and special education instructional strategies, or (ii) research on the effectiveness of or the comparison among instructional techniques, curricula, or classroom management methods.

_X_ (b) (2) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures or observation of public behavior, unless: (i) information obtained is recorded in such a manner that human subjects can be identified, directly or through identifiers linked to the subjects; and (ii) any disclosure of the human subjects' responses outside the research could reasonably place the subjects at risk of criminal or civil liability, or be damaging to the subjects' financial standing, employability, or reputation.

____ (b) (3) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures, or observation of public behavior that is not exempt under paragraph (b)(2) of this section, if: (i) the human subjects are elected or appointed public officials or candidates for public office; or (ii) federal statute(s) without exception that the confidentiality of the personally identifiable information will be maintained throughout the research and thereafter.

____ (b) (4) Research involving the collection or study of existing data, documents, records, pathological specimens, or diagnostic specimens, if these sources are publicly available, or if the information is recorded by the investigator in such a manner that the subjects cannot be identified, directly or through identifiers linked to the subjects.

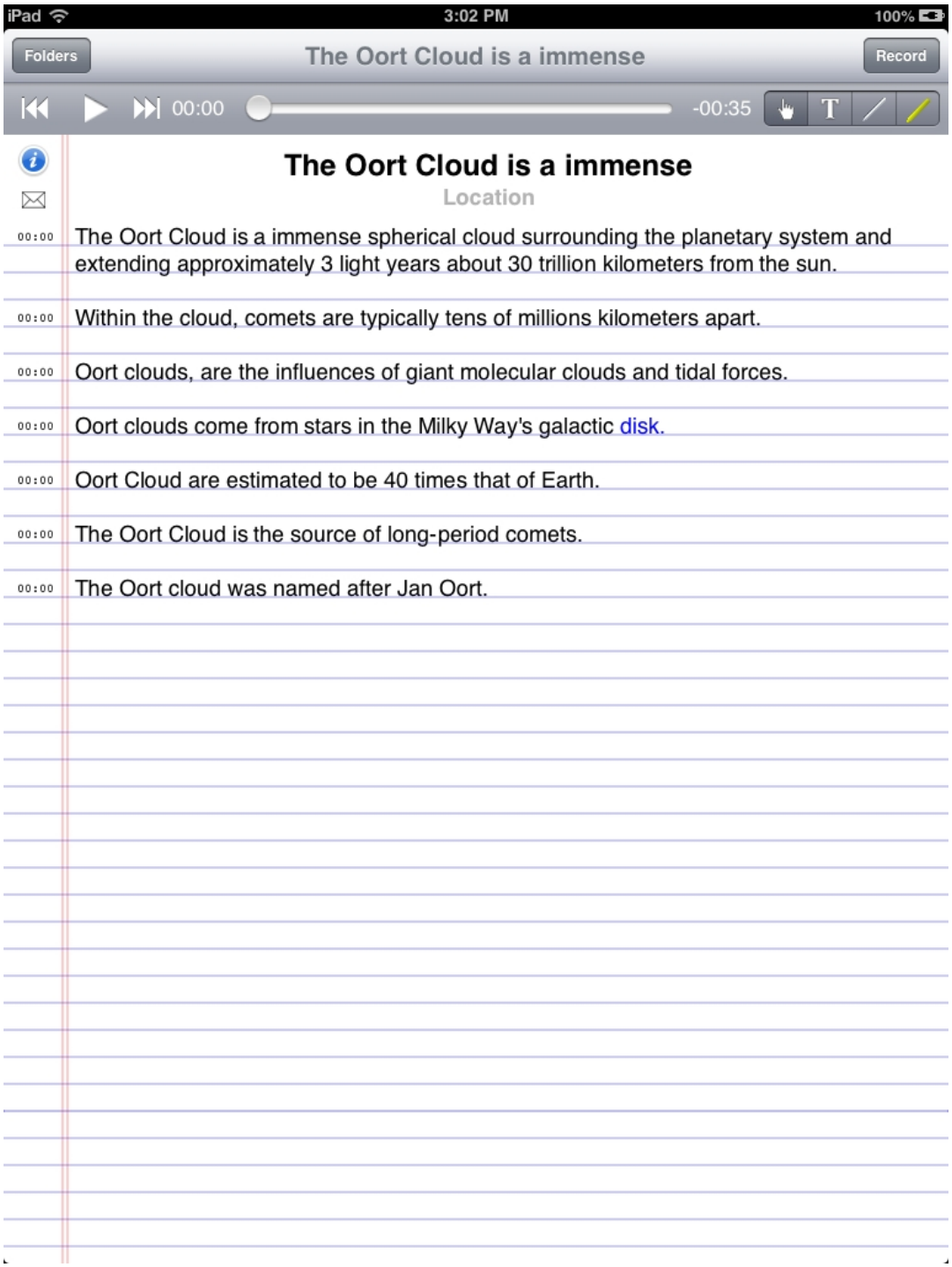
____ (b) (5) Research and demonstration projects, which are conducted by or subject to the approval of department or agency heads, and which are designed to study, evaluate, or otherwise examine: (i) public benefit or service programs; (ii) procedures for obtaining benefits or services under those programs; (iii) possible changes in or alternatives to those programs or procedures; or (iv) possible changes in methods or levels of payment for benefits or services under those programs.

____ (b) (6) Taste and food quality evaluation and consumer acceptance studies, (i) if wholesome foods without additives are consumed, or (ii) if a food is consumed that contains a food ingredient at or below the level and for a use found to be safe, or agricultural chemical or environmental contaminant at or below the level found to be safe, by the FDA, or approved by the EPA, or the Food Safety and Inspection Service of the USDA.

Although review by the Institutional Review Board is not required for the above research, the Committee will be glad to review it. If you wish a review and committee approval, please submit 3 copies of the usual application form and it will be processed by expedited review.

APPENDIX F

SAMPLE AUDIONOTE LITE SCRIPT


iPad
3:02 PM
100%
Folders
The Oort Cloud is a immense
Record
00:00
-00:35
The Oort Cloud is a immense
Location
00:00 The Oort Cloud is a immense spherical cloud surrounding the planetary system and extending approximately 3 light years about 30 trillion kilometers from the sun.
00:00 Within the cloud, comets are typically tens of millions kilometers apart.
00:00 Oort clouds, are the influences of giant molecular clouds and tidal forces.
00:00 Oort clouds come from stars in the Milky Way's galactic disk.
00:00 Oort Cloud are estimated to be 40 times that of Earth.
00:00 The Oort Cloud is the source of long-period comets.
00:00 The Oort cloud was named after Jan Oort.

APPENDIX G

PERIOD 8 SURVEY RESULTS, QUESTIONS 1-5

Table 6
Period 8 Pre and Post-Treatment Survey Scores, Questions 1-5 (N=16).

	Question 1 (Science is Fun)	Question 2 (Talks About Lessons At Home)	Question 3 (Wants To Learn More)	Question 4 (Motivated In Class)	Question 5 (Connects Science Lessons)	AVERAGE
PRE	4.5	2.9	3.5	4.0	3.1	3.6
POST	4.5	2.7	3.8	4.1	3.7	3.8

APPENDIX H

PERIOD 8 SURVEY RESULTS, QUESTIONS 6-10

Table 7
Period 8 Pre and Post-Treatment Survey Scores, Questions 6-10 (N=16).

	Question 6 (Technology Important In Learning)	Question 7 (Access to Technology)	Question 8 (Need Technology to Perform Best)	Question 9 (HHMD Preferred Over Computer)	Question 10 (HHMD As Effective As Computer)	AVERAGE
PRE	4.3	3.4	3.8	4.4	3.3	3.8
POST	4.6	4.2	4.1	4.5	4.1	4.3