A LITERATURE REVIEW: IPAD TECHNOLOGY IN THE MATHEMATICS AND SCIENCE CLASSROOMS

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ABSTRACT: Science, technology, engineering, and mathematics (STEM) education has become an emphasized component of PK-12 education in the United States. The US is struggling to produce enough science, mathematics, and technology experts to meet its national and global needs, and the mean scores of science and mathematics students are not meeting the expected levels desired by our leaders (Hossain & Robinson, 2011). In an effort to improve achievement scores in mathematics and science, school districts must consider many components that can contribute to the development of a classroom where students are engaged and growing academically. Technology for student use is a popular avenue for school districts to pursue in their goal to attain higher achievement. Research in computer technology has shown positive effects in academic achievement with the largest effects found in constructivist classrooms. Questions remain as to whether that translates to the use of iPads and other tablet devices being successful in raising the academic achievement of students in the mathematics and science classrooms.

Keywords: one-to-one, iPad, mathematics, science

INTRODUCTION

iPad Technology in the Mathematics and Science Classrooms

Science, technology, engineering, and mathematics (STEM) education has become an emphasized component of PK-12 education in the United States. The US is struggling to produce enough science, mathematics, and technology experts to meet its national and global needs, and the mean scores of science and mathematics students are not meeting the expected levels desired by our leaders (Hossain & Robinson, 2011). According to Cavanagh (2008), the Program for International Student Assessment (PISA, 2006) stated 15-year-old US students ranked 24th on the mathematics test and 17th on the science test compared to 29 other industrialized countries (as cited in Hossain & Robinson, 2011, p.2). The US's once acquired leadership status in mathematics and science education has fallen behind many other countries. Ramirez (2008) stated "The fact that some less developed countries now perform better in math and science achievement than the US is seen by many US educators, business leaders and politicians as a crisis" (as cited in Hossain & Robinson, 2011, p.2).

In an effort to improve achievement scores in mathematics and science, school districts must consider many components that can contribute to the development of a classroom where students are engaged and growing academically. Technology for student use is a popular avenue for school districts to pursue in their goal to attain higher achievement. It has become a much-studied research topic in the last few decades as school districts commit to spending their precious resources of time and money for technology integration in the classroom. Determining the best plan of implementation falls on all education partners including administrators and teachers. They must take many issues into consideration such as affordability, infrastructure, and best practices when deciding what technologies should be incorporated into the classroom.

The U.S. Department of Education, the National Council of Teachers of Mathematics (NCTM), the National Science Teachers Association (NSTA), and the International Society of Technology in Education (ISTE) have supported technology integration in the PK-12 classroom as a means to create more effective mathematics and science instruction for US students. The U.S. Department of Education (2010) contributed to this charge by stating in its National Education Technology Plan "technology is the core of virtually every aspect of our daily lives and work, and we must leverage it to provide engaging and powerful learning experiences and content, as well as resources and assessments that measure student achievement in more complete, authentic, and meaningful ways" (p. ix).

National Council of Teachers of Mathematics

Mathematics, Science, and Technology leadership organizations are promoting the use of modern technologies to enhance instruction. The NCTM (2011) released an organizational position stating we must provide regular access to technology in order to develop sense making, reasoning, problem solving, and communication in our students. Teachers who can effectively use technology to help students with their understanding, to increase their interest in the subject, and to raise mathematics proficiency will be successful in providing greater access to mathematics for every student. The Common Core State Standards for Mathematics (CCSSM, 2010) also encourages the use of technology in its fifth standard for mathematical practice: use appropriate tools strategically. It states mathematically proficient students will use available tools including calculators, spreadsheets, statistical packages, and dynamic geometry software to solve mathematical problems. Mathematics proficiency opens the door for a number of career choices in the STEM fields empowering our students for their future.

National Science Teachers Association

The NSTA, through its Next Generation Science Standards (NGSS, 2013), also encourages the use of technology for the role it plays in the learning of science by recognizing that new technologies have given our scientists new capabilities for studying the natural world. The advances in technology have also provided more precise ways to record, manage, and analyze data as students conduct investigations during the learning process. The NGSS framework states, “engineering and technology provide opportunities for students to deepen their understanding of science by applying their developing scientific knowledge to the solution of practical problems… By integrating technology and engineering into the science curriculum, teachers can empower their students to use what they learn in their everyday lives” (NGSS, Appendix A, p.5).

International Society of Technology in Education

ISTE (2013) developed the widely recognized standards for learning, teaching, and leading with technology. Through sets of standards designed for students, teachers, administrators, coaches, and computer science educators, ISTE has provided schools with a set of best practices for technology use designed to improve higher-order thinking skills, prepare students for the global job market, design student-centered, project-based and online learning environments, guide schools in creating digital places of learning, and inspire models for students to encourage working, collaborating and decision making.

With the support of the national groups and an abundance of technology appearing in schools, it is imperative teachers learn effective ways to incorporate technology into their classrooms to increase academic achievement. The National Education Technology Plan (US Department of Education, 2010) calls for teachers to use technology to create engaging and empowering learning experiences for their students that are designed to meet the individual needs and the prior knowledge of the learner.

The Choice of iPads for the Classroom

Mobile devices, such as the iPad and other tablet-based devices, are some of the latest technology schools are looking toward for assistance in the teaching of the CCSSM and NGSS standards. There has been a substantial amount of research on computer technology in the areas of mathematics and science showing the benefits of its implementation in the classroom (Bayraktar, 2002; Li & Ma, 2010). However, according to Fisher, Lucas, and Galstyan (2013), “There is very little research involving the direct observation of the usage of iPads in the classroom” (p.166). Most of the iPad-focused research involves analyzing students’ and teachers’ perceptions of the benefits of iPads rather than measuring its effects on academic achievement. In order for school systems to justify the expense of incorporating mobile devices, such as the iPad, into their instruction, research needs to be conducted to determine the effect, if any, on students’ learning.

The review of the literature for the use of iPads in the classroom centered on the following topics:

1. Technology in a constructivist learning environment (CLE)
2. Constructivist-oriented Technological Pedagogical Content Knowledge
3. Computer technology in the mathematics and science classroom
4. iPads in the mathematics and science classroom
5. iPads in a one-to-one environment
6. Laptops in a one-to-one environment

Constructivism and the Constructivist Learning Environment

Ertmer and Newby (1993) stated Constructivism sees knowledge as something an individual creates from his experiences. The learner and the environment play a part in the construction of knowledge through their interactions with each other, and knowledge is constantly evolving as the learner experiences more of the world. Learning must take place in a real world setting where students can relate prior knowledge to the task at hand. Strategies most appropriate for a constructivist-learning environment are providing tasks mirroring real world situations, modeling and coaching throughout the process, collaborative learning, discussions, debates, and reflection during and after the task. Constructivist teachers emphasize the context in which the learning occurs, encourage learners to actively use their prior knowledge, present information in multiple ways, and support using problem-solving skills. By analyzing different ways of representing a problem, they can design experiences that are authentic and relevant to the learner's world.

From Constructivism has come the instructional design of constructivist-learning environments (CLE). A CLE can be defined as "a place where learners may work together and support each other as they use a variety of tools and information resources in their guided pursuit of learning goals and problem-solving activities" (Wilson, 1996, p.5). Jonassen, Peck, & Wilson, (1999) add these environments provide students with the opportunities to "explore, experiment, construct, converse, and reflect on what they are doing so that they learn from their experiences" (as cited in Wang, Teo, & Woo, 2009, p.81). This leads to a more student-centered and collaborative learning environment. Participating in this environment allows students to deepen their understanding of content through the use of resources and sharing of knowledge (Kong, 2011).

Technology can aid in the construction of a CLE by providing current information not available in textbooks giving an authenticity to the lessons. The use of online resources can facilitate "the learner's journey of discovery and acquisition of new knowledge. Communication resources such as discussion boards enable learners to participate in collaborative learning with other students and with educators" (Sultan, Woods, & Koo, 2011, p.151). Fosnot (1996) stated students acquire knowledge by physically constructing it through active learning. Providing technology-based CLE's allows students to participate in varying activities and engage in meaningful conversations with others (Jonassen & Rohrer-Murphy, 1999).

Teaching in a digital classroom allows teachers to promote the tenets of constructivism. The use of mobile devices are removing the constraints of time and space from the learning process and instead providing opportunities for students to communicate, collaborate in and out of the classroom, and access information freely (Wong 2012). In the constructivist classroom, assessments can range from self-report measures, classroom observations, and varying analyses of student performance data. One-to-one technology can afford teachers the opportunities to incorporate many different forms of assessments (Sultan et al., 2011).

By definition, a traditional approach is teacher-oriented with instruction focused more on lecture, whole group lessons, and mastery of facts and skills. The teacher solves problems for the class and students' differences are only addressed if there is a problem. Typically, a single assessment for all students is used at the end of instructional units (Ornstein, Lasley, & Mindes, 2005). In contrast, a constructivist approach is student-oriented with activities designed to encourage active learning. Assessments are different from one single test at the end of a unit. Instead they can be formatted as project work, portfolios, self-assessments, and performance evaluations (Ayaz and Sekerci, 2015). iPads provide digital tools to enhance this type of assessment.

Hoffman (2010) stated that as we shift to a student-centered learning environment, we are providing opportunities for students to learn 21st century skills of inquiry, critical thinking, communication and collaboration. Technology can assist in this shift. However, it is essential schools are using technology to its fullest potential.

The challenge for teachers is to take the recommendations of the national organizations and the available technology and use them to provide students with a constructivist-learning environment that encourages participation both individually and collaboratively, addresses prior knowledge of the student, allows for the creation of activities that continuously spiral back to past learning, and provides opportunities to apply learning to real life scenarios.

Teachers' Perceptions of C-TPACK

With a shift to more technology-infused CLE's, it is important teachers know how to successfully integrate the devices into instruction. A constructivist classroom has shown to be effective in increasing achievement (Ayaz & Sekerci, 2015). However, teachers must feel comfortable with and prepared to use the technology in order to create a successful technology-infused learning environment for their students. Koh, Chai, and Tsai (2014) conducted a study to determine teachers' perceptions of their constructivist-oriented technological pedagogical content knowledge (C-TPACK). C-TPACK refers to a teachers' knowledge of using technology with appropriate teaching methods for their content area to implement constructivist instruction.

Koh's et al. (2014) research study included 354 teachers, 54% at the elementary level and the rest at the secondary or junior college level. The average teaching experience was 8.83 years and the average age was 34.93 years. The questions addressed were:

1. What are Singapore practicing teachers' constructivist-oriented TPACK perceptions?
2. How do teacher demographics (age, gender, teaching experience, and teaching level) and TPACK constructs (C-TK, C-PK, CK, C-PCK, TCK, and C-TPK) predict practicing teachers' constructivist-oriented TPACK (C-TPACK)? (p.187)

In order to create the survey, Koh, et.al., examined Jonassen, Howland, Marra, and Crismond's (2008) principles that relate to an information and communications technology (ICT)- supported constructivist learning environment. The five principles included students actively manipulating objects and observing results, reflecting and articulating their personal understandings of their observations, engaging in authentic tasks based on real world problems, intentionally setting goals for learning and planning problem-solving processes, and collaborating to problem-solve within their classroom community. Technology can serve as a tool to support these principles to encourage our students to be engagers and facilitators of thinking.

Koh et al. (2014) used these five dimensions and the seven-construct TPACK framework developed by Mishra and Koehler (2006) to assist in the creation of their teacher survey. The seven constructs included the following:

1. Technological knowledge (TK) – knowledge of technology tools
2. Pedagogical knowledge (PK) - knowledge of teaching methods
3. Content knowledge (CK) – knowledge of subject matter
4. Technological pedagogical knowledge (TPK) - knowledge of using technology to implement teaching methods
5. Technological content knowledge (TCK) – knowledge of subject matter presentation with technology
6. Pedagogical content knowledge (PCK) – knowledge of teaching methods with respect to subject matter content
7. Technological pedagogical content knowledge (TPACK) - knowledge of using technology to implement constructivist-teaching methods for different types of subject matter content

The researchers then added the constructivist-oriented component to the seven constructs to create C-TK, C-PK, C-CK, C-TPK, C-TCK, C-PCK, and C-TPACK to address the responses of the survey.

Koh's et al. (2014) survey collected teachers' reported abilities of incorporating technology into a constructivist-learning environment. It was designed on a Likert scale where 1- strongly disagree, 2 – disagree, 3- slightly disagree, 4 – neither agree nor disagree, 5 – slightly agree, 6 – agree, 7 – strongly agree. They found teachers rated themselves as highly confident of their content knowledge (CK) with a mean of 5.84, their ability to provide constructivist instruction (C-PK) with a mean of 5.56, and their ability to provide constructivist instruction specific to their content area (C-PCK) with a mean of 5.43. However, when the survey added technology into the equation, the confidence level dropped. Teachers rated their ability to use technology tools to create a constructivist instruction (C-TK) with a mean of 5.17, their use of technology to teach their content area (TCK) with a mean of 5.20, their use of technology in their teaching to create constructivist instruction (C-TPK) with a mean of 5.20, and their knowledge of technology to create constructivist instruction in their content area (C-TPACK) with a mean of 4.86. The teachers' surveys showed they were confident in implementing constructivist-oriented instruction but revealed their struggles were in the areas of ICT-driven constructivist-oriented instruction.

After reviewing the responses to the survey in regards to their confidence in the seven constructs, Koh et al. (2014) then turned to analyzing the results by teacher characteristics. They found a small negative correlation between age with TPACK constructs and teaching experience with TPACK constructs. They also found males rated themselves higher (small effect size) in constructs that had technology as a component. In addition, primary teachers rated themselves lower (small effect size) in the construct of C-TPACK than secondary and junior college teachers.

Some possible explanations of Koh's et al. (2014) finding are that more experienced teachers, who had a lower perceived C-TPACK, are more influenced by the exam driven school system that has traditionally been focused on the dissemination of knowledge and facts rather than a constructivist approach. Also, primary teachers, who perceived themselves as lower than other participants in C-TPACK, may be at a disadvantage solely due to the fact they teach multiple subjects at the elementary level. Secondary and junior college teachers typically focus on only one content area and thus may be more confident with C-TPACK.

Koh et al. (2014) concluded that this study could give insight into how school districts could provide professional development to assist teachers with technology implementation in the classroom. First, professional development needs to go beyond teaching constructivist instruction in general to more specific training of how to address ICT in a constructivist context. Greenhow, Dexter, and Hughes (2008) stated teachers focus their technology integration on how to represent content. However, Windschitl (2002) stressed teachers must learn how to instead focus on facilitating student learning through authentic problem-based tasks and creating opportunities for classroom discourse. Teachers need to have a strong C-TPACK in order to create a technology-infused constructivist-learning environment.

Constructivism and Technology in the Classroom

Overbay, Patterson, Vasu, and Grable (2010) found teachers who leaned toward a constructivist approach in the classroom and thought the technology could be used as a tool in a student-centered environment were more likely to report using technology. "With the rapidly changing landscape of the K-12 classroom, asking questions about the relationship between constructivist practice and the use of classroom technologies seems more important than ever" (p.104). As a result, teachers that adhere to the constructivist theory would use technology to engage students and to encourage them to find meaning in the material versus memorization of facts. The tools would be used for knowledge construction rather than drill and practice focused on skills.

Overbay et al. (2010) researched the IMPACT model of technology integration, designed to promote student-centered learning, being used in North Carolina schools. This model was designed to provide teachers and media and technology personnel the opportunity to collaborate as they developed a student-centered environment focused on 21st century learning. The project examined the relationship between teachers' level of constructivism and their reported use of technology in the classroom. One of the research questions was "What was the relationship among individual-level variables (e.g. sex, years of experience, and subject taught) and technology use, and do they interact significantly with level of constructivism in predicting technology use" (p.106)? Overbay et al. used The Activities of Instruction (AOI) survey to measure the amount of constructivist practices that were occurring in the North Carolina schools. This survey was developed to consider constructivist practices when describing classroom activities of teachers at different grade levels.

Overbay et al. (2010) found teachers' reported level of constructivist practice had a significant positive association with their level of reported technology use. After studying the other variables, they found the best predictor of teachers' reported technology use was the level of constructivism. They interpreted this to state, "teachers who use constructivist activities are also willing to incorporate technology into routine student-centered activities" (p.116). As school districts strive to find the most effective ways to implement technology, training teachers on how to create a constructivist- learning environment may result in classrooms that are actively incorporating technology into lessons.

Computer Technology in the Mathematics and Science Classroom

Mobile devices, specifically the iPad and other tablet-style devices, are the most recent in a long line of technology tools made available for classroom implementation over the past decades. Computer technology (CT) and computer assisted instruction (CAI) have been a part of the learning environment for quite some time and is only growing. By 2001, US public schools housed more than ten million computers and 87% of classrooms offered Internet access (Hernandez-Ramos, 2005, as cited in Holden, Ozok, & Rada, 2008). Now, years later, the issue is no longer access to technology but how can we use it to promote student learning and achievement (Holden et al., 2008). Is mobile technology a viable option for increasing learning and achievement? Past studies on computer technology seem to support answering that question positively (Bayraktar, 2002; Li & Ma, 2010).

The use of computer technology in education has been researched for the last few decades, and numerous studies and meta-analyses have been completed on the effects of CAI and CT use on achievement in the mathematics and science classrooms (Bayraktar, 2002; Li & Ma, 2010).

Computer Technology in the Mathematics Classroom

Li and Ma (2010) conducted a meta-analysis of the effects of computer technology on K-12 students' mathematics learning. The research encompassed 46 studies involving 36,793 learners. This meta-analysis included studies providing research findings on the numerous implementations of computer technology now being used in the classroom.

The research gleaned from the 46 primary studies showed an overall small, positive effect (0.28) of CT on mathematics achievement. Of the 85 effect sizes found, only seven showed a negative effect on mathematics achievement. Li and Ma (2010) sorted the technology use into four types- tutorial, communication media, exploratory environment, and tools. The findings showed the types of technology use had no effect on mathematics achievement of students. However, the meta-analysis found large effects with certain teaching styles. When analyzing the data, they categorized the studies into two pedagogical approaches- traditional and constructivist teaching. To make the classification, they defined a traditional style as one that is teacher-centered with whole-class instruction whereas a constructivist style is student-centered with discovery-based and problem-based learning, and situated cognition based on constructivism. They found there was a large effect with CT use in a constructivist environment rather than a traditional one (1.00). "When used in settings where teachers practiced constructivist approach to teaching, technology had much stronger effects on mathematics achievement than settings where teachers practiced a traditional approach to teaching" (p.228).

In conclusion, Li and Ma (2010) found CT had positive effects on mathematics achievement when analyzing 46 different studies. In addition, they found one of the largest positive effects (1.00) came when teachers used a constructivist approach, by adding techniques such as inquiry-based and problem-based instruction when implementing technology in the classroom.

Computer-Assisted Instruction in the Science Classroom

Bayraktar (2002) conducted a meta-analysis on the effectiveness of computer-assisted instruction (CAI) on student achievement in the secondary and college science classroom by comparing CAI instruction with traditional instruction. Computer-assisted instruction is the use of computers in the classrooms to aid in the teaching and learning process. The purpose of the analysis was to determine the overall effectiveness of CAI in physics, chemistry, biology, general science, and physical sciences.

After including 42 studies that produced 108 effect sizes, Bayraktar (2002) first examined the overall effects of CAI on achievement in science. Of the 108 effect sizes, seventy of the effects were positive for the CAI group being more effective, 38 were negative meaning the traditional instruction was found more effective, and one study showed no difference.

Bayraktar (2002) next analyzed the different CAI implementations and found the most effective use of CAI was simulations and the second most effective was tutorial. Using CAI for drill and practice in the science class actually had a negative effect on achievement. Other implementations that were found more effective were software developed by the experimenter/teacher rather than commercial software and using the computers as a supplement to instruction rather than a replacement for regular instruction. There was no difference in effect size when examining the school level, and CAI was most effective when the duration of use was four weeks or less. Overall, Bayraktar (2002) determined the best implementations for CAI were to use it as a supplement to traditional instruction.

Mobile Devices

The issue that now arises is to determine if the success of computer technology on raising achievement has translated to success of mobile devices. Within the classroom, there has been a move in the past few years from computer technology to mobile devices, including iPads and Android tablets. According to Kiger, Herro, and Prunty (2012), as these devices become more prevalent, schools are using them to improve student engagement, collaboration, communication among peers and teachers, and to move learning past the walls of the classrooms. For instance, students are using them on field trips to enhance learning outside of the school building. These devices are a cheaper option to computers and provide teachers a viable way to enhance learning. However, this movement should be approached with caution. Melhuish & Falloon (2010) warn the device should not become the focus in this situation. Instead, "our focus must remain on the way mobile learning can be integrated into effective, evidence-driven, innovative practices, so that the learner is empowered and enriched by the learning experience" (p.13). The researchers go on to state five benefits mobile devices can bring to the classroom. Portability of the device allows students the ability to learn beyond the school desk. The devices are affordable allowing for a larger number of users. They also allow for situated learning opportunities that promote collaboration with others enhanced by the use of cloud-based computing. The ease of connectivity allows participants to interact with others. Finally, the mobile devices offer the ability to individualize a learner's experience.

Melhuish and Falloon (2010) specifically speak of the mobile device, the iPad, and its potential uses in the classroom. When revisiting the five benefits, the iPad is not only portable but has many of the functions of a computer without the costs of a computer that has the same computing power. The iPad's functionality also allows for a constructivist-learning environment as it promotes collaboration and can provide authentic tasks for students to explore. Its connectivity feature allows students to communicate synchronously or asynchronously in online learning communities. Finally, teachers are able to use the multiple functions, such as the plethora of apps; to create individualized learning opportunities for students.

The search for apps to use in the classroom can be overwhelming to teachers. According to Larkin (2014), although there are many apps available, teachers must determine which are of high quality and will promote understanding of the content rather than essentially being flash cards in a digital format. The information given in the app store is often not enough to make those decisions resulting in frustration of teachers with locating appropriate technological tools for instruction. In the area of science, the iPad apps can provide an experience student cannot receive from traditional resources. For instance, in the area of life science, there are many apps that allow students to examine the brain and cells by rotating and zooming in on key components to create a better understanding of the workings of the human body than still pictures in a textbook can provide (TCEA, 2016). Beyond apps, there are other technological resources for teachers to use in the classroom with the iPads. Hohenwarter and Preiner (2007) discussed Geogebra, a dynamic geometry software, which allows students to view concepts through two representations, graphically and algebraically, to help develop a deeper understanding of the mathematics being studied. This program is available for use on the iPad giving students a virtual way to explore mathematics.

As the push for mobile devices continues, schools must ensure the use of the iPad is based on sound research-based practices. However, limited research is available to show the effects of this mobile device on student achievement. The following address some of the studies involving the iPads in educational settings.

iPad Use in a University Setting- Mathematics Classroom

As mentioned earlier, Fisher et al. (2013) noticed a deficiency in research that addressed the usage of iPads in the classroom. As a result of this, the researchers completed a project in a university setting by studying the use of the iPads versus laptops in a business calculus classroom. They based their research on Vygotsky who “recognizes that the process of learning is inherently social and our interaction with others is central to our development as a learner” (p.167). They also relied on activity theory when collecting data by focusing on collaborative learning rather than individual learning. They looked at how the iPads were being used as students interacted in groups. Data was collected through observations, focus groups, and surveys. Through coding of the observations, they found there were three tiers of how the technology was used: multi-use, multi-view, and single-use. Multi-use involved multiple students using one device to complete activities. Multi-view involved one student sharing his work on the iPad with other students. In the case of single-use, the students discussed their work on the iPad but did not show the evidence to others. Through the surveys and focus groups, Fisher et.al. determined how students were using the technology during the instructional unit.

Fisher et al., (2013) found through the observations that students with iPads incorporated them in almost all interactions with other students whereas the laptops were only brought into this type of learning environment approximately half the time. The iPad group was more willing to share screens and look at each other’s devices during the learning. Another difference found was 7.5% of the time the laptop group was off task compared to 0.8% of the iPad group. The openness of the iPad screen and the inability to have multiple windows open may have contributed to this result. The surveys showed students felt the iPad was more conducive to showing work and justifying their actions to groups and the class. Survey responses showed 82% of the iPad group used the technology to show information to classmates versus only 47% of the laptop group. Also, 53% of iPad group took advantage of the device for reading materials but only 16% of the laptop group used it for this reason.

Fisher et al., (2013) found iPads could be used not only for calculations but also for collaboration among students. It enabled the participants to explain their reasoning behind how they solved a problem and to share and defend their work to their peers. The Common Core State Standards (CCSSI, 2010) for mathematical practice states students will “construct viable arguments and critique the reasoning of others” (p. 298). They found students benefited from sharing their knowledge by being the teacher for others. This helped to strengthen their understanding of the mathematical content. The iPads served “as a public center of communication in which multiple students can view, discuss, and interact with the device simultaneously” (Fisher et al., 2013, p.176).

As more emphasis is placed on creating constructivist-oriented learning environments that encourage rich discussions among participants, this study was beneficial because it is one of the first to focus on how iPads can be used to enhance collaboration and communication in the classroom beyond the abilities of a laptop. This new technology revealed the many benefits to incorporating it into a student-centered learning environment at the college level. More research will need to be completed to find if its benefits transfer to the K-12 level of education.

iPad Use in the Fifth Grade- Mathematics Classroom

Castelluccio (2010) found teachers are beginning to use the iPads to engage, introduce, practice, and reinforce learning concepts. Castelluccio stated, "The iPad has specialized applications in which multiple sense (e.g., auditory, visual, and tactile) are incorporated; the use of multiple sensory inputs has been shown to reinforce student learning and to achieve a variety of mathematics objectives" (as cited in Carr, 2012, p.270). To add to the scholarly research, Carr (2012) completed a study with fifth-graders researching if iPads affected mathematics achievement when used for game-based learning.

Carr's (2012) quasi-experimental study was conducted with two 5th grade classes in which the experimental group used the iPads as one-to-one computing devices daily during mathematics class for nine weeks. A pretest/posttest was used to analyze if the iPads had a positive effect on student achievement. Using ANOVA to analyze the data, the experimental group saw a 6.74% increase in pretest to posttest scores whereas the control group saw a 6.67% increase. This difference was not large enough to be deemed significant.

Carr's (2012) findings showed iPads did not have a significant influence on students' mathematics achievement. When listing limitations, she stated students in the study had limited access of the iPads, which may have played a role in the findings. Carr's research highlighted some of the issues of technology availability and the possible impact it has on instruction. Suggestions for future research were to conduct studies where the students have 24-hour access to the technology, increase in the intervention duration, using a larger sample size, and collecting qualitative data. Carr stated the verdict for one-to-one devices has been mixed thus far. As more implementation occurs, more studies are needed to determine the benefits of iPad use in the mathematics classroom.

iPod Touch Use in the Third Grade- Mathematics Classroom

With limited research on iPad use to examine, one study that can provide a glimpse into its usefulness is Kiger's et al., (2012) research with third grade mathematics achievement using the iPod Touch technology. Although the iPod Touch has limited capabilities compared to the iPad, it has similar technological features. This nine-week project used iPods to promote a mobile learning intervention (MLI) to practice multiplication skills through multiple available math apps. The following research questions were addressed.

1. Does participation in the MLI explain a significant amount of variation on a post-intervention multiplication test controlling for several covariates including prior student achievement? If so, what is the influence of the intervention relative to the control variables?
2. Does participation in the MLI explain a significant amount of variation on the most difficult post-intervention multiplication items controlling for several covariates, including prior student achievement? If so, what is the influence of the intervention relative to the control variables? (p. 64)

Kiger's et al. (2012) study was conducted in four classrooms in which two practiced math facts by using flash cards each day and the other two practiced using math apps downloaded onto iPod Touches. The findings showed the MLI students outperformed the other students on the multiplication posttest with the effect size being a significant 0.22 indicating a small effect. "MLI participation was the most influential 'explainer' of test performance excepting the pretest" (p. 75).

The Kiger et al. (2012) study in contrast to Carr (2012) showed a positive effect on student's mathematic achievement. With multiple studies finding conflicting results, this reinforces the need for more research of its use in the classroom.

iPad Use in the High School- Science Classroom

Physics courses enable students to apply the mathematics they have learned in meaningful ways. Students use analytical skills to solve word problems that can represent real world situations and begin to understand the background of many of the technological advances we use today. Success in physics can help open the doors to many STEM careers for our students. The question in the next study was whether iPads could facilitate that success. Through a project called iPad Enhanced Active Learning (iPEAL), Van Dusen & Otero (2012) set out to determine the effects iPads would have on students' interactions with and relationships to physics. The study was conducted with five high school physics classes consisting of approximately 140 junior and senior level students. The project provided a classroom set of iPads and activities designed to supplement the traditional physics assignments. For example, the students used the iPads to create screencasts of how to solve problems from the textbook.

Van Dusen and Otero (2012) based their research on the idea that if a learner is actively engaged in something personally meaningful, then learning is more likely to occur. The study was focused on providing a positive experience in physics class by incorporating the iPads into instruction. Through the use of field notes, artifacts, video recordings, student surveys, and student interviews, the researchers found the iPads had an effect on four specific areas. First, by using iPads for data collection, analysis, and collaboration, the students were able to construct their own learning based on evidence they collected rather than knowledge from the teacher or book. Secondly, the iPads created excitement for learning and students began to come to work on physics projects outside of class time. Thirdly, the iPads increased student agency as students used the screencasts to take more responsibility for their own learning. Finally, students experienced an impact on their social status of being a member of this learning community as others verbalized a desire to be part of their learning community.

Van Dusen and Otero (2012) concluded the iPads created an environment that promoted a positive relationship between students and physics. This could set up a situation where the students would continue to enroll in future physics courses.

iPad Use in a One-to-one Environment

As schools move to more technology-infused environments, one of the biggest technological changes in education today is the implementation of one-to-one programs. These programs can be loosely explained as every student having their own device such as a laptop, iPad, or another tablet device to be used at home and school; however, the school largely defines the organization of that implementation. Penuel (2006) stated the policies vary among institutions. Some may have all students buy the same device, while others may have devices student rent or lease for the school year. Others may have students check them in and out each school day but not take them out of the school building. Another option is to follow a bring your own device (BYOD) policy where students may choose the best option for them. However, in each case, there are three common characteristics: students each have a device, Internet is provided through wireless access, and the devices are used for academic tasks such as completing homework and assessments and for presentations. Overall, "ubiquitous, 24/7 access to computers makes it possible for students to access a wider array of resources to support their learning, to communicate with peers and their teachers, to become fluent in their use of the technological tools of the 21st century workplace" (p.332).

One-to-one Tablet Initiative Private Middle School Program

Oliver and Corn (2008) completed a study to measure differences in students' technology use and skills after a one-to-one tablet initiative with middle-school students. In this research project, participants were students in the sixth through eighth grade at a private middle school in the US who completed a survey before and after participating in a one-to-one program for a year. The survey asked questions about how satisfied they were with technology use at their school, their technology experiences in the classroom, how it was used in the different content areas, and their technology skills. A control group also completed the surveys, as well. The researchers completed observations of the classrooms to collect data on how the technology was being implemented.

Oliver and Corn (2008) found students in the one-to-one group were more satisfied with the technology use at their school, more time was spent in class using technology, and significantly more frequent use of technology in the mathematics and science classes. Observations showed more project-based learning, teachers acting as coaches, and student-centered projects assigned. However, teacher-centered instruction was still the most common approach to teaching in the classroom. Even with one-to-one technology, teachers were still not using them to create learner-centered environments that would encourage collaborative learning.

One-to-one iPad Initiative PreK-4th Grade Program

One-to-one technology integration is appearing not only at the secondary and university level, but also in our elementary schools. Milman, Carlson-Bancroft, & Boogart (2012) analyzed the implementation of a one-to-one iPad program at a PreK-4th grade school. They researched how teachers and students were using the iPads for teaching and learning, specifically how they were being used for differentiation and how they were used across content areas.

Milman's et.al. (2012) mixed methods study collected data by completing 68 observations for a total of 50 hours, and by collecting surveys. Although the study is in the preliminary stages, they have found the use of iPads have netted the following results. Student engagement has been very high and helped with attention issues of the students. Even after months of use, students were still excited to participate in lessons that incorporated the iPads. Also, the observations showed teachers taking a facilitative approach to teaching when the iPads were in use. Students showed a collaborative spirit as they assisted each other with activities. Finally, all teachers were able to use the iPads to differentiate instruction in their classrooms. Overall, the iPads were being successfully incorporated into instruction to provide for an engaging, personalized learning experience.

One-to-one iPad Initiative Private Middle/High School Program

Heinrich (2012) at the Longfield Academy in Kent, England conducted research of the students at the school who were participants in a one-to-one iPad initiative. The school has approximately 960 students in year 7 to year 13 and 76% of the students have iPads. The school's goal of the one-to-one program was to provide students with engaging lessons, the ability to use technology in every lesson, and for the technology to improve learning. The academy's research done prior to the one-to-one implementation showed iPads were a significant tool to support learning (Learning Exchange, 2011), students preferred it to a laptop and it aided learning (Gliksman, 2011), the device was beneficial for note taking (Vrtis, 2010), and encouraged group collaboration (Garcia & Friedman, 2011). Heinrich pointed out most of the research available was based on class sets of the devices rather than a one-to-one setting. Their study strived to determine the implications of all students having their own device. Surveys were collected from students, teachers, and parents to determine the success of the program.

Heinrich (2012) first found the implementation of the iPads into instruction to be abundant. 84% of students reported iPad use in one to ten lessons per week with 27% of those stating use in 6 to 10 lessons per week, and 12% reporting iPad use in the majority of lessons. Teachers corroborated those numbers by 80% reporting use in 1 to 10 lessons, 38% in 6 to 10 lessons, and 17% using the technology in the majority of their lessons. It was found the majority of the lessons were in English, math, and science and determined offering these devices in a one-to-one environment played a significant role in how much the devices were being used.

Heinrich (2012) identified three main implementations of the iPad: researching topics online, using mind-mapping tools, and creating presentations. The devices were also used for traditional activities such as word processing and watching videos. Collaboration was also an aspect used frequently with 42% of students and 52% of teachers reporting the use of collaboration. When students were asked what were the benefits of using an iPad compared to the pre-iPad classroom, some of the responses were easy internet access, making movies, educational games, mind mapping, apps for learning, communication with teachers, creating and delivering presentations, and annotation of texts. Heinrich reported, "There is a clear message that students regard the iPad as a tool that enables them to work more efficiently and thus, by extrapolation, more productively" (p.23). When teachers were asked how the iPads had changed their setting, they stated the personal benefits were the ability to create podcasts, easier lesson planning and sharing of resources. The classroom benefits were creating engaging lessons for students, immediate research capabilities, ease of differentiating instruction and immediate feedback for students of learning.

Overall, Heinrich (2012) found 90% of students reported being happy with the use of iPads for learning and 77% of teachers were happy to regularly use them. Both participant groups felt they could work more effectively with the iPads and their level of collaboration had improved. In the end, it was reported the devices had a significant and very positive impact on learning and teaching, and there was an expectation the impact would be noticeable in future achievement.

One-to-one Laptop Initiative Middle School Setting

With the lack of studies completed addressing the effect of one-to-one iPads on academic achievement in the middle school mathematics and science classroom, Dunleavy's and Heinecke's (2007) study can be used to shed some light on the benefits of a one-to-one program. They conducted research in a middle school that used Apple iBooks laptops as their mobile devices. The urban school in the study had 972 students in grades six through eight, a percentage poverty of 59.67 and a percentage minority of 87.20. As the students entered sixth grade, approximately one third of the students were randomly assigned to the one-to-one program. The students were allowed to use the devices in every class and take them home during the week. However, devices were required to be left at school on the weekends.

Dunleavy and Heinecke (2007), by using a pretest-posttest control-group design, analyzed the effects of the laptop implementation on eighth graders who had used the technology for two years. The students' fifth grade pre-existing mathematics and science achievement scores on the state standardized test were used as the covariate to equate the treatment and control groups. Using ANCOVA, the researchers used the scores on the eighth-grade standardized test to determine any effects as a result of the intervention of the one-to-one program. The participants in their study consisted of 54 students in the treatment group and 113 students in the control group.

Dunleavy and Heineche (2007) had three main findings from the analysis. First, after accounting for differences using the pretest scores, the laptop initiative was found to have a small, significant, positive effect (0.24) on the science posttest scores. Secondly, this effect was found to be more significant for males (0.55) than females (0.04). Finally, in regards to mathematics, the laptop treatment had no significant impact on achievement.

In discussion, Dunleavy and Heineche (2007) brought up some interesting questions to be addressed in future studies. With a significant effect on students' science achievement found, why does that not carry over to mathematics? Was the technology implemented differently in science class or were there possibly more technological resources available for science content? Why was the positive effect in science found to me larger in males than females? Although this study helped to shed light on whether one-to-one programs have a place in education, it also leaves a need for more research in this area.

Summary

Throughout the last decades, technology has flourished in our schools and more emphasis has been placed on creating student-centered environments that follow the tenets of Constructivism. A constructivist style of teaching has been shown to be effective with academic achievement significantly higher for those students learning in a constructivist setting. Ayaz's and Sekerci's (2015) meta-analysis showed strong effect sizes for using a constructivist approach in the classroom, with the strongest effects found at the high school and college level.

Through the use of meta-analyses, Bayraktar (2002) found CAI was significantly more effective than traditional instruction when analyzing 42 studies of high school and college level science classes. Li and Ma (2010) discovered the same results in the area of mathematics and not only did CT have a positive effect on mathematics achievement but it also had larger effects when paired with a constructivist-learning environment.

With the previous studies showing positive effects of a constructivist learning environment and the use of computer technology on mathematics and science academic achievement, more research is now needed to see if that effect translates to the use of iPads in a one-to-one setting. Research has shown the use of iPods positively effected mathematics achievement when used in the classroom (Kiger et al., 2012); however, there have not been large amounts of studies completed on the iPads effects, especially in a one-to-one setting. The research of one-to-one iPads have focused mostly on analyzing students' and teachers' perceptions of the technology and how the iPads are being implemented with little research conducted on actual achievement scores (Oliver and Corn, 2008; Milman et al., 2012; Heinrich, 2014). Research on one-to-one settings with laptops has shown this type of implementation is effective in raising science achievement (Dunleavy and Heineche, 2007).

A key component to a one-to-one initiative, though, is our teachers' abilities to create effective technology-infused classrooms. Koh et al. (2014) showed not all teachers have the strong C-TPACK necessary to successfully implement technology into a constructivist-learning environment, especially those who have been teaching for a long period of time and those teaching at the elementary level. With more and more iPads and tablets appearing in school districts, it is not only imperative that more research be conducted to determine the effectiveness of these technological tools on the academic achievement of our students but that continued professional development be provided for teachers to ensure they have the knowledge needed to incorporate the tools effectively into their mathematics and science classrooms.

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