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The Impact of One-to-One Laptop Initiatives on K-12 Math and Science Pedagogy and Achievement: A Literature Review

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The Impact of One-to-One Laptop Initiatives on K-12 Math and Science Pedagogy and Achievement: A Literature Review

by

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Dedication

To my family for their support, to my friends for their encouragement, and to Matt for the love he gives me each day.

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I want to acknowledge Dr. Joan E. Hughes and Dr. Min Liu for their support during my time in the Learning Technologies program at The University of Texas at Austin.

Abstract

The Impact of One-to-One Laptop Initiatives on K-12 Math and Science Pedagogy and Achievement: A Literature Review

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The use of computers in education has evolved over the past thirty years and provided a new platform for teaching and learning. The student to computer ratio rapidly decreased during the 1990s and increased access to wireless Internet connections and portable devices at the beginning of the 21st century prompted more and more schools to provide each student with a laptop computer. The purpose of this report is to provide a review of literature that evaluates how one-to-one laptop initiatives support student-centered pedagogy and impacts achievement in K-12 math and science classrooms. More specifically, this review examines how the frequency of laptop use and the specific programs and applications that are used in math and science can support student-centered learning and affect achievement. The results of the literature review provide insight as to what educators can expect when each student has a laptop.

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Chapter 1: Introduction

Overview of One-to-One Laptop Initiatives

The development of educational, computer-based instructional programs used for drill and practice, tutoring, and testing dates back to the early 1960s (Kulik & Kulik, 1991). Personal computers first became widely available in the early 1980s. Computers in schools were first housed in labs where teachers could take their classes at a scheduled time. However, many believed that if students had access to computers more than once or twice a week, computers could have a larger impact on learning (Penuel, 2002). Advances in technology are occurring faster than ever, and K-12 schools have expanded the use of computer access to students over the past three decades.

The 1990's saw a rapid decrease in the student to computer ratio. In 1992, the ratio was 19.2:1 and fell to 5.7:1 by 1999 (Jerald & Orlofsky, 1999). In the late 1990s, schools began to upgrade to multimedia computers, which included sound cards, CD-ROM drives, and other components necessary to run educational software with multimedia components (Jerald & Orlofsky, 1999). In 1997, the student to multimedia computer ratio was 21.2:1 and dropped to 9.8:1 by 1999 (Jerald & Orlofsky, 1999). During this time, schools were feeling more and more pressure to wire their computers with Internet connections as they struggled to keep equipment up-to-date (Jerald & Orlofsky, 1999). As a result, the student to internet-connected computer ratio dropped from 19.7:1 in 1998, to 13.6:1 just one year later, and was 3.1:1 in 2008 (Jerald & Orlofsky, 1999; U.S. Department of Education, 2010). As schools increased the number of computers, infrastructure issues such as physical space, table space, and electronic outlets have made it challenging to accommodate more computers in classrooms (Clariana, 2009). Wireless laptops can overcome these barriers because they take up less space, do not require a constant source of power, and do not have to be physically plugged in to access the Internet. Therefore, many schools acquired laptop computers and gained wireless Internet access. By 2008, 51% of schools had laptops on carts, 39% of public schools provided wireless Internet to the whole school, 30% provided it to part of the school, and 9% provided it from the laptop carts only (Gray, Thomas, & Lewis, 2010).

Throughout the past decade, an effort has been made to provide each student with his or her own laptop and commonly referred to as one-to-one initiatives. Early one-to-one laptop initiatives began in the mid-1990's with Microsoft's Anytime, Anywhere Learning program, which allowed students to buy or lease laptops (Penuel, 2006). By 2006, 31% of superintendents in the US reported implementing one-to-one programs in at least one classroom within their school district (Clariana, 2009). In a synthesis of one-to-one initiatives, Penuel (2006) noted that technology leaders had a variety of reasons for implementing one-to-one programs, and defined three characteristics of one-to-one computing: (1) students are provided with a portable laptop loaded with production software, (2) Internet access is available through the school's network, and (3) the laptops should be used to complete academic tasks. The benefits to ubiquitous computing include giving students equitable access to a wide-variety of up-to-date resources and learning opportunities (Penuel, 2006).

Within the fields of math and science, the processing capabilities of computers can benefit learning by influencing mental representations and cognitive processes (Kozma, 1991). For example, dynamic, symbolic representations of non-concrete concepts can be constructed using computers. As learners manipulate these representations, they are able to build accurate mental models, which may have initially been incomplete. Learners could elaborate their understanding through real world experiences and real time phenomena. Many of the examples given in Kozma's (1991) review are directly related to the impact of computers on math and science learning, including interpreting graphs and manipulating data related to the laws of physics.

Now that one-to-one laptop initiatives have made their mark in K-12 education, numerous studies have been conducted examining the impact of laptops on teaching and learning. This report is a literature review that examines the research reports and evaluations of one-to-one laptop initiatives implemented in K-12 math and science classrooms and their impact on student-centered pedagogy and student achievement. The next section provides more insight and approaches to student-centered learning as well as discusses how technology can influence this type of instruction.

Defining Student-Centered Learning

Many of the reports reviewed discussed elements of student-centered learning that were supported by laptops. In a traditional K-12 classroom, it is common for the teacher to state the learning objective, plan activities that will help students meet the objective, and direct students through the steps needed to meet the objective, while helping them solve problems along the way. According to Pederson and Liu (2003), this is defined as a teacher-directed classroom. In contrast, a student-centered learning environment occurs when the teacher poses a central question or problem and then acts as a facilitator to support students as they formulate a process to determine a response (Pederson & Liu, 2003). This new learning environment promotes student motivation and ownership of learning, while enabling students to address their individual and unique learning interests as they construct personal meaning by relating new knowledge to existing understanding (Hannafin & Land, 1997; Pederson & Liu, 2003). Student-centered learning also affords the ability for students to engage in multiple levels of complexity, deepen understanding, enrich their thinking and learning, and promote cognitive engagement and knowledge construction (Hannafin & Land, 1997).

Technology and computers have made student-centered approaches to learning both possible and feasible. Technology provides access to resources that facilitate construction of knowledge and create a rich media environment that can enhance student interest and intrinsic motivation (Hannafin & Land, 1997; Pederson & Liu, 2003). According to Pederson and Liu (2003), computer-based programs that support student-centered learning environments should provide scaffolds for students with special needs, support factual knowledge acquisition, and take advantage of the affordances that computer technology provides to create multimedia-based learning experiences. Technology-enhanced student-centered learning environments do not simply serve as an alternative to direct instruction, but rather are instructional approaches with fundamentally different learning goals (Hannafin & Land, 1997).

The literature reviewed in this report mentioned several instructional approaches specific to student-centered learning, which include: teacher as facilitator, differentiated instruction, individualized instruction, collaborative learning, cooperative learning, constructivist learning, problem-based learning, project-based learning, higher-order thinking skills, and scientific inquiry skills; see Table 1 for definitions. Laptop computers can be used to enhance these instructional approaches and impact learning.

Table 1

Approaches to instruction

Differentiated Instruction	Instruction that is tailored to the needs of the learner; the learning goal is the same for all students, but the instructional approach varies according to the learners' preferences, interests, readiness, potential, and talents (Atkins, Bennett, Brown, Chopra, Dede, Fishman & Williams, 2010; Tomlinson, 2001).
Individualized Instruction	Instruction that is designed to suit individual interests, abilities, and experiences by providing self-paced learning activities while maintaining the same learning goal for all students (Atkins et al., 2010; Dick & Carey, 2009).
Collaborative Learning	Students are grouped together, in person or at a distance, to work together toward achieving a common academic goal (Atkins et al., 2010; Gokhale, 1995).
Cooperative Learning	Students work with each other to accomplish a shared goal and are responsible for each other's learning. All students contribute, help, and encourage one another so that the outcome is beneficial to all and results in the group performing at a higher academic level than they would have as individuals (Johnson & Johnson, 1999; Slavin, 1996).
Constructivist Learning	An internal process in which learners construct meaning by relating existing knowledge and previous experiences to new ideas and knowledge gained through social, cultural, and physical experiences; learners use conceptual and strategic thinking in order to solve authentic problems (Dick & Carey, 2009; Jonassen, 1999)
Problem-Based Learning	Students are presented with a real-world problem scenario where they analyze facts, generate a hypothesis, conduct research, integrate theories, and construct new knowledge to develop a solution to the problem (Hmelo-Silver, 2004; Savery, 2006).
Project-Based Learning	Students engage in real world activities and construct understanding by investigating questions, proposing hypotheses and explanations, and discussing ideas. Learners follow appropriate procedures and learn by doing in order to reach the project goal (Krajcik & Blumenfeld, 2006; Savery, 2006).
Higher-Order Thinking	Process of taking new information or information stored in memory and rearranging or extending the information by judging and interpreting criteria, which can be conflicting and poses a sense of uncertainty. The path to a achieving a purpose or finding an answer is complex, unspecified, requires self-regulation, and there is a possibility for multiple solutions (Lewis & Smith, 1993; Resnick, 1987).
Scientific Inquiry Skills	Students develop knowledge and understanding of scientific ideas and how scientists study the natural world. The learner poses questions; examines information; plans investigations; reviews known facts; gathers, analyzes, and interprets data; proposes explanations based on evidence; and communicates results. (National Research Council, 1996; National Science Teachers Association (NSTA), 2004).

Methodology

The purpose of this report is to provide a review of the literature concerning the impact of one-to-one laptop initiatives on K-12 math and science learning environments. The two primary research questions guiding this literature review are:

1. How do one-to-one initiatives support student-centered pedagogy in math and science classrooms?
2. What impact do one-to-one initiatives have on student achievement in math and science?

Three databases were used to conduct the search: ERIC, Education Source, and PsycINFO using EBSCOhost. Two search conditions were used, and both included the following conditions: "1 to 1" OR "one to one" OR "1:1"; comput* (computer, computing, etc.) OR tablets OR laptops OR ipad OR chromebooks; stem OR science OR math* OR engineering. The first condition also included achievement and resulted in 109 results, while the second condition included pedago* (pedagogy, pedagogical, etc.) and resulted in 156 results.

Next the abstracts were read in order to choose relevant articles, meaning those that directly related one-to-one initiatives in K-12 math or science. During these readings, it was decided to only include research articles published after 2000 from peer-reviewed publications or school district reports. After analyzing the abstracts of the reports, the results were narrowed to twenty-eight reports that presented findings relevant to pedagogical practices or student achievement in K-12 math or science classrooms related to one-to-one initiatives. Twenty-five reports discussed laptop use, while only five discussed tablet or mobile device use. Therefore, it was decided to focus only on laptop use, narrowing the search to 25 research reports, 13 of which were doctoral dissertations. The literature reviews of the dissertations were analyzed, and 6 additional sources were found to be relevant to this literature review. The dissertations were not included in the final selection of literature, making a final total of 18 reports.

After the reports were read, they were placed into one or more of the following categories: use (frequency and ways), student-centered learning, math achievement, or science achievement. Then the findings were summarized and documented in this report.

Many of the reports were evaluations of one-to-one programs initiated by specific school districts and were provided by the following: Denver School of Science and Technology, Maine Education Policy Research Institute, Texas Center for Educational Research, and The University of California, Irvine. Other reports were published articles in academic journals; see Appendix.

The majority of the reports, 12 out of 18, occurred at the middle school level (grades 6 – 8), while three occurred at the elementary school level (grades K – 5) and five at the high school level (grades 9 – 12). Eleven of the studies discussed the effects of one-to-one laptop programs in both math and science, while three only addressed math and four only addressed science. Half of the studies compared laptop classrooms and students to non-laptop users, while the other half analyzed only laptop users. The measures used to collect data for these studies include: classroom observations, focus groups, interviews, questionnaires, surveys, assessment results, test scores, and other necessary data and documents; see Appendix.

Chapter 2: Literature Review

Descriptions of One-to-One Programs and Research

A summary of each laptop program or research study is provided in this section and includes information about when and where each study took place, who participated in the study, the goal of the researchers, and other information relevant to the program. Throughout the remaining sections, these studies are referenced based on their findings.

Harvest Park Middle School. The Laptop Immersion Program at Harvest Park Middle School launched in 2001 with 6^{th} grade participants, and 7^{th} and 8^{th} grade participants were added each year over the next two years. The study by Gulek and Demirtas (2005) took place during the third year of the program with 259 6^{th}, 7^{th}, and 8^{th} grade participants. Both teacher and student participants in the program were voluntary and parents either purchased the laptops or applied for a waiver, in which case the school purchased the laptop. This school, located in Pleasanton, California, is a highly educated, high-income community. All participating students attended a computer camp in order to learn computer basics before using them in the classroom. Researchers conducted a longitudinal study consisting of three cohorts using GPAs, end-of-course grades, and standardized test scores to investigate the impact of the laptop program on student math achievement.

CompassLearning. Clariana (2009) evaluated the one-to-one laptop initiative that utilized *CompassLearning* in northeasthern Pennsylvania during the 2005-2006 school year, the second year of the program, in order to inform policy and planning for the program. *CompassLearning* is instructional software that can be accessed online, and it provides digital learning activities aligned with standards, direct instruction, independent practice, and support. Eight schools, one laptop and seven control, participated in the study, and it was found that the laptop class spent more time and completed more lessons using this software. The study also compared the 6th grade math achievement scores of the laptop school to the control schools, where the laptop to student ratio was five laptops for every one student. The data used for the comparison consisted of 5th grade Pennsylvania System of School Assessment (PSSA) math test scores (benchmark), four quarterly benchmark tests, and 6th grade PSSA math test scores.

New South Wales Digital Education Revolution. A study related to the Australian Government's Digital Education Revolution took place in 2010 and referred to as the New South Wales Digital Education Revolution program (Zuber & Anderson, 2013). This study observed twenty-eight high school math teachers at five schools where the students received laptops as 9th graders and the majority of the teachers taught 10th grade math. Researchers sought to investigate how math teachers are using the laptops, what teacher factors relate to use, and what aspects of math teaching influence use.

Crossriver School District. The Crossriver School District conducted a study of a pilot, voluntary laptop program where 5th, 6th, and 7th grade students paid a leasing fee of $50 per month for the laptops (Lowther, Ross, & Morrison, 2003). The school waived the fee for students who could not afford it. Researchers studied twelve laptop classrooms and nine control classrooms across four middle schools and one elementary school, and control classrooms contained five to six desktop computers. In both the laptop and control classrooms, teachers received *NTeQ* (*iNtegrating Technology for inQuiry*) training. A research question driving this study was, “Is teaching and student behavior different in laptop compared to control classrooms?” (Lowther et al., 2003, p.26).

Maine Learning Technology Initiative. The Maine Learning Technology Initiative issued wireless laptops to all teachers and 7th grade students starting in 2002 and all 8th grade students the following year (Fairman, 2004). Teachers, administrators, students and parents from twenty-three different schools were interviewed, twenty-two classroom observations at seven schools were conducted, and state-wide surveys were given to teachers, students, and technology coordinators. The schools consisted on nine elementary schools (K-8), two elementary/secondary schools (K-12), eleven middle schools (6-8), and one middle/secondary school (6-12). This study sought to investigate how the role of teachers and students changed, how teachers structured learning tasks, and what pedagogical shifts occurred as a result of the laptops.

Hillside Middle School. A case study was conducted with two math and science teachers who taught at a middle school in Maine where the Maine Learning Technology Initiative (MLTI) provided each student with Apple iBook computers (Garthwait & Weller, 2005). One of the teachers, Rick, had a masters in Instructional Technology, and the second teacher, Susan, was previously enrolled in a graduate class about using laptops for middle school math. Therefore, both teacher participants had a high level of technology integration expertise. The study took place in 2002-2003, during the first year of implementation of the laptop program. The purpose of the study was to evaluate how one-to-one computing affects teaching styles and determine any barriers that exist when integrating laptops into teaching and learning. Data was collected from teacher interviews, classroom observations, teaching artifacts, and news articles about MLTI.

Fullerton School District. The Fullerton School District in Orange County, CA launched a one-to-one laptop program during the 2004-2005 school year. A research study evaluated the first year implementation of the laptop program at three schools (Warschauer, Grimes, Rousseau, Suhr & Nyberg, 2005). The first school, Fisler K-8, is heavily focused on science and technology, hired teachers who were interested in using the technology, and provided laptops to all 3^{rd} – 7^{th} graders. The second school, Hermosa Elementary, implemented the laptop program with students in two gifted and talented classes with teachers who were interested in integrating technology into the curriculum. The third school, Nicolas Junior High, provided laptops to all 7^{th} grade students and teachers, and it was the largest of the three schools and included the largest percentage of English language learners and special education students. The report evaluated the use of laptops at all three schools and examined test scores at the laptop schools to identify relationships between laptop use and achievement.

Henrico County Public Schools. Henrico County Public Schools in Virginia implemented a one-to-one initiative in 2001 in middle and high schools, becoming the largest district in the U.S. to do so. Twenty-seven percent of students in Henrico County were eligible for free or reduced lunch, which classified them as low socioeconomic (Zucker & McGhee, 2005). High school teachers and students received iBook laptops at the beginning of the 2001-2002 school year, while middle school teachers received them in January 2002 and students in the fall of 2002. SRI International and Education

Development Center (EDC) initiated an evaluation on the laptop program during the 2003-2004 school year in order to increase understanding of one-to-one initiatives in math and science. Site visits took place at two middle and two high schools and surveys were sent to 540 math and science teachers and 3,000 randomly selected high school students. The study sought to determine how the laptops were used and what structures and resources are in place to support the use of laptops in math and science instruction.

Mid-Atlantic Middle School. A two-year longitudinal study took place at a middle school in an urban mid-Atlantic state (Dunleavy & Heinecke, 2007). The one-to-one laptop program began during the 2001-2002 school year where 100 7^{th} graders were randomly selected to be placed into laptop classrooms, while the remainder of 7^{th} graders were placed in non-laptop classrooms. The following school year, a new group of 100 6^{th} graders and 100 7^{th} graders were selected to participate in the laptop program, and the previous group continued in the program as 8^{th} graders. Although students used the laptops during their classes at school, the district did not allow them to take the laptops home. This research study sought to determine whether the one-to-one laptop initiative increased student achievement in math and science.

Technology Immersion Pilot. The Technology Immersion Pilot (TIP), sponsored by the Texas Education Agency, provided a wireless learning environment, which included laptops, to middle schools across the state of Texas (Shapley, Sheehan, Maloney, Caranikas-Walker, & Huntsberger, 2007). Schools eligible for the program included those that met the requirements for Title II, Part D (schools with high-needs population due to low income, schools that have been identifies for improvement, or those with a substantial need for technology). 70% of the students came from economically disadvantaged backgrounds and 67% were eligible for free and reduced lunch. The Texas Center for Educational Research (TCER) conducted a two-year study, from 2004 – 2006, that included twenty-one immersion and twenty-one control schools. This study sought to evaluate how technology immersion was implemented and what effects it has on teaching and learning, and researchers documented how the laptops were used in math and science classes.

The Denver School of Science and Technology. The Denver School of Science and Technology is a public charter high school located in northeast Denver (Zucker & Hug, 2007). The school opened in 2004 as a ubiquitous computing environment serving ninth grade students. Each year, a new grade level was added, and it graduated its first class in 2008. College preparation is a core value of the school and all students are expected to attend 4-year colleges. The school received a grant from HP that provided 9th and 10th graders with laptop computers, 11th and 12th graders with tablet computers, and most teachers also received tablet computers. A study of the one-to-one laptop program was conducted in the summer and fall of 2007, and two goals of the study were to investigate the ways that the school was incorporating computers into its academic program and observe how teachers and students were using the laptops.

Berkshire Wireless Learning Initiative. The Berkshire Wireless Learning Initiative was a three year pilot program in Massachusetts that provided laptop computers to all 7th grade students and teachers in 2006, and expanded to all middle schools students and teachers the following year (Bebell & Kay, 2010). The research study observed five laptop middle schools (three public and two private) and two comparison schools (both public) during the 2007-2008 school year. Two of the targeted outcomes of the program were to create fundamental changes in teaching strategies and curriculum delivery and enhance student achievement.

New Brunswick. A two-year study was conducted in New Brunswick Canada with 7th and 8th graders in eight experimental classrooms (Freiman, Beauchamp, Blain, Lirette-Pitre, & Fournier, 2010). The study sought to measure the effects that laptops have on a student's ability to investigate scientifically complex problems and reason mathematically. Researchers evaluated the use of laptops as the students engaged in two cross-curricular (math, science, language arts) problem-based learning scenarios.

International Society for Technology in Education (ISTE). Members and registered users of the International Society for Technology in Education (ISTE, SIG-1:1 Computing) participated in an online survey in order to reveal different pedagogical classroom practices in one-to-one computing environments (Inserra & Short, 2012). Of the 209 teacher participants, 170 high school teacher responses were analyzed in order to compare how teachers across disciplines (math, science, social studies, English, and foreign language) differ in the implementation of collaborative learning, constructivist learning, project-based learning, and differentiated instruction while using laptops.

Astronomy Case Study. A case study was conducted in an 8th grade science classroom in the southeastern U.S. in order to identify learning activities that use laptops (Yang, 2002). The study took place during the astronomy unit where one teacher taught five class periods in a one-to-one laptop environment during the second year of implementation. The case study sought to identify learning activities and teaching strategies that used the laptop in order to help teachers systematically and successfully integrate laptops to enhance learning.

EcoScienceWorks Project. In 2002, Maine introduced the Maine Learning Technology Initiative (MLTI), and in 2003, it provided every 7th and 8th grade student and teacher with a laptop (Allan, Erickson, Brookhouse, & Johnson, 2010). Starting in 2005, a project called EcoScienceWorks began with a goal to provide middle school students with engaging and challenging inquiry software to help them learn science. Like many other one-to-one initiatives, a need had risen in the MLTI for more professional development. Therefore, collaboration among software developers, learning technologists, teachers, and other appropriate stake holders, who offered a role in the TPACK (technology, pedagogy and content knowledge) framework, came together to provide professional development while creating a curriculum based around computer simulations and hands-on activities in ecology. Twenty-three middle school ecology teachers committed three years to the project.

Enhancing Education Through Technology (EETT) Grant. A year-long comparison study was conducted in 5th grade classrooms at four laptop schools and four non-laptop schools in an urban school district in California (Zheng, Warschauer, Hwang, & Collins, 2014). A federal grant for Enhancing Education Through Technology (EETT) funded the purchase of netbooks starting in 2010. Two goals of the study were to investigate how teachers make use of the laptops to facilitate students' science learning and evaluate the impact of laptops on academic achievement in science. More specifically, this impact was evaluated with English language learner (ELL), ethnicity, and socioeconomic status. All of the experimental and control schools had a high percentage of Hispanic students, ELL students, and students on free or reduce lunch (low socioeconomic).

Australian Government's Digital Education Revolution. A study was conducted in Sydney, Australia to measure the impact of one-to-one laptop use on students' academic success after the implementation of the Australian Government's Digital Education Revolution (Crook, Sharma, & Wilson, 2015). Half of all 9th grade students in New South Wales received laptops in 2008 and half did not. All students were taught using the same curriculum, and this study evaluated how laptops affected science students (biology, chemistry, and physics) in Sydney, Australia over three years. Of the twelve high schools that participated in this study, seven were laptop schools and five were control schools. Researchers evaluated the way that the laptops were used and the impact that the laptops have on senior high school student attainment on statewide biology, chemistry, and physics exams.

Student-Centered Pedagogy

Laptops can be incorporated into math and science curriculum in a variety of ways. This section addresses the first research question by discussing the findings of eleven reports that investigated how laptops are being used to support math and science learning. The following discusses the frequency of laptop use in math and science classrooms as well as the specific ways that students and teachers used the laptops.

Frequency of Laptop Use. Five of the research reports collected data to measure the frequency in which the laptops were being used in math or science classrooms. One report included elementary participants, three included middle school participants, and two included high school participants. Four studies compared the percentage of time students are using the laptops across the four core subject areas: English language arts, social studies, science, and math. The fifth study looked at how often math teachers are using laptops during instruction.

First, in the Crossriver School District, 5^{th}, 6^{th}, and 7^{th} grade students volunteered to participate in the one-to-one laptop program (Lowther et al., 2003). A student survey was given to both laptop and control students concerning the way they used the computers. The categories of computer use were productions tools (word processing, databases, spreadsheets, draw-paint graphics, presentation authoring, concept mapping, and planning), Internet or research tools (Internet browser, CD reference materials, and communications), and educational software (drill-practice-tutorial, problem solving, and process tools). When comparing the core academic subjects, laptop students reported using laptops less frequently in math and science classes for most activities. In addition, math and science laptop students used the computer more often than their peers in control classrooms.

In another study, Warschauer and Grimes (2005) evaluated the first year implementation of the laptop program at three schools in the Fullerton School District. Students self-reported the time that they used the laptops for educational purposes in the four core subject areas. It was found that students used the laptops less frequently in math than the other three subjects. 55% of students reported using the laptops in math less than one hour per week compared to 34% for science, 43% for social studies, and 23% for English language arts. Further, 44% of students reported using the laptops three or more hours per week for language arts, 27% for social studies, and 32% for science, compared to only 20% for math.

Next, Zucker and Hug (2007) evaluated how high school teachers and students used the laptops at The Denver School of Science and Technology, which placed college preparation as one of the school's core values. Across the four core subject areas, the amount of use was fairly consistent, with the majority of students reporting using their computers everyday in class. However, use in math and science was slightly less frequent than in English and history.

In the fourth study, Bebell and Kay (2010) observed the use of laptops by middle school students participating in The Berkshire Wireless Learning Initiative. Students at all seven schools reported the average number of school days they used technology, including the laptops, in the four core subject area. In general, students typically used technology less frequently in math and science classes than in the other subjects. On average, laptop students reported using technology on 20.4 days in math and 33.6 days in science during the 2007-2008 school year compared to 46.8 days in ELA/Reading and 44.4 days in social studies.

The last study that evaluated the frequency of laptop use was conducted by Zuber and Anderson (2013) and surveyed how math teachers participating in The New South Wales Digital Education Revolution program used laptops. Teachers completed a questionnaire about how frequently students used the laptops for seven specific purposes: discover concepts, explore concepts, internet research, drill-and-practice, homework, spreadsheets, and digital textbooks. One average, 77% of teachers reported using the laptops for these purposes “never/monthly”, 13% “weekly”, and 10% “most lessons.” The results on the questionnaire indicated that many of the math teachers were struggling to incorporate the laptops into instruction. Two conditions that may explain why so many math teachers struggled were teacher confidence and teacher beliefs. Teachers who used technology more in the classroom typically pursued their own training and often had more experience using technology outside of the classroom. These teachers were more confident in their own technology skills, thus were more likely to use the laptops for instructional purposes. The other technology barrier for math teachers is that many believe that, “Mathematics is something you do on paper” (Zuber & Anderson, 2013, p.290). Some teachers feared that students may lose the ability to write, and others felt that the laptops were more useful for higher-ability students and learning the technology is an extra demand for lower-ability students.

Although many of the math teachers were reluctant to incorporate the laptops into their lessons, there were some who were enthusiastic about the idea. The results of this study gave the researchers a better understanding of the needs and concerns of math teachers related to integrating laptops into the classroom and believe that the potential exists to leverage the use and value of one-to-one initiatives in math classrooms.

Summary. These five reports provided evidence that laptop use in math and science classes was less frequent than the other core subject areas, such as English language arts and social studies. The study evaluating the New South Wales Digital Education Revolution (Zuber & Anderson, 2013) revealed some challenges that math teachers face when implementing the laptops, which included teacher confidence in technology use and teacher beliefs about how students "should" learn math. The next section will discuss specific ways that the laptops are being used in math and science classrooms.

Ways laptops are used. This section describes the findings of ten research studies that reported specific ways that teachers and students were using laptops in math and science classrooms. Six studies reported uses specific to math and nine report uses specific to science. Two of the studies report use at the elementary level (K-5), six at the middle schools level (6-8), and four at the high school level (9-12).

Math. The most common ways that the laptops were incorporated into math included educational software, data analysis, production tools, and online resources; see Table 2. Specific educational software used for math included Larson Math, GeoGebra, Geometer's Sketchpad, and ExploreMath; see Table 3 for descriptions.

Table 2

Ways Laptops are used in Math

	Source	Grade Level	Educational Software	Online Math Resources	Internet Research	Games	Assessment Tools	Data Analysis	Calculator	Production Tools	Electronic Textbook
Fullerton School District	Warschauer et al. (2005)	K – 8	✓	✓	✓					✓	
Texas Immersion Pilot (TIP)	Shapley et al. (2007)	6 – 8	✓	✓		✓	✓	✓	✓	✓	
New Brunswick	Freiman et al. (2010)	7 – 8						✓		✓	
Henrico County Public Schools	Zucker & McGhee (2005)	6 – 12	✓	✓			✓	✓			
The Denver School of Science and Technology	Zucker & Hug (2007)	9 – 12	✓						✓	✓	✓
New South Wales Digital Education Revolution	Zuber & Anderson (2013)	9 – 12	✓	✓	✓			✓		✓	✓

Table 3

Educational software descriptions

Discovery Education Science	Features e-Book reading passages, virtual and inquiry-based exploration of science concepts, interactive glossaries, and scaffolding tools such as text-to-speech
GeoGebra	Dynamic math software covering geometry, algebra, statistics, and calculus with graphing and spreadsheet capabilities
Geometer's Sketchpad	Interactive geometry program that allows users to construct and manipulate geometric figures as well as make calculations and measurements
Inspiration	Software that provides visual learning tools such as graphic organizers, concept mapping, plots and graph, etc.
Larson Math	A supplemental software package that accompanies the textbook

7th grade students in New Brunswick, Canada were tasked with investigating environmental issues and 8th grade students researched health and safety issues (Freiman et al., 2010). A concept mapping software on the laptops was used to represent science knowledge and Excel spreadsheets were used to make mathematical graphs.

Microsoft Excel was the data analysis tool reported by many studies, and production tools included word processors, OneNote, Google Sketchup, *i*Movie, Camtasia, and a concept mapping software. In addition, specific online resources named in the studies include BrainPOP, ExploreLearning Gizmos, United Streaming, and Study Island; see Table 4 for descriptions. For example, second grade students in the Fullerton School District researched California math standards online, created games based around these standards, and made videos to explain how to play the game using iMovie (Warschauer et al., 2005).

Table 4

Online resources descriptions

BrainPOP	Creates animated content aligned to academic standards and includes quizzes, game play and activities
Cells Alive!	A website that contains a collection of film and computer-enhanced images of living cells and organisms
ExploreLearning Gizmos	Library of interactive simulations for 3rd – 12th grade math and science
United Streaming	Provides multimedia resources aligned to content standards
SAILOn	Subject Area Interactive Lessons Online: a library of interactive Internet resources that are linked to learning objectives
Study Island	Provides standards-based instruction, practice, assessment, and productivity tools

At the high school level, students in Henrico County used a software program on iBooks to simplify radicals (Zucker & McGhee, 2005). They were given hints when needed in order to successfully complete the problems and received immediate feedback. Another middle school math teacher believed that immediate feedback helped to maintain students' attention. In addition, a math teacher at The Denver School of Science and Technology used Camtasia to record and narrate explanations, graph manipulations (Zucker and Hug, 2007). He then made the video available to his students via a file server so that the students could watch and learn at their own pace.

Science. The two most common ways that the laptops were used in science were production tools and simulations; see Table 5. Production tools were used to create diagrams, charts, illustrations, presentations, and videos using tools such as *i*Movie, Microsoft Word, and PowerPoint. Students often used these production tools to present findings from research and experiments. For example, a biology teacher in Henrico

Table 5

Ways Laptops are used in Science

	Source	Grade Level	Educational Software	Online Science Resources	Internet Research	Games	Assessment Tools	Data Analysis	Calculator	Production Tools	Electronic Textbook	Simulations	Other
EETT Grant	Zheng et al. (2014)	5	✓							✓		✓	interactive videos
Fullerton School District	Warschauer et al. (2005)	K – 8	✓		✓			✓					
Texas Immersion Pilot (TIP)	Shapley et al. (2007)	6 – 8		✓		✓				✓	✓	✓	
EcoScienceWorks Project	Allan et al. (2010)	7 – 8										✓	
New Brunswick	Freiman et al. (2010)	7 – 8						✓		✓			
Astronomy Case Study	Yang (2002)	8						✓		✓			student-created webpages
Henrico County Public Schools	Zucker & McGhee (2005)	6 – 12		✓	✓		✓			✓		✓	student-created webpages
The Denver School of Science and Technology	Zucker & Hug (2007)	9 – 12	✓		✓				✓	✓	✓	✓	
Australian Government's Digital Education Revolution	Crook et al. (2015)	9 – 12	✓					✓		✓	✓	✓	wikis, blogs

County said that her students researched infectious diseases online and then used Word to create a pamphlet (Zucker & McGhee, 2005).

Virtual experiments and simulations were a large focus of many of the studies. For example, starting in 2005, a project called EcoScienceWorks began with a goal to provide middle school students with engaging and challenging inquiry software to help them learn science (Allan et al., 2010). Therefore, collaboration among software developers, learning technologist, teachers, and other appropriate stakeholders, who offered a role in the TPACK (technology, pedagogy and content knowledge) framework, came together to provide professional development while creating a curriculum based around computer simulations and hands-on activities in ecology. Twenty-three middle school ecology teachers committed three years to the project, and as a result, five targeted simulations about ecology and one about programming were developed and used to teach students.

In addition, simulations were frequently used in high school physics classes. For example, 100% of physics teachers who participated in a study conducted in Sydney, Australia reported using computerized simulations (Crook et al., 2015). The physics students reported that they used simulations 30.7% more frequently compared to biology and chemistry students. Simulations were also frequently used in physics classes at the Denver School of Science and Technology, a public charter high school (Zucker & Hug, 2007). Physics students used the laptops to collect and analyze data, and used Probeware and online resources from CU Boulder to conduct probe simulations and download data about motion, temperature, pH levels, and other phenomena. In addition, LoggerPro software was used to measure acceleration, select relevant data from scatterplots, and solve problems presented by the teacher. The use of computerized simulations allows students to manipulate conditions and analyze and interpret more data than they would be able to with physical simulations since no equipment is needed and no time is lost having to setup the experiments.

Educational software and online resources were also ways that science teachers used the laptops for teaching and learning. Specific applications named in the literature include: BrainPOP, Cells Alive!, Discovery Education Science (DES), ExploreLearning, Inspiration, SAILOn, and Study Island; see Tables 3 and 4. Discovery Education Science (DES) software was used in 5th grade science classrooms in an urban school district in California (Zheng, Warschauer, Hwang, & Collins, 2014). It features e-Book reading passages, virtual and inquiry-based exploration of science concepts, interactive glossaries, and scaffolding tools such as text-to-speech. This software is aligned to state standards, and teachers were able to use it and the laptops to present video explanations, animations and visualizations of science concepts that the students could not otherwise see in a textbook.

Summary. The studies discussed in this section reported specific ways that laptops were used in math and science classrooms. Educational software and production tools were the most commonly reported way of using laptops in math. Other common math uses include data analysis tools and online math resources. Some math teachers felt that there were too few resources available to help them integrate the laptops into instruction, and the laptops were used primarily for enrichment or extensions (Shapley et al., 2007). Many of these teachers believed that pencil-paper activities were the best teaching strategy for math, and some students believed that laptops were unsuitable for math because problems needed to be worked out on paper. These beliefs will be further investigated in the next section.

The most common ways that laptops were used in science classes were production tools and simulations. Other commonly reported uses for science were educational software and data analysis tools like Microsoft Excel. Although science teachers used the laptops in a variety of ways, some experienced frustration. 5th grade teachers in California who were provided laptops through the Enhancing Education Through Technology (EETT) Grant suggested that there be more professional development and training for how to use the laptops for classroom learning as well as expressed a need for more collaboration and sharing among the science teachers (Zheng et al., 2014). The next section will discuss how using the laptops can support student-centered learning in math and science classrooms.

Shift toward student-centered learning.

This section will discuss the ways in which one-to-one laptop initiatives impacted student-centered pedagogy in math and science classes, as reported by eight research studies; see Table 6. The two most common student-centered attributes that one-to-one laptops afford are the teacher serving as a facilitator and individualized instruction. Fairman (2004) reported that teachers said that they were able to move away from being the "keeper of the knowledge" to being a "learner" within a "community of learners" (Fairman, 2004, p.14). As a result of the teacher becoming a facilitator, teachers acknowledged that more students were becoming owners of their learning.

For example, a case study was conducted with two math and science teachers who taught at a middle school in Maine (Gartwait & Weller, 2005). Both teachers in this study frequently circulated the room to assist students as they learned using the computers, thus becoming more of a facilitator. They also felt that the laptops increased students' motivation, creativity, and ability to work independently. One of the teachers, Rick, has a masters in Instructional Technology and therefore has a high level of technology integration expertise. He often experimented with new instructional patterns, was willing to try new things, and learned from failures. During a statistics unit, he adapted the curriculum to allow students to create spreadsheets on the laptops. The laptops increased his opportunity to act spontaneously, provide just-in-time help, and his students were able to use the laptops to learn independently. He said that the laptops "totally changed my classroom" (Gartwait & Weller, 2005, p. 368).

Table 6

Student-Centered Attributes

	Source	Grade Level	Subject: Math or Science	Teacher is Facilitator	Differentiated Instruction	Individualized Learning	Collaborative Learning	Cooperative Learning	Constructivist Learning	Problem-Based Learning	Project-Based Learning	Higher-Order Thinking Skills	Inquiry Skills
Fullerton School District	Warschauer et al., (2005)	K – 8	Both		✓	✓						✓	
Crossriver School District	Lowther et al. (2003)	5 – 7	Both	✓				✓		✓			✓
Compass Learning	Clariana (2009)	6	Math	✓		✓	✓						
Hillside Middle School	Gartwait & Weller (2005)	6 – 8	Both	✓		✓							
Maine Learning Technology Initiative (MLTI)	Fairman (2004)	7 – 8	Both	✓	✓	✓	✓						✓
Astronomy Case Study	Yang (2002)	8	Science	✓			✓		✓	✓	✓		
Australian Government's Digital Education Revolution	Crook et al. (2015)	9 – 12	Science					✓	✓			✓	
International Society for Technology in Education (ISTE)	Inserra & Short (2012)	9 – 12	Both		✓	✓			✓		✓		

Not only did laptops afford opportunities for individualized instruction, but also for differentiated instruction and learning activities requiring higher-order thinking skills. For example, differentiated instruction was observed when a science teacher in the Fullerton School District used online videos of protein synthesis and mitosis in lieu of the textbook in order to better support English language learners (Warschauer et al., 2005). Science teachers also used multimedia to enhance engagement and allow students to get more involved with complex learning tasks like analyzing the spread of disease. In addition, the previous section discussed how second graders in the Fullerton School District researched California math standards online, created games based around these standards, and made videos explaining how to play the game using iMovie (Warschauer et al., 2005). Researchers stated that these types of learning activities help develop skills like self-direction, interpersonal, thinking, problem solving, information, and communication.

In the previous section, findings stated that simulations were frequently used in science classes, especially physics. The study evaluating the Australian Government's Digital Educational Revolution (Crook, 2015) suggested that these activities promote higher-order thinking skills because they give students the opportunity to perform experiments, experience phenomena, and represent and analyze data. Students were also able to collaborate and co-construct knowledge through the use of wikis. In addition, teachers who participated in the EcoScienceWorks project found that the use of computer simulations changed the learning environment and the way students learn (Allan et al., 2010). For example, one teacher stated that the simulations integrate well into the curriculum and is convinced that this type of learning activity increased retention for the students.

Another attribute of student-centered learning is problem-based learning. Sixth grade students in the Crossriver School District were given a problem where soda cans were accumulating in city parks, and they were tasked with helping the park commission motivate visitors to recycle (Lowther et al., 2003). Students' problem-solving skills were assessed using a rubric consisting of the following criteria: (a) "understands problem," (b) "identifies what is known about problem," (c) "identifies what needs to be known to solve the problem," (d) "determines how the data need to be manipulated to solve the problem," (e) "describes use of technology," (f) "describes how to present findings," and (g) "collaborative learning" (Lowther et al., 2003, p.30). The analysis of the assessment scores revealed that the laptop students showed significant advantages over the control students in five of the seven categories. Researchers stated that laptop teachers may have emphasized problem-solving skills more than the control teachers and that the laptop students may have had better software application skills that served as a tool for open-ended learning tasks, thus resulting in greater performance by the laptop students.

170 high school teachers who are registered members of the International Society for Technology in Education (ISTE) were surveyed concerning the implementation of collaborative learning, constructivist learning, project-based learning, and differentiated instruction while using laptops (Inserra & Short, 2012). Overall, math teachers reported the lowest frequency of implementing laptops for these purposes and science reported the second lowest frequency. Therefore, teachers of other disciplines, especially English and

social studies, reportedly have a greater capacity for the implementation of individualized instruction, constructivist learning, project-based learning, and differentiated instruction, compared to math teachers.

Summary.

The eight studies discussed in this section revealed numerous impacts that one-to-one laptop initiatives have on student-centered pedagogy in math and science classrooms. First, one-to-one laptop classrooms can provide opportunities for teachers to become facilitators, guiding students to learn together, promoting collaboration and cooperative learning. In addition, teachers are able to provide individualized learning activities to students and differentiate instruction to allow students to work at their own skill level and appropriate pace. These pedagogical practices foster a constructivist learning environment, providing opportunities for problem-based and project-based learning activities, as well as promote inquiry and higher-order thinking skills. The laptops have afforded a paradigm shift toward a student-centered learning environment. However, one-to-one computing does not automatically shift instructional styles and the dynamics of the classroom, but rather provide opportunities for teachers to create a student-centered learning environment (Clariana, 2009; Gartwait & Weller, 2005). The pedagogical shift toward student-centered learning takes time and will not occur unless there is a common understanding between administrators and teachers about the goals, purposes, and barriers of one-to-one computing (Gartwait & Weller, 2005). The next section will discuss the impact that one-to-one laptops have on student achievement in math and science.

Impact on Student Achievement

Math achievement

Five research reports used quantitative data to analyze the impact of one-to-one laptop use on student math achievement (Bebell & Kay, 2010; Clariana, 2009; Dunleavy & Heinecke, 2007; Gulek & Demirtas, 2005; Warschauer et al., 2005). All of the studies were conducted at the middle school level and one also included elementary participants (Warschauer et al., 2005). This section addresses the second research question and discusses the impacts that these research studies found on student math achievement.

First, Gulek and Demirtas (2005) analyzed students' GPAs, end-of-course grades, and standardized test scores to investigate the impact of the laptop program on student math achievement at Harvest Park Middle School in Pleasanton, California, a highly educated, high-income community. First, the results found that laptop students achieved higher overall GPAs than non-laptop students for each grade level (6 – 8). In addition, a higher percentage of laptop students in each grade received *A*s and *B*s as end-of-course letter grades in math compared to non-laptop students.

The third measurement of student achievement was the 2004 6th – 8th grade math scores from two California achievement tests that are part of the State's Standardized Testing and Reporting Program (STAR):

1. Norm-Referenced Test (NRT): the results reported the percentage of students scoring at or above the national average.
2. California Standards Test (CST): the results reported the percentage of students scoring proficient or advanced.

A higher percentage of laptop students at each grade level scored at or above the national average in math on the CAT/6, the NRT version at that time, compared to non-laptop students. Similarly, a higher percentage of laptops students at each grade level scored proficient or advanced on the STAR CST math test compared to non-laptop students. However, this analysis did not consider the effects of prior achievement, therefore researchers addressed this issue by conducting cohort analysis and using 5th grade test scores as baseline data, prior to laptop enrollment.

Cohort 1 students were 8th graders in 2003-2004 and the laptop students participated in the program for three years. There was no baseline data available for the CST math test, however baseline data from the NRT math test showed that there was no statistically significant difference in achievement between laptop and non-laptop students. After the first year of laptop implementation, laptop students showed significantly higher achievement on both the NRT and CST math tests as 6th graders. However, there was no significant difference in achievement between laptop and non-laptop students in year 2 or year 3.

Cohort 2 students were 7th graders in 2003-2004 and the laptop students participated in the program for two years. Baseline data was available for both the NRT and CST tests and the difference in performance between laptop and non-laptop students was not statistically significant on either test. After the first year in the laptop program, laptop students demonstrated significantly higher achievement on the CST math test compared to non-laptop students, but there was no significant difference on the NRT math test. Year 2 test data showed that there was no significant difference in performance on either test.

Cohort 3 students were 6th graders in 2003-2004 and the laptop students participated in the program for one year. Baseline data showed no significant difference in achievement between laptop and non-laptop students on either the NRT or CST math tests. However, laptop students demonstrated significantly higher achievement than non-laptop students after the first year of the laptop program on both tests.

A longitudinal analysis of the effect of laptops use on individual scores was conducted with cohort 1 and 2 participants. It indicated that students who participated in the laptop program tended to perform at a higher level in math compared to the non-laptop students. It also suggested that the effectiveness of laptop use on test scores was not influenced by the number of years that the students used the laptops. Further, as was stated above, the laptop students received higher GPAs on average compared to non-laptop students, and longitudinal analysis found that laptop use resulted in a 0.40 increase in a student's math cumulative GPA.

One limitation of the study was that both students and teachers volunteered for the program, eliminating random assignment from research methodology. Another limitation was that data was not collected which described how participants used the laptops. Therefore, researchers were unable to estimate the effects of specific laptop uses on student achievement. In summary, implications from this study suggest that all students should have equal access to technology rich environments in order to increase student achievement.

The second research report was a two-year longitudinal study at an urban mid-Atlantic state and sought to determine whether the one-to-one laptop initiative increased student achievement in math and science (Dunleavy & Heinecke, 2007). Researchers used pre-existing 5^{th} grade State Standardized Test scores as pretest data and the 8^{th} grade State Standardized Test scores as posttest data for both the experimental and control groups of students. It was found that there were no significant main or interaction effects of the laptop implementation on 8^{th} grade math test scores, but there was a significant main effect on 8^{th} grade science scores, which is discussed in the next section. The report did not provide statistical evidence for math test scores, but did pose ideas for further research, such as the level of implementation of laptops in the math classrooms compared to the science classrooms and the differences in impact of laptops among different content areas. The researchers also questioned whether there are more computer applications and web resources available for science instruction or whether science lends itself to more laptop-based instruction.

Third, Warschauer and Grimes (2005) examined test scores at three laptop schools and other non-laptop schools in the district in order to identify relationships between laptop use and test scores. California State Test (CST) data was analyzed on a matched cohort basis, meaning that the 2004 math CST scores were compared to the 2005 CST math scores on a school-by-school basis for all students who were in the district both years. This allowed researchers to compare the rise or fall of laptop student scores to non-laptop student scores.

The district-wide average on the 3rd – 6th grade CST math tests for matched cohort students (both laptop and non-laptop) was 351.9 in 2004 and 365.8 in 2005, which accounted for an average increase of 13.8. Students at Fisler, a laptop school that has a strong focus on science and technology, ranked among the best in the district for mathematics both years and showed an average growth of 13.0, slightly less than the district average growth. At Hermosa, 62 students participated in the laptop program and 53 of those students were also in the Gifted & Talented Education Program (GATE). Therefore, two analyses were conducted: one for all Hermosa students in the laptop program and a second for only GATE students. Students in the laptop program averaged the highest scores in the district on the math CST both years, but experienced an average decrease of 10.7. The Hermosa GATE students' scores decreased by 11.0 on average, while the district-wide GATE students' scores showed an average increase of 11.1. Overall, the students in the laptop program at Fisler and Hermosa showed less growth on the math CST than students in the entire district. However, because of the small sample size at Hermosa (n=62), the matched cohort analysis was not found to be significant and cannot be linked to the laptop program.

Students at Nicolas and Fisler took the math CST in grade 7. District-wide, the average math test score for matched cohort students was 349.4 in 2003-2004 and 345.0 in 2004-2005, which accounts for an average decrease of 4.5. Students at Nicolas, the school with the largest percentage of English language learners and special education students among the three schools, averaged the lowest 7th grade math scores in the district. However, they did not experience the same decrease as the district reported, but rather maintained the same average score from one year to the next. Similar to the grade 3–6 students, 7th grade students at Fisler performed second highest in the district on the math CST both years. They also achieved an average increase of 4.0 from one year to the next, and it was the only school in the district to report positive growth. Overall, 7th grade students in the laptop program at Nicolas and Fisler experienced a higher growth rate on the 7th grade CST than those students who did not participate in the laptop program.

This study found that some laptops students made greater improvement in math performance relative to the district average, while others did not. Although some patterns appeared in the analyses of grades 3 – 7 math test scores over a two-year period, researchers stated that no clear pattern emerges to draw conclusions about how the laptops impacted student math achievement. A multi-year test score evaluation is needed to more precisely understand the relationship between laptop use and student performance.

In the fourth study, Clariana (2009) compared the 6th grade math achievement scores of one laptop school to seven control schools who were all utilizing CompassLearning. The data used for the comparison consisted of 5th grade Pennsylvania System of School Assessment (PSSA) math test scores (benchmark), four quarterly benchmark tests, and 6th grade PSSA math test scores.

The results showed that the laptops students' 5th grade PSSA math benchmark scores were significantly lower than two of the control schools, but not significantly different than the other five control schools. The quarterly benchmark test data showed that the students at the laptop school significantly outperformed five schools on the 1st quarter test, three schools on the 2^{nd} quarter test, six schools on the 3^{rd} quarter test, and three schools on the 4^{th} quarter test. The laptop students' performance on the 6^{th} grade PSSA test was not significantly different than any of the control students' performance except for the top school, which outperformed all schools.

Overall, the laptop students outperformed the non-laptop students on the quarterly benchmark tests with effects sizes ranging from 0.47 to 0.90, but they did not outscore their peers on the 6^{th} grade PSSA test. The author stated that one discrepancy could be the abnormal test administration circumstance, as the PSSA was given in a large group setting in the laptop school's gymnasium, a setting that the students were not accustomed to. Another discrepancy could be that the benchmark tests were given on computers at all schools, and since the laptops students had more experience using computers, this may have given them an advantage. The researcher did not state that laptops directly impacted student achievement, but rather concluded that the laptops made it easier for teachers to create learning environments that positively affect student engagement and learning.

In the final study, the Berkshire Wireless Learning Initiative had a goal to enhance student achievement, and 75% of teachers surveyed felt that the laptop program positively affected student academic performance. Bebell and Kay (2010) analyzed 8^{th} grade math MCAS scores from 1998 to 2008, and the BWLI was launched in 2006. The data revealed a general trend that the number of 8^{th} graders passing the math MCAS is rising and that the laptops students decreased the achievement gap between comparison schools and average state scores. The improvement of math passing rates among BWLI students also corresponds with the number of years that the students participated in the program. 8th graders who took the test in 2006 had used the laptops for one year, and 8th graders who took the test in 2007 and 2008 had used the laptops for two and three years respectively. Although there is a clear trend, researchers stated that there was not enough evidence to completely attribute the one-to-one laptop program to increased math achievement due to the fact that this was not a randomized experimental study and prior knowledge was not measured. Therefore, a further examination of a "cohort effect" was used to inform the impact that the laptops had on math achievement by examining prior performance and performance growth over the three-year period.

Researchers stated that 11% more laptop students received a passing score on the 8th grade MCAS math test in 2008 compared to their 6th grade score in 2006, however, laptops students' raw math scores dropped an average of 1.7 points, while comparison schools dropped 1.4 points. Math scores diminished even more when the special education population was removed from the data. Since no clear conclusions could be drawn from these results, researchers created student level regression models to analyze the overall program effect on student achievement.

As expected, students' prior 2006 math MCAS score proved to be a major statistically significant predictor of 2008 math MCAS scores. Therefore, researchers also looked at the relationship between student computer use and math achievement, calculated correlations and wrote a regression equation that incorporated these technology use variables. This model accounted for 43% of the variance in the 2008 math MCAS laptop student scores. Although, "student use of computers in math" fell just short of qualifying for statistically significant status, all laptop use variables failed to result in a statistically significant relationship to math scores. The 2006 prior math test score remained as the only statistically significant predictor of math performance.

Researchers revealed some positive trends related to laptop students' math performance and participation in the BWLI program, yet the results were not conclusive in relation to the impact of the one-to-one laptop program on student achievement.

Summary. Of the five research reports that provided quantitative analysis of the impact of one-to-one laptop use on math achievement, only one study concluded that participation in the laptop program resulted in higher math achievement (Gulek & Demirtas, 2005). This school, Harvest Park Middle School, was the only one where students and teachers volunteered to participate in the program and students had to provide their own laptops, which creates self-selection bias. Further research could determine whether other factors like motivation, technology access, or socioeconomic status could have been a factor in the results of the study. Clariana (2009) suggests that the laptops help create a learning environment that increases student engagement which positively affects learning, but the laptops themselves cannot be directly attributed to higher achievement. Prior knowledge was a factor in each study and it proved to be a significant predictor of student test scores. The longest longitudinal study discussed in this section occurred over a three year period, and Warschauer et al. (2005) suggest more multi-year studies be conducted to better examine the impact of one-to-one laptop use on math achievement.

Science achievement

Three research studies in the literature review provided quantitative data concerning the impact of one-to-one laptop initiatives on science achievement (Crook et al., 2015; Dunleavy & Heinecke, 2007; Zheng, 2014). All three studies used test data to compare the scores of students who participated in laptop programs to the scores of students who were not part of a laptop classroom. Two studies were conducted in a middle school setting and one in a high school setting. The results of the studies are discussed in this section.

The first study was conducted at a middle school in a mid-Atlantic state and compared the math and science achievement scores of a group of randomly selected middle school students in one-to-one laptop classrooms to a group of control students in non-laptop classrooms (Dunleavy & Heinecke, 2007). As stated in the previous section, the study found that there was no significant main effect on math test scores when comparing a 5^{th} grade pretest scores to 8^{th} grade posttest scores. However, there was a significant main effect on science posttest scores.

The laptop students made great gains on the science test compared to the non-laptop students, however the effect size was 0.24, which is relatively small. Further, a significant interaction effect of treatment and gender on science posttests was revealed in the analysis. The larger adjusted mean for boys suggests that laptops have a greater effect on male science achievement compared to females. This led researchers to question whether boys are more engaged with science, technology, or a combination of both compared to girls. Do boys spend more time on task or more time with the laptops? Are boys more socialized to use technology or is the one-to-one laptop program gender bias? The study did not make any definitive conclusions based on their finding, but do suggest that these questions be further explored

In the second study by Crook et al. (2015), the impact of one-to-one laptops on senior high school student attainment on statewide biology, chemistry, and physics exams were analyzed. The results indicated that laptops increased student attainment in biology by one-third of a standard deviation and increased attainment in chemistry by one-half of a standard deviation. With an effect size of 0.26 for biology and 0.23 for chemistry, the impact of one-to-one laptops on student attainment in biology and chemistry are considered small. However, the impact of laptops increased student attainment in physics by over 40% of a standard deviation. With an effect size of 0.38, the laptops are considered to have a medium impact on student attainment in physics.

The researchers concluded that simply giving students laptops does not automatically mean that they will perform better. However, as discussed in the previous section, the laptops do provide a catalyst to a paradigm shift that provides students with a more student-centered learning environment. The most substantial effect size, occurring in physics, can be attributed to the new student-centered pedagogies that afford personalized learning, specifically in the ways that simulations and spreadsheets were used on the laptops.

Last, Zheng (2014) conducted a yearlong study at eight schools in an urban California school district. The report compared the achievement scores of 5^{th} graders at four laptop schools to 5^{th} graders at four non-laptop schools in order to evaluate the impact the laptops had on academic achievement in science. In addition, achievement levels were evaluated based on three specific groupings of students: English language learners (ELL), ethnicity status, and socioeconomic status. All of the schools in this study had a high percentage of Hispanic students, ELL students, and students on free or reduce lunch (low socioeconomic).

A residualized change model was used to investigate the impact of California Standards Test (CST) science scores when controlling standardized math test scores from the year before; California does not have a 4^{th} grade CST science test. First, data shows that ELL students who participated in the laptop program scored significantly higher on the science CST compared to ELL students who did not have laptops (coef. = 86.48, $p < 0.05$, effect size = 0.59). In addition, Hispanic laptop students achieved higher scores than their peers in the control group (coef. = 77.40, $p < 0.05$, effect size = 0.53). And lastly, free-lunch recipients in the laptop program achieved significantly higher science scores compared to those in non-laptop classrooms (coef. = 74.24, $p < 0.05$, effect size = 0.53).

The positive gains in science achievement scores were limited to ELL, Hispanic, and low-income students who participated in the laptop program. Results suggest that one-to-one laptop initiatives can help close the gap in science achievement for at risk students.

Summary. Of the three studies discussed in this section, all reported gains in science achievement as an impact of the one-to-one laptop programs. The study at the mid-Atlantic middle school (Dunleavy & Heinecke, 2007) found that middle school laptop students made greater gains on the science post-test compared to non-laptop students, yet the effect size was small. 5th grade ELL, Hispanic, and low-income students who were part of a laptop program at an urban California school achieved significantly higher science scores that their peers who did not use laptops (Zheng, 2014). High school science students who participated in the laptop initiative in Australia achieved higher than non-laptop students in biology and chemistry with a small effect size and achieved higher in physics with a moderate effect size (Crook et al., 2015). Even though achievement gains for laptop students were found in these studies, researchers concluded that laptops do not automatically produce significant gains in science achievement for all students. More research is needed to determine the best ways that laptops can be implemented into science curriculum and teaching in order to enhance learning for students.

Chapter 3: Conclusion

This report reviewed eighteen reports and evaluations of one-to-one laptop initiatives implemented in K-12 math and science classrooms and examined their impact on student-centered pedagogy and student achievement. The first three sections addressed the first research question: what impact do one-to-one initiatives have on math and science teacher pedagogy? Three themes were found in the literature concerning teacher pedagogy: frequency of laptop use, ways that the laptops were used, and a shift toward a student-centered learning environment.

Findings revealed that math classrooms implemented the use of laptops the least when compared to the other core subject areas, English, social studies, and science. Teacher beliefs and philosophies about teaching and technology strongly influenced their implementation of the laptops (Garthwait & Weller, 2005; Zuber & Anderson, 2013). Some math teachers and students believe that math required pencil and paper and other teachers felt that the purpose of the laptop was to provide a more efficient way of completing and performing traditional work (Garthwait & Weller, 2005; Shapley et al., 2007; Zuber & Anderson, 2013). One teacher struggled to find appropriate activities on the laptops for math, and mostly used games to reinforce what the students were learning in class apart from the laptops. She believed that the laptops had educational potential, but did not feel that the laptops had a major influence on her teaching during the first year of implementation (Gartwait & Weller, 2005). Zuber and Anderson (2013) also found that math teachers who used the laptops more frequently were more confident in their technology skills and often pursued training on their own.

Some math teachers felt that there were too few resources available to help them integrate the laptops into instruction, and the laptops were used primarily for enrichment or extensions (Shapley et al., 2007). However, when the laptops were used for math, educational software, production tools, online resources, and data analysis tools were the most common applications used. In science, the most common ways that the laptops were used included production tools, simulations, data analysis tools, and educational software. Learning activities that utilize these tools promote higher motivation and ownership of learning.

As the teachers implemented laptops into the curriculum, researchers observed that the teachers became facilitators, guiding students to learn together, providing just-in-time help, and promoting more collaboration and cooperative learning. In addition, teachers are able to provide more individualized learning activities to students and differentiate instruction to allow students to work at their own skill level and appropriate pace. These pedagogical changes foster a constructivist learning environment, providing more opportunities for problem-based and project-based learning activities, as well as promote inquiry and higher-order thinking skills.

Finally, the last two sections addressed the second research question: what impact do one-to-one initiatives have on student achievement in math and science? Many researchers compared the achievement level of laptops students versus non-laptop students. Laptops students often outscored their non-laptop peers on math and science achievement tests, but the effect size was often small. In fact, only one in five reports concluded that laptops have a positive effect on math achievement. This leads to the conclusion that using laptops affords more student centered learning opportunities, which can lead to more learning and higher achievement, but the laptops themselves do not directly cause an increase in achievement.

Chapter 4: Implications

The review of the literature uncovered numerous themes and trends presented in the research articles. Three implications taken from the literature are:

1. Implementing one-to-one computing does not guarantee that all teachers across all subject areas will use them equally.
2. Laptops do not automatically create a shift toward student-centered instruction.
3. Laptops themselves do not cause an effect on student achievement.

First, the quality of laptop integration is not simply determined by the frequency in which the laptops are being used, but rather the way in which they are being used. The learning activities for math and science are different than other subjects. They involve more calculations and procedural steps and finding good resources can be challenging. Professional development can help prepare math and science teachers by first exposing them to a library of resources that are appropriate to the subject area and grade level they are teaching and then training them how to use the applications. In addition, teachers should have a voice in choosing which technology is provided and works best to support the curriculum since they are the subject-matter experts. Teachers can also play a part in designing laptop-based activities that support the curriculum. For example, in the EcoScienceWorks project (Allan et al., 2010), twenty-three teachers participated on a team that designed and developed computer-based ecology simulations and activities. Taking ownership of these activities gives teachers a better understanding of how to incorporate the laptop activities into the curriculum.

Second, teachers will not automatically change their pedagogy and teaching style due to the fact that students have laptops. Change takes time. Teachers need time to learn the technology and discover new ways of teaching the curriculum ands schools are expected to provide support. The purpose of using laptops for learning is not just to replace pencil and paper or a chalkboard with more high-tech devices, but rather provide opportunities for students to engage in meaningful learning activities that could not be possible with non-technological teaching tools. It is not expected that every learning activity be transformed into a laptop-based activity, but teachers should be aware of what technological resources are available, trained in how to use them, and knowledgeable of how to incorporate them into instruction.

Third, the laptop itself does not cause a change in a student's achievement. When laptops are issued to students, it becomes a tool for learning. It may afford a constructivist, collaborative approach to learning where teachers become facilitators and can use the laptops to offer more individualized and differentiated instruction. The amount of time and the specific ways that laptops are used are related the impact that laptops have on achievement. If the laptops are rarely used, they cannot be directly linked to any change in achievement. Analyzing student test scores without a full understanding of how the students use the laptops leaves gaps in understanding just how the laptops effect achievement. Zheng, et al. (2014) gave a good example of how specific laptop use can positively effect achievement. Fifth grade science students used the laptops to conduct virtual and inquiry-based explorations and had tools available like interactive glossaries and text-to-speech. This study reported positive gains in science achievement scores for ELL, Hispanic, and low-income students who participated in the laptop program, suggesting that laptops could help close the gap in science achievement for at risk students. Pinpointing the specific ways that laptops are used that positively effect achievement in math and science should be the goal of researchers, educational technologist, and teachers as they continue to uncover the best practices for using laptops in math and science classrooms.

The literature used for this review was balanced in terms of representing math and science contexts and design methods. The majority of the articles addressed the impact of laptops on both math and science learning environments, seven used mixed methods analysis, while five used strictly quantitative methods and four used strictly qualitative methods. However, there were some limitations.

One limitation is the lack of research studies conducted at the elementary school and high school levels. Eleven out of the seventeen articles conducted research at the middle school level, but more research is needed at the upper and lower grade levels.

Another limitation of this review is the time period in which the research occurred; three reports were published prior to 2005, ten between 2005 and 2010, and four after 2010. Over the past five years, the way users interact with computers has changed with the advancement of web 2.0 and the beginning of web 3.0. Are there new web-applications that will afford more student-centered learning opportunities? More research over the next five years related to using laptops in conjunction with the semantic web could inform educators of more engaging and interactive ways of incorporating laptops in the math and science curriculum.

Another limitation was the imbalance of research articles reporting the impact on the learning environment versus student achievement. Only eight reports presented data analyzing the impact of laptops on math or science achievement, while fifteen reports discussed the relationship between laptops and teacher pedagogy. Also, the majority of achievement data analyzed in the reports consisted of state standardized test scores, which may not have matched the learning approaches the students were experiencing with laptops. This raises the question, how reliable are standardized tests at measuring achievement levels? Some reports use district benchmark exams and GPA, but are there other ways to measure student achievement besides a score? Further research could be conducted to evaluate the impact of laptops on student achievement in math and science using alternative assessment measures.

Finally, the literature presents opportunities for educational technologist to continue to develop computer-based applications for K-12 math and science. One theme found in the literature is that math teachers struggle the most with how the laptops can be incorporated into instruction as well as accessing appropriate resources that go beyond simply replacing what students do on paper with a laptop application. This struggle calls for educational technologists to push the limits of present-day educational math resources in order to promote meaningful and purposeful use in classrooms. In science, many of the teachers and students reported using simulations and spreadsheets. The laptops provided a way for students to run multiple experiments and quickly analyze data, which promotes higher-order thinking skills and scientific inquiry skills. This presents an opportunity for developers in the field to create more computer-based simulations and virtual experiments that will provide problem-based learning opportunities for students.

Appendix

Reference	Source	Purpose	Focus	Design	Grade Level	Participants	Data Sources	Laptops
Allan, Erickson, Brookhouse, and Johnson (2010)	Tech Trends	Evaluate the implementation of a middle school ecology curriculum that incorporates computer simulations	Science	n/a	7 - 8	23 Laptop Teachers	Classroom observations, surveys	Not specified
Bebell and Kay (2010)	The Journal of Technology, Learning and Assessment	Evaluate the impact of laptops on achievement, engagement, pedagogy, and student research and collaboration	Both	Quantitative	6 - 8	5 Laptop Schools; 2 Comparison Schools	Surveys, documents, classroom observations, assessment results, interviews	Apple iBooks
Clariana (2009)	Journal of Computers in Mathematics and Science Teaching,	Investigate the impact of a one-to-one laptop program on teaching, learning, and achievement in order to inform future instructional and policy decisions	Math	Mixed Methods	6	1 Laptop School; 7 Control Schools	Classroom observations, software data, test scores	Not specified
Crook, Sharma, and Wilson (2015)	International Journal of Science Education	Evaluate the impact of laptops on science attainment and the way laptops are used that indicate an attainment advantage	Science	Quantitative	9 - 12	7 Laptop Schools; 5 Control Schools	Questionnaires and attainment scores	Not specified

Dunleavy and Heinecke (2007)	Computers in the Schools	Determine whether one-to-one laptop initiatives increase math and science achievement	Both	Quantitative	6 - 8	1 school with laptop program; Approximately 1/3 of students and teachers enrolled in program	Test scores	Apple iBooks
Fairman (2004)	New England Educational Research Organization	Evaluate the impact of laptops on pedagogy and the learning environment	Both	Qualitative	7 - 8	23 Laptop Schools	Interviews, classroom observations, and surveys	Not specified
Freiman, Beauchamp, Blain, Lirette-Pitre, and Fournier (2010)	Procedia-Social and Behavioral Sciences	Evaluate the impact of laptops on learning	Both	Mixed Methods	7 - 8	6 Laptop Schools	Questionnaires, interviews, classroom observations, and documents	Not specified
Garthwait and Weller (2005)	Journal of Research on Technology in Education	Examine how one-to-one computing affects teaching and learning	Both	Qualitative	7	2 Laptop Classrooms	Interviews, classroom observations, and documents	Apple i Books

Gulek and Demirtas (2005)	The Journal of Technology, Learning and Assessment	Examine the impact of a laptop program on student achievement	Math	Quantitative	6 - 8	1 school laptop program; Approximately 25% enrollment by year 3	GPA, end of course grades, standardized tests	Parent/Student purchase
Inserra and Short (2012)	Journal of Educational Technology Systems	Compare pedagogical approaches of implementing laptops into teaching across subject areas	Both	Quantitative	9 - 12	170 high school teachers	Survey	n/a
Lowther, Ross, and Morrison (2003)	Educational Technology Research and Development	Evaluate the impact of laptops on teaching, student behavior, and achievement	Both	Mixed Methods	5 - 7	12 Laptop Classrooms 9 Control Classrooms	Classroom observations, surveys, student assessments, student focus group, teacher interviews	Not specified
Shapley, Sheehan, Maloney, Caranikas-Walker, and Huntsberger (2007)	Texas Center for Educational Research.	Investigate how technology immersion impacts teaching, learning, and student achievement	Both	Mixed Methods	6 - 8	21 Immersion Schools 21 Control Schools	Interviews, focus groups, surveys, test scores	Apple iBooks; Dell Inspirons and Latitudes

Warschauer, Grimes, Rousseau, Suhr, and Nyberg (2005)	Fullerton School District	An evaluation of the first-year implementation of the laptop program, including laptop use and achievement	Both	Qualitative	K - 8	3 Laptop Schools 19 Control Schools	Surveys, classroom observations, interviews, documents and records (including test scores)	Apple iBooks
Yang (2002).	Association for the Advancement of Computing in Education	Identify learning activities and teaching strategies that incorporate laptops	Science	Qualitative	8	1 Laptop Classroom	Classroom observations and interviews	Not specified
Zheng, Warschauer, Hwang, and Collins (2014)	Journal of Science Education and Technology	Investigate the impact the laptop program has on science achievement, teaching, learning, and future interest	Science	Mixed Methods	5	4 Laptop Schools 4 Control Schools	Test scores, interviews, and classroom observations	netbooks
Zuber and Anderson (2013)	Mathematics Education Research Journal	Examine how math teachers are using laptops, how the laptops influencing math teaching, and the relationship between laptop use and teacher characteristics	Math	Mixed Methods	9 - 12	5 Laptop Schools	Questionnaire, interviews	Lenovo Netbooks

Zucker and Hug (2007)	Denver School of Science & Technology	Analysis of 1:1 implementation, the ways computers and other technology are incorporated at the school, and use of laptops and technology by students and teachers	Both	Mixed Methods	9 - 12	1 Laptop School	Surveys, interviews, focus groups, classroom observations, documents	HP Laptops and Tablets
Zucker and McGhee (2005)	Henrico County Public Schools	Evalutate the district's one-to-one computing initiative, esepecially the laptop uses in math and science	Both	Qualitative	6 - 12	4 Laptop Schoos	Classroom observations, interviews, focus groups, documents, surveys	Apple iBooks

References

Allan, W. C., Erickson, J. L., Brookhouse, P., & Johnson, J. L. (2010). Teacher professional development through a collaborative curriculum project–an example of TPACK in Maine. *TechTrends*, *54*(6), 36-43.

Atkins, D. E., Bennett, J., Brown, J. S., Chopra, A., Dede, C., Fishman, B., & Williams, B. (2010). *Transforming American education: Learning powered by technology*. Office of Educational Technology U.S. Department of Education.

Bebell, D., & Kay, R. (2010). One to one computing: A summary of the quantitative results from the Berkshire wireless learning initiative. *The Journal of Technology, Learning and Assessment*, *9*(2), 1-60.

Clariana, R. (2009). Ubiquitous wireless laptops in upper elementary mathematics. *Journal of Computers in Mathematics and Science Teaching*, *28*(1), 5-21.

Crook, S. J., Sharma, M. D., & Wilson, R. (2015). An evaluation of the impact of 1: 1 laptops on student attainment in senior high school sciences. *International Journal of Science Education*, *37*(2), 272-293.

Dick, W., & Carey, L. (2009). *The systematic design of instruction* (7th ed.). Upper Saddle River, N.J.: Merrill/Pearson.

Dunleavy, M., & Heinecke, W. F. (2007). The impact of 1: 1 laptop use on middle school math and science standardized test scores. *Computers in the Schools*, *24*(3-4), 7-22.

Fairman, J. (2004, May). *Trading roles: Teachers and students learn with technology*. Paper presented at Annual Conference of the New England Educational Research Organization, Portsmouth, NH.

Freiman, V., Beauchamp, J., Blain, S., Lirette-Pitre, N., & Fournier, H. (2010). Does one-to-one access to laptops improve learning: Lessons from New Brunswick's individual laptop school initiative. *Procedia-Social and Behavioral Sciences*, *2*(2), 5686-5692.

Garthwait, A., & Weller, H. G. (2005). A year in the life: Two seventh grade teachers implement one-to-one computing. *Journal of Research on Technology in Education*, *37*(4), 361-377.

Gokhale, A. A. (1995). *Collaborative learning enhances critical thinking*. Retrieved from http://scholar.lib.vt.edu/ejournals/JTE/v7n1/gokhale.jte-v7n1.html?ref=Sawos.Org

Gray, L., Thomas, N., & Lewis, L. (2010). *Educational technology in U.S. public schools: Fall 2008* (NCES 2010– 034). U.S. Department of Education, National Center for Education Statistics. Washington, DC: U.S. Government Printing Office.

Gulek, J.C., & Demirtas, H. (2005). Learning with technology: The impact of laptop use on student achievement. *The Journal of Technology, Learning and Assessment*, *3*(2), 1-39.

Hannafin, M. J., & Land, S. M. (1997). The foundations and assumptions of technology-enhanced student-centered learning environments. *Instructional Science*, *25*(3), 167-202.

Hmelo-Silver, C. E. (2004). Problem-based learning: What and how do students learn?. *Educational Psychology Review*, *16*(3), 235-266.

Inserra, A., & Short, T. (2012). An analysis of high school math, science, social studies, English, and foreign language teachers' implementation of one-to-one computing and their pedagogical practices. *Journal of Educational Technology Systems*, *41*(2), 145-169.

Jerald, C. D., & Orlofsky, G. F. (1999). Raising the bar on school technology. *Education Week*, *19*(4), 58-62.

Johnson, D., & Johnson, R. (1999). Making cooperative learning work. *Theory Into Practice*, 67-73. doi:10.1080/00405849909543834

Jonassen, D. H. (1999). Designing constructivist learning environments. In C. M. Reigeluth (Ed.), *Instructional-design theories and models: A new paradigm of instructional theory* (Vol. II, pp. 215-239). Mahwah, NJ: Lawrence Erlbaum Associates.

Lewis, A., & Smith, D. (1993). Defining higher order thinking. *Theory Into Practice*, *32*(3), 131-137.

Lowther, D. L., Ross, S. M., & Morrison, G. M. (2003). When each one has one: The influences on teaching strategies and student achievement of using laptops in the classroom. *Educational Technology Research and Development*, *51*(3), 23-44.

Krajcik, J., & Blumenfeld, P. (2006). Project-based learning. In *The Cambridge Handbook of the Learning Sciences* (pp. 317-334). Cambridge University Press.

Kozma, R. B. (1991). Learning with media. *Review of Educational Research, 61*(2), 179-211.

Kulik, C., & Kulik, J. (1991). Effectiveness of computer-based instruction: An updated analysis. *Computers in Human Behavior, 7*, 75-94.

National Research Council. (1996). *National Science Education Standards.* Washington, DC: National Academy Press.

National Science Teachers Association (NSTA). (2004). *Scientific Inquiry*. Retrieved from http://www.nsta.org/about/positions/inquiry.aspx

Pedersen, S., & Liu, M. (2003). Teachers' beliefs about issues in the implementation of a student-centered learning environment. *Educational Technology Research and Development*, *51*(2), 57-76.

Penuel, W. R., Kim, D. Y., Michalchik, V., Lewis, S., Means, B., Murphy, R., Korbak, C., Whaley, A., & Allen, J. E. (2002). *Using technology to enhance connections between home and school: A research synthesis*. US Department of Education. Washington, D.C.

Resnick, L. B. (1987). *Education and learning to think*. National Academy Press. Washington, D.C.

Savery, J. R. (2006). Overview of problem-based learning: Definitions and distinctions. *Interdisciplinary Journal of Problem-Based Learning*, *1*(1). Retrieved from http://dx.doi.org/10.7771/1541-5015.1002

Shapley, K., Sheehan, D., Maloney, C., Caranikas-Walker, F., & Huntsberger, B. (2007). Evaluation of the Texas Technology Immersion Pilot: An Analysis of Second-Year (2005-06) Implementation. *Texas Center for Educational Research*.

Slavin, R. E. (1996). Cooperative learning in middle and secondary schools. *The Clearing House*, *69*(4), 200. Retrieved from http://ezproxy.lib.utexas.edu/login?url=http://search.proquest.com/docview/196884311?accountid=7118

Tomlinson, C. A. (2001). *How to differentiate instruction in mixed-ability classrooms.* Association for Supervision and Curriculum Development, Alexandria: Virginia.

U.S. Department of Education. (2010). *Number and internet access of instructional computers and rooms in public schools, by selected school characteristics: Selected years, 1995 through 2008.* Digest of Education Statistics. Retrieved from http://nces.ed.gov/programs/digest/d10/tables/dt10_108.asp

Warschauer, M., Grimes, D., Rousseau, M., Suhr, K., & Nyberg, J. (2005). *First year evaluation report Fullerton school district laptop program*. Retrieved from http://www.education.uci.edu/person/warschauer_m/docs/fsd-laptop-year1-eval.pdf

Yang, C. C. (2002, June). *Integration of Laptops into a K-12 Learning Environment: A Case Study of a Science Teacher in the Middle School*. Paper presented at ED-MEDIA 2002 World Conference on Educational Multimedia, Hypermedia & Telecommunications.

Zheng, B., Warschauer, M., Hwang, J. K., & Collins, P. (2014). Laptop use, interactive science software, and science learning among at-risk students. *Journal of Science Education and Technology*, *23*(4), 591-603.

Zuber, E. N., & Anderson, J. (2013). The initial response of secondary mathematics teachers to a one-to-one laptop program. *Mathematics Education Research Journal*, *25*(2), 279-298.

Zucker, A. A., & Hug, S. T. (2007). *A study of the 1: 1 laptop program at the Denver School of Science & Technology*. Retrieved from http://files.eric.ed.gov/fulltext/ED500425.pdf

Zucker, A.A., & McGhee, R. (2005). *A study of one-to-one computer use in mathematics and science instruction at the secondary level in Henrico County Public Schools.* SRI International. SRI Project, P12269.