A Systematic Review of One-to-One Access to Laptop Computing in K-12 Classrooms: An Investigation of Factors That Influence Program Impact

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ABSTRACT

A Systematic Review of One-to-One Access to Laptop Computing in K-12 Classrooms: An Investigation of Factors That Influence Program Impact

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In 2005, Nicholas Negroponte stepped onto the stage at TED and challenged the audience: “What would happen if we gave every student a laptop computer?” Ten years later, and twenty-five years after the first laptop program, this dissertation attempts to answer that question using two systematic review procedures, case survey analysis and mixed effects meta-analysis. Literature searches and review resulted in 162 primary studies being included in the case survey of which 88 studies yielding 231 effect sizes and representing approximately 116,150 participants, were selected for the meta-analysis. The case survey analysis revealed that typically, programs were co-educational, involving public middle schools, and conducted at the board or district levels. Program theories, whether stated or inferred clustered around three main themes: technology-enhanced environments, technology-enhanced instruction, and computers as mind tools or learning tools. Program goals were numerous and varied, but centered on technology use and proficiency, achievement, questions of technology equity, and improved instruction. The meta-analysis revealed that one-to-one computing had an impact on five of the six outcomes tested: technology use (mean effect size 0.53), technology proficiency (0.29), student achievement (0.23), student engagement (0.15), and student satisfaction (0.26). Attendance was not significant (0.00). The general effects were moderated in expected and unexpected ways – technology use was moderated by program theory and year, technology proficiency was moderated by technology use and duration, and achievement was moderated by program size, participant age, program year, technology integration, duration, and teacher-centered instruction. Explanations were proposed for these findings, and new directions for future research outlined.

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DEDICATION

I dedicate this dissertation to my wife, Tasha, my son, Jaxon, and to the memory of my late parents, E. Clement Bethel and Dr. Keva Bethel.

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CHAPTER 1 – INTRODUCTION

General Introduction

On a wet summer night in 1989, when a bedraggled and unshaven man arrived at the launch party of the experimental Sunrise School in Melbourne, Australia, organizers took him for a street person looking for a bite to eat and shelter from the incessant rain. Being philanthropist types, the organizers accommodated the man, and to their surprise he seemed less interested in the cocktail sandwiches than the students working at their computers. Inauspicious beginnings for what would become a worldwide educational experiment. The "homeless man" was in fact David Loader, Principal of the Methodist Ladies' College (MLC), a nearby private day school for girls. Inspired by what he saw that evening, Loader had a vision of a school where each student had her own computer. Within a year, MLC piloted what would become the world's first school-wide one-to-one laptop program (Johnstone, 2003). Today, 25 years later, one-to-one laptop programs have spread and continue to spread throughout the world, fueled by an unflagging faith in the potential of digital technologies to impact a variety of educational goals.

New technologies, digital or otherwise, have always played a prominent role in education. Every technological advance has been followed closely by educational reformers championing the "transformational potential" of the new technology. Attempts at educational transformation through technology have been followed by frustration, disappointment, disillusionment, and, inevitably, teacher bashing (Cuban, 1986). The cycle repeats itself with every new technological advance. Clark's (1994) explanation for this vexing state of affairs is simple and irresistible: media attributes are neither unique nor necessary to affect learning gains. Rather, the technological medium is a substitutable delivery mechanism. Learning gains are the result of skillful teaching, instructional design, or some combination thereof (Clark, 1983, 1994).

For Clark it is no surprise that new technologies have repeatedly failed to live up to their billing. Because they are inherently interchangeable, choices of instructional technology and media ultimately should be determined by cost and efficiency. Reform aimed at “technology integration” is misguided and potentially wasteful of precious educational resources. All the same, the use of digital technology and media in education continues to increase.

In a rebuttal to Clark, Cobb (1997) points out that Clark’s requirement that an instructional medium must be both unique and necessary for learning, could equally be applied to instructional methods. There is no instructional method that is unique or necessary – methodology choices come down to efficiency as do technology choices. Moreover, Cobb points out that in fact instructional efficiency is exactly what we should be considering if we are looking to maximize learning gains. The interaction between media and method is natural and should not present an obstacle to research much the same way as in medical research, both method (drug used to treat an ailment) and medium (form in which the drug is administered), are considered to be crucial variables. Media should once again be considered an essential part of the learning equation (Kozma, 1994a).

Perhaps Clark’s thesis is better understood as a critique of a media-centric focus as opposed to a critique of media themselves. Learning never happens through direct osmosis – there are always some intervening mechanisms that make up the learning environment, that can facilitate or hinder the learning process. The key question is no longer should media be incorporated, but rather which media should be incorporated into the learning environment, when, and how.

Clark's objections notwithstanding, as more and more evidence is collected, the reformers' faith in the educative potential of learning technology seems justified to a degree.

Aggregating the findings of 37 meta-analyses of studies on the impact of technology in education, Tamim, Bernard, Borokhovski, Abrami & Schmid (2011) found a small but significant effect of technology-enhanced learning. This finding is important, as each meta-analysis included in Tamim et al. is itself an aggregation of primary studies of technology in education. When all these aggregate studies are themselves aggregated in a “second-order meta-analysis” results are that much more robust. Tamim et al. does appear to settle the issue of whether technology can have a positive impact on learning. Although Clark's reply would be that these findings are conflating medium with method, the volume and variety of studies included in Tamim et al. would tend to suggest an underlying media effect, regardless of method, however.

The earliest attempts to integrate technology into the classroom were hampered by a lack of access. Those schools fortunate enough to have technology programs would typically follow one of two models: a set of computers would be deployed to a central lab or classrooms would have a few computers for students to share. In neither case could the benefits of technology integration truly be realized as students’ technology exposure would be limited at best. As laptop computers became more affordable and the machines themselves became more portable, ubiquitous technology access was at last possible. In 1990, when Methodist Ladies’ College launched the first one-to-one laptop program, the world took notice and followed suit. Programs have ranged from individual schools, to school boards, to districts, regions, states and most recently to international organizations with One Laptop per Child (OLPC).

Nonetheless, technology integration proceeds at a snail’s pace. In a world of 3D printers, smartphones, and wearable technology, our classrooms are still based on the same “sage on a stage” model so harshly criticized by many. Technology integration has always come with the assumption and promise of a new paradigm of student-centered learning. In the classrooms of the technological future, where each student has their own device, students will direct their own learning and technology-supported instruction will be tailored to the needs of each student.

Problem Statement

In many ways, the pace of development has outstripped our knowledge base about the effectiveness of the programs. Has it all been worth it? While there have been positive signs and success stories, there have also been criticisms and failures. How do we determine whether this experiment has made any difference at all? Certainly the lack of definitive answers does not reflect a lack of study. Well over a thousand pieces of research, evaluation, advocacy, commentary, and criticism, and over forty reviews all chime in on the impact of one-to-one computing. No strong unison message emerges, however, not even pleasing harmony. Instead is heard a cacophony of clashing sounds that confuse rather than clarify. To resolve it all a more systematic approach is required. The main purpose of a systematic review is to locate whatever research is available about a particular question or idea, and use systematic methods to determine what conclusions or inferences can be drawn reliably from this data (EPPI-Centre, 2009). This study will sift through the diverse evidence using established systematic review methodologies in an attempt to bring clarity to and to quantify the impact of one-to-one computing in K-12 settings.

Meta-analysis is perhaps the most well-known and well-developed of the review methodologies (Bethel & Bernard, 2010). Meta-analysis was developed as a systematic method to bring order to and reconcile varied research findings on a single research question. By treating individual studies like participants in a primary study, the meta-analyst extracts "effect sizes" or estimates of the actual or standardized impact of the intervention. The effect sizes are averaged to estimate the "true" effect of the intervention – the point estimate of the population effect size, formally. It is assumed that study effect sizes will converge around the point estimate, much the way that sample scores converge around the sample mean. When studies are similar in design, research question, and treatment, meta-analysis can yield robust estimates of intervention effect (Bethel & Bernard, 2010). Unfortunately the evidence base of one-to-one computing is anything but - rather than similarity, one-to-one studies are characterized by diversity.

In his essay “Open Secrets,” Malcolm Gladwell (2007) explains the difference between puzzles and mysteries. A puzzle is a question for which we have too little information to answer, whereas a mystery is a question for which we have information, but we do not know what the information means. The approach to solving puzzles as opposed to mysteries is different. To solve a puzzle, we simply get more information – collect more data. For a mystery, more data may not help, and may even obscure the answers even further. In this case, we need methods that enable us to make sense of masses of diverse and frequently contradictory data. The contrast between methods to solve puzzles and mysteries exactly parallels the contrast between primary and secondary research. The role of primary research, both qualitative and quantitative, is to collect data to answer questions for which there is too little information, presently. The role of secondary research – systematic review – is to synthesize multitudinous and diverse data to answer questions for which there is too much information.

As noted earlier, the evidence base of one-to-one computing is diverse. A minority of studies lend themselves to effect size extraction. If strict meta-analytic protocols were followed, only a small proportion of the evidence would be included in the review. This study must incorporate a systematic methodology or methodologies to synthesize diverse studies that are as faithful as possible to the traditions of both quantitative synthesis (meta-analysis) and qualitative synthesis (narrative synthesis, meta-ethnography, and others).

Objectives of the Study

The proliferation of diverse, sometimes conflicting one-to-one computing research calls out for systematic analysis. This dissertation attempts to bring order to this diversity of information through a three-fold analysis. The first component is exploratory and uses the case study methodology to categorize and draw general themes from as broad a selection of studies as possible. The second component is inferential and attempts to answer the following substantive questions regarding the impact of one-to-one computing in K-12 environments using meta-analytic methods:

1. Are there general laptop effects on the variables of student achievement, technology use, technology proficiency, engagement, attendance, attitudes toward technology and discipline?
2. Are the general effects moderated by study characteristics: quality of design, type/level of measurement used, type of study in relationship to the program (internal, external or published study)?
3. Are the general effects moderated by other variables as predicted in the literature, namely: does technology use moderate technology proficiency; do any or all of the following moderate achievement: technology use, technology integration, program theory, program implementation?

The third component is explanatory and uses the findings of the first component to attempt to explain the findings of the second component in a synthesis of syntheses.

In this study, one-to-one computing is defined as educational settings in which each student has a computer to use for educational purposes in every class, every day for no less than 6 weeks. This definition incorporates two of Penuel's (2006) core characteristics of one-to-one programs, but does not include his requirement that programs involve access to the Internet. This study is looking at one-to-one laptop programs since the early 1990's when wireless access to the Internet was rare. Wireless access was coded as a study feature. In terms of program duration, there is a degree of disagreement. On the one hand Slavin and Lake (2008) suggest that one complete semester (12 weeks) is the minimum duration to see the benefit or otherwise of an educational intervention, while on the other, Bernard et al. (2009) suggest that 15 hours for a course is sufficient. Falling between these two, this study uses half a semester (6 weeks) as the minimum program duration and codes for program duration as a study feature.

While there is fertile data for research in both K-12 and post-secondary schooling, this study is limited to one-to-one computing in K-12 environments for the sake of limiting scope. A parallel study focusing on postsecondary environments would be equally important. In some one-to-one programs students have full time access to the computers: that is they are allowed to take them home; in others, students can only use the computers at school. Fuchs and Wößmann (2005) demonstrated that computer home use can prove harmful or beneficial to learning outcomes. These two types of one-to-one programs – school and home as opposed to school only – may exhibit unique characteristics, for the purpose of this study they are both be classified as one-to-one programs and coded for whether they whether students had laptop access at school and home or just school only. Given the need for portability, one-to-one computing initiatives involve students being issued with or purchasing laptop computers. Some programs refer to portable computers as laptops, while some call them notebooks. This study uses the term "laptops" to refer to laptop or notebook computers. Initiatives where students use handheld computers as opposed to laptops are not included in this study. This study asks how, to what extent, and under what circumstances does one-to-one computing in K-12 settings impact educational goals including but not limited to student achievement, technology use, technology proficiency, and attitudes toward technology, through a systematic review of primary implementation and intervention studies and evaluation reports.

CHAPTER 2 – REVIEW OF THE LITERATURE

Technology in Education

Welcomed or spurned, then, technology use in education is increasing. Portable computers with Internet access are only the most recent of a long list of popular technology interventions meant to transform educational practice. Technology champions see this transformation happening in several ways. For some, computers can improve learning by transforming and enhancing the learning environment (Bransford, Brown & Cocking, 1999; Jonassen, Howland, Moor & Marra, 2003; Kuh & Vesper, 2001; McCombs, 2001; Siemens, 2005; United States. Web-based Education Commission, Kerrey, & Isakson, 2000). Learning environments can be transformed and enhanced in several ways: increasing access to information (Bransford, Brown & Cocking 1999); providing access to a richer learning experiences (Bagui, 1998; Brown, 2006; Caplan & Graham, 2008; Craig, 2001); making learning more situated (Bransford et al. 1999); increasing opportunities for active learning and inter-connectivity (Laurillard, 2002; Shuell & Farber, 2001; Yazon, Mayer-Smith & Redfield, 2002); enhancing student motivation to learn (Abrami, 2001); and increasing opportunities for feedback (Jonassen, Howland, Moore & Marra, 2003; Laurillard, 2002). Others see computers as powerful learning tools (Hannafin & Land, 1997; Harasim, Hiltz, Teles & Turoff, 1995; Jonassen, Carr, & Yueh, 1998; Lou, Abrami & d'Apollonia, 2001; Scardamalia & Bereiter, 1996). Others still see computers as gateways to online virtual learning communities (Jonassen, 2007; Paloff & Pratt, 2005; Swan, 2002). Of particular interest are new, rigorously designed studies reporting the success of web-based basic literacy tools (Savage, Abrami, Piquette-Tomei, Wood, & Deleveaux, 2008; Savage & Abrami, 2007; Schmid, Miodrag, Di Francesco, 2008), and the impact of computers in one-to-one settings on broader conceptions of literacy (Warschauer, 2006:

Warschauer, 2007; Warschauer, Grant, Del Real, & Rousseau, 2004). Indeed, there is sufficient optimism for technology's positive impact that governments have established committees, formed task forces, and dedicated substantial funds to the delivery or enhancement of technology-based instruction (CMEC, 2001).

At the same time, some commentators have expressed concern and criticism (Clark & Sugrue, 1995; Cuban, 2001; Healy, 1998; Noble, Shneiderman, Herman, Agre, & Denning, 1998) about the use of technology to improve learning, including suggestions that it represents a threat to formal education, from kindergarten through university. For example, it may create an imbalance between computer skills and essential academic and thinking skills, foster technology dependencies and isolation rather than independent and interdependent learners, and erode the joy and motivation to learn, replacing them with frustration because of underused, failing equipment. Some teachers hold beliefs concerning the usefulness of information and communication technologies (ICT) that parallel their attitudes towards any change to teaching and learning, be it through government mandated reform or societal pressure. "If the computer can accomplish the task better than other materials or experiences, we will use it. If it doesn't clearly do the job better, we will save the money and use methods that have already proven their worth" (Healy, 1998, p. 218). As noted earlier, Clark and Sugrue (1995) famously point out that the most likely explanation for increased learning with computer technology is instructional method differences, content differences, or novelty effects, and not the technology itself.

Technology Integration and Student Achievement

No one doubts that introducing technology into the learning equation changes the environment and learning process. The question is whether technology produces unique changes that result in learning gains. Narrative and quantitative reviews of primary research have addressed the question of technology integration and student achievement. The findings are mixed. While many have reported positive effects of technology integration, others reviews have found that such a conclusion is not supported.

Reporting the findings of several different meta-analyses of technology integration, Kulik and Kulik (1989) reported that several found positive average technology effects on learning ranging from 0.22 standard deviations to 0.57 standard deviations improvement compared to control participants. Several studies reported by Schacter (1999) found higher achievement, motivation, and engagement for students in technology-enriched environments. In their meta-analysis, Waxman, Lin, and Michko (2003) found small but positive technology effects on student outcomes. Gains in language arts and reading, mathematics, science and medicine, social studies, foreign and second language acquisition, and programming languages such as LOGO were found in studies cited by Sivin-Kachala and Bialo (2000). Kulik (2003) cited studies reporting positive impacts of word processor use on student writing skills, as well as on teaching programs in math, and in the natural and social sciences. Bangert-Drowns (1993) similarly found a positive effect of the impacts of word processing on student writing. Students improved the quality of their writing and wrote longer documents, but did not have more positive attitudes towards the technology (Bangert-Drowns, 1993). In a meta-analysis of studies from 1992 to 2002, Goldberg, Russell and Cook (2003) found a positive technology effect of 0.50 standard deviations on quantity of writing, and 0.41 on quality of writing for students who learned writing using computers.

Other reviews are less enthusiastic. Though Coley, Cradler and Engel (1997) report achievement gains for drill-and-practice computer-assisted instruction, they found studies of more pedagogically complex uses of technology have been less convincing, reporting only interesting anecdotes. More concerning, while Fuchs & Wößmann (2005) initially found mathematics achievement gains for home computer use, adjusting for family background and school characteristics, they found "the mere availability of computers at home is negatively related to student performance in math and reading, and the availability of computers at school is unrelated to student performance" (p. 17). Reviewing mostly Canadian research, Ungerleider and Burns (2002) found few methodologically rigorous studies reporting positive technology effects on student achievement, motivation, and meta-cognitive learning and on instruction in content areas in elementary and secondary schools. They also emphasized that access to computers in the classroom will not improve student academic achievement without concurrent changes to instruction. Methodologically sound studies must be undertaken with proper experimental and statistical controls.

In their meta-analysis of technology use in post-secondary education, Schmid et al. (2014) underscore an important distinction in technology studies, those comparing technology to no technology, and those comparing technology to some technology. Studies of the first type sought only to establish proof of concept: does technology work? Studies of the second type asked a more interesting and perhaps more informative question: how will differing levels of technology impact student performance? For all intents and purposes, the first question has been answered in the affirmative by Tamim et al. (2011) and similar studies. Nonetheless, this approach still informs many technology studies. For certain, many one-to-one studies take this approach even when there is evidence that the control group has access to some technology. In answering the second question Schmid et al. (2014) found that levels of technology matter. Low (effect size = 0.28) to medium (0.34) uses significantly outstripped high uses of technology (0.07), suggesting that there is a saturation point beyond which technology becomes a hindrance.

In addition to examining levels of technology use, Schmid et al. compare the impact of different types of technology use.

Schmid et al. (2014) further refine the discussion about the merits of technology and media in education. Their findings support Clark's argument to a degree. Technologies that are used as educational content delivery mechanisms, like PowerPoint or other presentation platforms, are unlikely to have much of an impact. These content delivery uses produced a small average effect size of between 0.10 and 0.20. While significant, these effects are small enough to provide support for Clark's argument (Schmid et al., 2014). When technologies were used as tools to support learning, for example as cognitive supports (effect size between 0.30 and 0.45), as information retrieval tools (effect size 0.5 to 0.75), or as communication tools (0.2 to 0.3), stronger effects may be realized, however.

Bernard, Borokhovski, Schmid, Tamim, & Abrami (2014) use a similar framework to meta-analyze studies comparing technology supported blended learning with classroom instruction. Their findings echo those of Schmid et al. (2014). They find a general "blended learning" effect (0.33), but again, that general effect is moderated by types of technology applications. Once again, different models of technology use had differential learning impacts. Where technologies were used as learning tools such as cognitive supports (0.59), communication supports (0.31) and search and retrieval tools (0.54 – not significant) larger effects were found than when technologies were used as content delivery mechanisms (0.24). It should be noted also that in both meta-analyses, although technology used as delivery mechanisms resulted in the smallest gains, these gains were significant nonetheless. Media influence learning after all, small though that influence might be.

These findings are significant for one-to-one programs not only because they suggest appropriate ways that technology can be deployed to greatest impact, but also because they suggest that there may be a technology saturation point beyond which there are diminishing returns. One of the justifications of one-to-one programs is that prior technology interventions suffered from inadequate technology saturation (Zucker, 2004). When implementing one-to-one computing, care must be taken not to exceed productive levels of technology integration.

One-to-One Computer Implementations

Until recently, studies of technology integration in schools have reported limited student access to technology in a variety of configurations including:

- Dedicated computer labs for select periods during the week;
- Classroom computers where computers are available but at ratios of several students per computer;
- "Laptop carts" where a cart with enough laptops for a one-to-one ratio is shared by several classrooms so that students can use their own computer in their own classroom for select periods during the week.

Now, interest is shifting to a model of more widespread and ubiquitous technology use, that is, when each student is provided with a computer for use throughout the day. Underpinning this interest is the belief that increased access to technology will lead to increased technology use, which will in turn lead to improvements in a variety of educational outcomes (Russell, Bebell & Higgins, 2004).

One-to-one computer implementations that provide students with Internet access and laptop computers for use at school and at home, are rapidly increasing in number. Decreasing costs, increased portability, and availability of wireless networking all contribute to making broad implementations feasible (Penuel, 2006). This cheap technology is seen as the key to achieving a number of educational goals, including bridging the “digital divide,” increasing technology use, facilitating the acquisition of 21^{st} century skills, improving student achievement, improving students attitudes, behavior, and increasing student attendance and retention rates (Zucker, 2004). Evidence is beginning to emerge linking laptops to improvements in student writing and literacy (Gulek & Demirtas, 2004; Silvernail & Gritter, 2007; Warschauer, Grant, Real & Rousseau, 2004), though quality research on the impact of laptops on other learning goals is mixed as best. In a synthesis of studies, Penuel (2006) reports that not only does research lag behind such rapid expansion, but of the research studies that have been done, few analyze implementation outcomes in a rigorous manner. Concurring, Zucker (2004) states that research has not provided policy makers with enough concrete evidence of the costs and benefits of one-to-one computing, nor has research identified the appropriate mix of factors to maximize intervention benefit.

This is not to say that one-to-one technology has no effect on student achievement. The studies reporting increases in student achievement all report these increases in particular areas. In their evaluation of the Laptop Immersion Program at Harvest Park Middle School in Pleasanton, CA, Gulek and Demirtas (2005) found that when achievement results were controlled for prior performance, only differences in Language Arts and Writing remained statistically significant. Similarly, Lowther, Ross, and Morrison (2003) report substantial increases in writing and critical thinking achievement in their evaluation of a one-to-one technology integration using the iNtegrating Technology for inQiry (NTeQ) model (Morrison & Lowther, 2002). Trimmel and Bachmann (2004), in their comparison of 27 laptop and 22 non-laptop students, report that significant differences in student achievement could be accounted for by differences found in achievement on one sub-category of the testing measure used – spatial intelligence. Particularly interesting is that in at several studies (Bernard et al., 2008; CRF & Assoc., 2003; Mitchell Institute, 2004; Stevenson, 1999), even though overall gains for the treatment group as a whole were minimal, the authors report that within the treatment groups, low-performing students gained disproportionately.

Russell and Higgins (2003) raise another issue. They question whether standardized paper and pencil tests accurately measure the particular learning that might take place in a one-to-one classroom. In particular, they report research where two groups of students, a one-to-one group and a control group, take two versions of the same writing test, a computerized version and paper and pencil version. Predictably, the one-to-one group did better on the computerized version than they did on the paper and pencil test, while the control group did better on the paper and pencil test. In other words, the familiar format over-predicts and the unfamiliar test format under-predicts the performance of both groups. Moreover, Russell and Higgins (2003) repeat the oft-heard argument that standardized tests do not measure the kinds of skills that one-to-one learning may be developing, for example technological literacy, spatial reasoning and problem solving (Davies, 2004; Grimes & Warschauer, 2008; Warschauer, 2007). Though care must be taken with arguments of this sort, the findings of Trimmel and Bachmann (2004) and Lowther et al. (2003) seem to support this line of reasoning.

Why One to One?

There are two things always heard in a debate over one-to-one laptop programs: “One-to-one computing will transform learning” and “It's not about the laptops.” And the responses can only be “How?” and “Really?” In truth, these two refrains reflect a division in the one-to-one community that dates back to the very earliest implementations and can be thought of as endpoints on a spectrum of beliefs about the role that technology in general and personal laptops in particular should play in the classroom. For the first group, computers *are* the solution, while for the second group, computers are *part* of the solution. In many ways this debate is a reflection of a much broader debate in education between the proponents of guided and unguided learning (rekindled by Kirschner, Sweller, & Clark, 2006).

One-to-One Computing Will Transform Learning

What Loader saw that summer night at the Sunrise School was a classroom of engaged and excited students using computers to build things, draw diagrams, operate a mechanical turtle, and solve mathematical problems without any direct instruction from teachers (Johnstone, 2003). In fact, to the degree that teachers were involved at all, they acted in a supporting role, becoming involved when it was clear the students could not work their way out of a problem. In short Loader saw, and fell in love with, the prototypical "constructionist" classroom (Johnstone, 2003). When MLC piloted a laptop program the following year, this was the model from which they drew inspiration.

Student-centered learning. Constructionism or some version of student-centered constructivism were the pedagogical models upon which the very first laptop programs were based. The idea was that meaningful learning – students' knowledge construction as opposed to the transfer of knowledge from teachers or textbooks to students – happened when students were not being taught abstract concepts about artificial subjects, but rather when they were actively constructing some sort of learning artifact, whether it be a computer program, a scale model of a building, an anthology of poetry, or a concrete solution to a challenging real-world problem (Papert, 1980, 1993). The computers were seen as the medium that enabled this shift from "instructionism" to "constructionism" (Papert, n.d.). Note that several "minimally guided" approaches to learning, for example, problem-based learning, project-based learning, discovery and inquiry learning, constructionism, and some forms of student centered constructivism, share the general idea that learning by doing engages students, and gives abstract concepts tangible forms from which students can build knowledge. These ideas have inspired and continue to inspire one-to-one laptop programs to a greater or lesser degree (see for example Davies, 2004).

"Teacherless learning." In many ways, the turn towards constructionism represents a desire to untether the student from the direct instruction of the teacher and the teacher-dominated classroom where knowledge flows in one direction, from the teacher or textbook, to the student (Harel & Papert, 1991). The laptops here are seen not only as a tool for artifact and hence knowledge construction, but also as cognitive support, information source, and communication device that enables radical new forms of student-centered, "teacherless" learning. This radical reformulation of the constructionist ideals has resurfaced with the global deployment of "$100 laptops" in the One Laptop per Child (OLPC) initiative (Negroponte, 2005, 2006a; Rowell, 2007).

One Laptop per Child. The premise behind The One Laptop per Child (OLPC) project is that given the perceived capacity of emerging technologies to facilitate learning, and given Clark's questions about economics and cost, if personal computers can be produced for an extremely low unit cost and distributed widely, we must consider substituting laptops for classrooms where none exist, or are functioning poorly. The idea is that this revolutionary "$100 Laptop" has the capacity be the centerpiece of a newly imagined learning environment. The laptop itself is seen as the primary vehicle that will facilitate students' learning through research, construction, peer-to-peer collaboration, and problem solving (Negroponte, 2006a, 2006b). Some even argue that the emergence of free or low cost technology combined with open educational resources expands educational access far more broadly than classroom based learning (Caswell, Henson, Jensen & Wiley, 2008). Critics argue that improving educational access is not that simple. Criticisms warn about the potential for social disruption and dislocation that inevitably results from exposing traditional communities to modern technologies and practices, hidden costs, and lack of needed infrastructure for distribution or implementation, all of which limit the potential educational benefits (Kraemer, Dedrick & Sharma, 2009; Warschauer, 2009; and Warschauer & Ames, 2010).

The idea of teacherless learning with computers is not without precedent. In the late 1990s the “Hole-in-the-Wall” experiment was conducted in several remote villages in India. The brainchild of Sugata Mitra, in this experiment computer terminals were placed in kiosks in remote communities so that the public – particularly children – had access to the screens, a modified joystick, and other navigational controls. The computers were connected to the Internet and were on 24 hours a day. No instruction was given on how to operate the machines. Researchers then observed what happened. And indeed teacherless learning did take place in combinations of discovery, trial and error, collaborative and peer-led learning (Hole-in-the-Wall Education Ltd., 2009; Inamdar, 2004; Inamdar & Kulkarni, 2007; Mitra, 2000; Mitra et al., 2005; Mitra & Rana, 2001).

The Hole-in-the-Wall project was described as an experiment in “minimally invasive education,” which had its roots in earlier teacherless (and non-technological) projects, like “Summerhill” (Neill, 1960). The researchers wanted to see what if anything children could learn if given free, unsupervised access to computers. The experiment was a success – not only did children learn computer literacy, they also demonstrated improved performance in mathematics as well (Inamdar, 2004; Inamdar & Kulkarni, 2007; Mitra & Rana, 2001). It follows that if students learn from a 24-hour public access terminal with no instruction, how much more could they learn if they have their own computers? The idea that access to computers alone is sufficient to stimulate student learning is one of the cornerstones of the OLPC project. Its founder, Nicholas Negroponte, is famous for his pronouncements that although the essence of the project is to provide specially designed laptops to all the children of the world, it is an education project not a laptop project (Diodato, 2007). In fact, by giving students the tools and raw materials needed for productive discovery-learning, the OLPC project as originally conceived could possibly subvert existing hierarchical school structures and sidestep direct teacher influence altogether (Negroponte, 2005, 2006a; Rowell, 2007). This is not seen as a bad thing. The underlying rationale of the OLPC assumes that essential learning occurs by experimentation, exploration and collaboration – always by doing – and not by instruction and training for standardized measures (Korman, 2007).

Technology saturation. For proponents of ubiquitous computing what makes the OLPC and all the one-to-one laptop programs special is that through these programs everyone has access to technology all the time. Prior to one-to-one, technology interventions depended on limited student access to technology. Technology proponents could always use the lack of saturation argument to explain why technology implementation did not deliver expected results (Kozma, 1994b; Penuel, 2006; Zucker, 2004). One-to-one computing is the “full technology condition.” Every student has access to all the affordances of the technology all the time. If there are in fact benefits to be realized from technology-enhanced learning, then one-to-one classrooms have the best chance of realizing those benefits. At the same time, Schmid et al. (2014) highlight the fact that there may be an upper limit to the degree to which saturation is beneficial. Care must be taken to ensure that enthusiasm for widespread use does not in fact hinder learning.

Bridging the "digital divide." Technology access for all has its own rationale. Every new innovation in technology and digital connectivity widens and deepens the "digital divide" – the gap between those who have access to information and communication technologies and those who do not. By providing laptops and wireless internet to all students policy makers hope to narrow the gap and bring a new generation of technologically disadvantaged students into the digital age (e.g., Davis, Garas, Hopstock, Kellum, & Stephenson, 2005; Gravelle, 2003; The Greaves Group, The Hayes Connection, 2006; Lane, 2003; Rowell, 2007; Shapley et al., 2006a). Essentially, in addition to educational goals, one-to-one laptop programs are implemented to meet technology goals as well. This goal is reflected in the program objectives: many of the laptop programs include "technology use" and "technology literacy" among their main objectives (Davis, Garas, Hopstock, Kellum & Stephenson, 2005; Gravelle, 2003; Lowther, Ross, Strahl, Inan and Pollard 2005; Stevenson, 1999). The argument is that being on the wrong side of the digital divide has consequences for the educational well-being of students, so interventions that reduce the technology gap are justified in and of themselves. Ubiquitous technology use is believed to have direct or indirect educational benefits whether they are observable and measurable or not.

Social impact of one-to-one interventions. If we are to discuss the digital divide, we must also acknowledge that technology interventions such as one-to-one laptop computing have impacts beyond the classroom. Particularly in communities where technology is scarce, where a child's computer may be the only technology in a household, that computer will be shared among family members (Helmersen, 2006). Moreover, while laptop interventions assume a western notion of individual ownership, many societies at which the one-to-one interventions are aimed have more communal notions of ownership. A student's computer may be treated as a community asset and used accordingly (Lowes & Luhr, 2008). Although formal evaluations available do not report in detail about these indirect impacts of one-to-one interventions, stories are emerging about how computers are transforming family and community life. The broader social impact of laptops in the classroom, particularly in traditionally low-technology societies, is a fertile area for study for future evaluations.

It's Not About The Laptops

Perhaps the harshest critics of the technology-first approach taken by the OLPC and other similar one-to-one programs come from within the one-to-one community itself. Lively discussions of why laptop programs in general and OLPC in particular are anything from a regrettable waste of money to a revolutionary step to bridging the digital divide can be found in educational technology journals, websites, blogs, and news forums (Canuel, 2009; Ploskonka, 2009; Warschauer, 2009). Warschauer (2009) says it best, lamenting the OLPC approach of giving children laptops and getting out of the way. Instead what is needed is a balanced approach that plans for curriculum development, teacher training, funds set aside for development of wireless networks and other supporting devices, and laptop maintenance (Warschauer, 2009). Involving all stakeholders is essential to program success as is gradual, staged deployments that take advantage of ongoing evaluation. Not only are these all missing from OLPC, but in some cases they are actively discouraged (Educational Technology Debate, 2009; *Lessons Learned and future challenges*, 2009).

Central to the debate over one-to-one laptops is the role to be played by the teacher in a laptop classroom. Those who see the computers as *the* solution propose scaling back the role of the teacher – consistent with the principles of constructionism or radical constructivism. At best, the teacher's role is one of support or guide. Those, like Warschauer, who see the computers as a *part* of the solution, propose a central role for the teacher. In fact, they argue that appropriate teacher orientation and professional development are two of the most important components of a successful one-to-one laptop program (Lowther, Ross, & Morrison, 2003; Shapley et al., 2006a; Warschauer, 2006, 2009; Warschauer et al., 2004). This second approach to one-to-one programs that emphasizes building the right environment for the laptops to have their expected impact fits well with Clark's (1994) argument: the expected impact is largely due to the support systems in place. He would argue that laptops can only be justified if their *replacement value* outstrips other possible interventions. In other words, assume that the same effort was made to support an alternative, perhaps non-technology based, intervention to the point where that intervention could have the expected effect. Laptops would only be justified as a replacement for the alternative intervention if they represent the better value (less cost for the same expected gains).

To be clear, however, Warschauer and others like him (Lowther et al., 2003; Shapley et al., 2006a; Warschauer, 2006, 2009; Warschauer et al., 2004) agree that there will be a transformation when one-to-one laptop programs are introduced. They take issue with the idea that by simply adding computers to the equation, the learning transformation will be realized. Rather, they contend that while those radical experiments do lead to learning, this learning is of the technology itself. At the same time, existing educational, family, and social relationships are undermined as the technology plays a larger and larger role in students' lives (Warschauer, 2002, 2004). Instead they propose a planned, balanced, sustainable transformation, where learning environments are re-vamped to make maximum use of the affordances offered by the new technology, where provisions are made for the continued maintenance and updating of hardware and software; where teachers are trained to make the most of digital devices and content; and where pedagogies and curricula incorporate the information management and communication capabilities of the new machines (Warschauer, 2006). In short, they believe in an *evolution* of the present system into a new digitally enhanced learning environment. The technology-first proponents, on the other hand, see little in the present system worth saving and see the laptops serving as catalysts of an educational *revolution* where laptop-supported students direct their own learning.

Finally, despite all of this, technology-first proponents would contend that their approach is still justified because the Internet-ready laptops allow the students to cross the digital divide that threatens to cleave the world into digital haves and have-nots (Yang et al., 2013). Access to technology has become as reliable an indicator of socioeconomic advantage or otherwise as wealth, education, or healthcare. Added to which, like the other three, the digital divide acts as a multiplier, allowing digital haves better access to wealth, education and healthcare, and thereby causing the divide to deepen and widen (McKinsey & Co., 2014).

The critics would argue that this view of Internet connectivity and access may be too simplistic. The term "digital divide" itself may be too simplistic as it implies a dichotomous categorization of access with the determinant variable being the presence or absence of the requisite technology (DiMaggio & Hargittai, 2001; Hargittai, 2002, 2003; Jarboe, 2001; Selwyn, 2004; Vigdor & Ladd, 2010; Warschauer, 2002, 2004). The reality is that differences in access can be better described as a "digital inequality continuum" with access varying from little to no access to almost continuous access (Warschauer, 2004). But even this is insufficient to describe the factors at play. Although actual access to the Internet is obviously an important part of digital inequality, universal Internet access will not necessarily close the digital inequality gap. In fact, digital inequality reflects and is influenced by existing societal inequalities. Even if we look only at those who already have access, online skills and Internet usage patterns are not equally distributed, and the inequalities that are found reflect broader social inequalities (DiMaggio & Hargittai, 2001; DiMaggio, Hargittai, Celeste & Shafer, 2004; Hargittai, 2002, 2003; Jarboe, 2001; Selwyn, 2004; Vigdor & Ladd, 2010; Warschauer, 2002, 2004). The “digital divide” is better described as a multi-dimensional “digital inequality” continuum. There is no reason to expect that providing internet-connected machines will close the gap on any dimension other than that of connectivity. In order to close the so-called digital divide, what is needed is a balanced, multi-faceted approach where the new technologies are a part of a much broader plan to maximize the value of new connectivity to the new users through productive use of the technology's information retrieval and communication capabilities.

The One-to-One Continuum and Guided/Unguided Instruction

From the above we see that there is a continuum of opinions concerning how and why one-to-one computing will have maximum educational impact. On the one end of the spectrum (the “balanced approach”) we have those who argue that teachers must lead the way by adapting curricula and by finding pedagogically sound ways to integrate the laptops into classroom practice. At the other end of the spectrum, the technology-first advocates argue that laptops will enable true student-centered learning and transform the traditional teacher role of direct instruction to one of support and guidance. This spectrum parallels and is analogous with the continuum of instructional practices with guided instruction on one end and unguided learning on the other (for an exhaustive debate on the merits of the different types of instruction see: Hmelo-Silver, Duncan & Chinn 2007; Kirschner, Sweller & Clark, 2006; Kuhn, 2007; Mayer, 2004; Schmidt, Loyens, Van Gog & Paas, 2007; Strobel & van Barneveld, 2009; Sweller, Kirschner & Clark, 2007; Tobias & Duffy, 2009). Not only will the arguments presented in the debate inform the discussion of the best ways to approach one-to-one computing in schools, the guided/unguided continuum can provide another way to classify one-to-one interventions.

Theoretical Frameworks

Program Theory, Implementation Fidelity and Technology Integration

Clark's (1994) arguments notwithstanding, one-to-one laptop programs are first and foremost about getting technology into the hands of every student. The justification for such a program is based on certain beliefs and assumptions that underlie an expected sequence of mechanisms, processes and contingencies through which the laptops are hoped to impact learning outcomes. Together, these make up the program theory (Fitz-Gibbon & Morris, 1996; Rogers & Weiss, 2007; Weiss, 1997). For example, if the program theory holds that learning will be enhanced because students will have much more access to accurate, up-to-date information, then that laptop program should be characterized by continuous Internet access, instruction on the use of browsers and browser-based tools for information search and retrieval, instruction in digital rights and copyrights and related matters, information search and retrieval activities, evidence of students evaluating the quality and veracity of sources, evidence of students incorporating retrieved information into their work, and other activities that link computers to information retrieval, information retrieval to learning activities, and those activities to actual learning.

Understanding program theory allows for a more complete understanding of complex causal networks, in this case, whether, why, and how a laptop program is successful. Programs can then be assessed according to how successfully they fulfill the expectations of the given theory. This approach, known as theory-based evaluation (TBE) allows the researcher to evaluate the mechanisms – the participants' responses to the program – through which change, in our example actual learning, takes place (Fitz-Gibbon & Morris, 1996; Rogers & Weiss, 2007; Weiss, 1997).

Theory-based evaluation makes a clear distinction between implementation theory and program theory. Implementation theory tests the degree to which the program is carried out as planned. Successful outcomes are the result of faithful implementation. Program theory, on the other hand, examines the mechanisms of actual change. That is program theory first makes explicit the expected impacts that program will have on the participants, then second, evaluates whether the program impact has resulted in the expected change and outcomes (Rogers & Weiss, 2007).

While the central focus of TBE is the program theory, without evidence about program implementation, it is not sensible to attempt to describe program mechanisms. Methods for assessing implementation fidelity are needed. The assessment of implementation fidelity is the process of measuring the degree to which actual program implementation reflects the program model or design (Leinhardt, 1980; Mowbray, Holter, Teague & Bybee, 2003; O'Donnell, 2008; Scheirer & Rezmovic, 1983). If expected outcomes are not realized, measures of implementation fidelity help determine whether this reflects theory failure or implementation failure.

Fidelity measures can be grouped into two broad categories, fidelity to structure (presence, strength, and duration of treatment), and fidelity to process (quality of treatment, differentiation of treatment delivery mechanisms) (Mowbray et al., 2003; O'Donnell, 2008). Clearly, implementation fidelity will be easiest when all facets of program implementation are explicit. When they are not, the researcher must first describe a complete implementation theory from both the implicit and explicit implementation information. Fidelity to this framework can then be tested (O'Donnell, 2008).

One-to-one laptop program evaluations rarely report explicit implementation or program theories though they may describe implementation activities and report evaluation data on a number of different variables without clearly linking one to the other. Implementation success for one to one programs is usually judged by the degree to which technology is integrated in teaching and learning activities. Several studies have explicitly identified factors influencing technology integration (Dalgarno, 2009; Inan & Lowther, 2010a, 2010b; Lowther et al., 2007; Shapley et al., 2010). Inan and Lowther (2010a) propose a path model where three primary variables, professional development, technical support and overall support, impact two secondary variables, teacher beliefs and teacher readiness, which in turn impact technology integration. Wozney, Venkatesh and Abrami (2006), on the other hand have proposed a model of integration that is dependent on teachers' beliefs. They found that technology integration was dependent on teachers' expectations for technology (expectancy), how they valued technology (value) and the costs in terms of time, effort, personnel and resources of technology integration (costs). For Ertmer (2005) and Ertmer, Ottenbreit-Leftwich, Sadik, Sendurur & Sendurur (2012), teachers' pedagogical beliefs, their beliefs about how they teach best, how their students learn best and what are the most appropriate approaches to teaching and learning, underpin decisions on whether or not to commit to technology integration in the classroom. These beliefs are strongly held, deeply ingrained and difficult to change, as they are frequently the result of experience with classroom success and failure, lessons learned, and ideas confirmed in practice. Letting go of these requires leaps of faith that teachers are not usually prepared to take especially when it puts at risk their and their students' success. Shapley et al. (2006a & b, 2007, 2008, 2009), evaluating the Texas Technology Immersion Pilot found that school and board level factors played a significant role in technology integration. They found that strong leadership at all levels from the district to school, support structures that encouraged all stakeholders including administrators, teachers, parents and students, technology support at every level, continual professional development opportunities, and teachers' and students' beliefs all contributed to successful integration. Several themes emerge: (a) teachers' beliefs on several levels play a critical role in determining integration success; (b) professional development is an essential ingredient and must be designed to impact these beliefs in addition to teaching new skills; and (c) support structures are central to program success to ensure not only that things work the way they should, but also to provide comfort to teachers, students, parents and administrators as they let go of tried and true methods and commit to the new and unknown.

Assessment of implementation fidelity has proven particularly useful for systematic review and meta-analysis (Mowbray et al., 2003). In health and medicine, very specific research questions are tested in randomized controlled trials. Even so, for findings to be accepted generally, studies must be replicated as often as possible in a variety of contexts to increase generalizability. When these studies are aggregated and meta-analyzed, implementation fidelity measures can be used as potential moderating variables. That is, researchers can investigate whether the degree to which program administrators followed the prescribed program had an impact on outcomes. In fact, implementation fidelity does predict treatment success in many instances (Mowbray et al., 2003). On the other hand, in social science reviews and meta-analysis, even when researchers are studying the same construct, research questions and treatments are diverse. In these cases, reviewers must posit a construct that defines this particular set of studies and treatments and derive from that construct ideal program characteristics against which fidelity can be evaluated. Implementation fidelity measures can then be used in one of three ways: as inclusion criteria where studies not meeting a certain degree of fidelity are excluded from the review; grouping variables where constructs can take on different values and fidelity measures are used to assign studies to one of several groups (for example, in Bernard et al., 2009, the construct of interest was interaction, studies were grouped according to whether they primarily considered student-student interaction, student-teacher interaction, or student-content interaction); or as moderating variables of treatment effectiveness as discussed above.

As noted above, for one-to-one computing, technology integration has been used as a yardstick for program implementation fidelity. Although technology integration has been measured in several studies, attempts to directly link integration levels to hoped-for outcomes have been rare. Even more rare are attempts to articulate program theory and its relationship to integration and to outcomes. This study will attempt to do just that - to link program theory and technology integration to program goals and to measured outcomes.

Other Theoretical Approaches: Comprehensive School Reform and Cost Analysis

Given the nature of the evidence base and the need to limit scope, the theoretical approaches discussed above guide the analysis in this study. At least two others are worthy of consideration and fertile ground for future exploration and study: Comprehensive School Reform (CSR) and Cost Effectiveness Analysis.

Comprehensive School Reform. One-to-one proponents are quick to point out that these programs are not only about technology. They also describe school-wide and even board-wide changes that impact the entire school community. The laptops are seen as one important component of a much larger educational transformation (Canuel, 2009; Davis et al., 2005; Hill & Reeves, 2004; Morrison, Ross, & Lowther, 2009; Shakeshaft, Mann, & Tinsley, 2009; Silvernail

& Lane, 2004), usually centering on themes of bridging the digital divide, the transformative power of educational technology, and student-centered learning. As such, one-to-one programs are much broader than classroom-based interventions, though little emphasis has been placed on how the change management outside the classroom will affect program impact (Zucker, 2004).

In many ways, one-to-one laptop implementations closely resemble the whole-school transformational approach of comprehensive school reform (CSR) models. The mechanisms of organizational change have been researched more extensively in the CSR literature. Clear parallels between one-to-one laptop implementations and CSR can be identified. Perhaps new insights can be gained by incorporating theoretical frameworks developed in the CSR literature for understanding how organizational and implementation dynamics can determine one-to-one program impact (Borman, Carter, Aladjem, & LeFloch, 2004; Borman, Hewes, Overman, & Brown, 2003; Ross Rowan & Miller, 2007; Gil, & Cross, 2004; Vernez, Karam, Mariano, & DeMartini, 2006).

That said, there is an important difference between the CSR approach and one-to-one laptop program approach: although both reforms are systemic overhauls. CSR models provide explicit guidelines for program implementation and procedures from the roles of the administrators to the actual lesson plans teachers will carry out. One-to-one laptop programs are rarely as explicit in their systemic models. Instead, implicit models of implementation and program theory are inferred from reported intentions and activities.

Technology integration and costs. Hattie (2009) raises another issue. In his book, *Visible Learning*, he aggregates over 800 meta-analyses of educational interventions to determine which interventions are actually successful in improving student learning (Hattie, 2009). These comparisons raise an important issue in evaluating intervention utility−that of opportunity cost.

That is, the idea that when we decide on one intervention, we also decide not to do many others. An intervention cannot only be judged by whether it produces a positive effect size or not, rather an intervention should be judged by how its impact compares to the potential impact of an intervention not chosen. Harris (2009) and others remind us moreover that in addition, we must consider the unit cost in order to appropriately compare interventions.

We recall that Clark (1994) makes two points about the potential for technology and media to impact learning. First, he argues that any learning benefits are the result of the instructional design rather than the technology medium. This point has been debated at length and is discussed above. The second point, that technology and media decisions should be made on the basis of cost and efficiency given that they are ultimately interchangeable, has received considerably less attention. Clark himself says little other than of interchangeable interventions, the cheaper should always be chosen. As a rule, educational research has focused on outcomes and ignored questions of cost and efficiency (Harris, 2009; Levin & McEwan, 2001; Monk & King, 1993; Rice, 1997), and the technology and media debate is no different. This oversight is perhaps understandable given the challenges in estimating and calculating educational costs. Without this analysis, however, the technology and media in learning debate tells only half the story. Decisions of cost are not trivial, nor are they independent of technology choice and instructional design. If one medium requires novel instructional design to produce the same impact as another medium that additional instructional design translates to increased costs. Media are interchangeable only in the sense that different media can achieve the same learning impact. Given finite educational and training budgets, media and technology alternatives are not interchangeable if they have different costs.

Framed this way educational interventions are properly assessed not only by their impact, but more importantly by their efficiency, in other words, their impact per student dollar spent. Even an intervention that is clearly superior in terms of learning impact is not necessarily the best choice. If an intervention raises performance by fifty percent, but is three times as expensive as the existing program, that intervention may not be a good choice in a fixed budget (Levin & McEwan, 2001). Only if that fifty percent gain cannot be achieved at a lower cost, would that intervention be considered cost-effective and hence a good educational investment (Harris, 2009).

But this type of analysis has a second important consequence. Education can be improved by reducing existing inefficiencies, not only by adding additional inputs (Hanushek, 1997). Reducing inefficiencies is not necessarily the same thing as reducing costs, however. This point is often missed, even in scholarly literature, where “cost-effective” and “cost-efficient” usually mean “the cheapest alternative” rather than the alternative with the best cost to effectiveness ratio (Levin & McEwan, 2001). In fact, efficiencies can be realized without any reduction, and sometimes with increases, in current expenditures if as noted, those increases boost performance at a greater rate, decrease waste, or both. Grade repetition and student dropout result in wasted educational resources. By improving school quality and hence reducing repetition and dropout, schools can become more efficient (Hanushek, 1997). A comprehensive evaluation of cost must become a central part of the technology integration debate as increasingly, successful integration only occurs when changes are made at multiple organizational levels, support structures are built, and capacity-building exercises are undertaken. Costs are normally extensive, though hidden, as they will often be indirect, secondary, or the result of missed opportunities. The most complete evaluation of technology or media interventions in education, must account for both cost and effectiveness data. Sadly, cost data are rarely reported, and when they are, methods of measuring, calculating and reporting costs are not consistent enough to allow for useful comparisons at this time. Standardization in this area is sorely needed as cost effectiveness analysis can prove a powerful tool for decision-makers, evaluators and program coordinators (Creemers & van der Werf, 2000; Harris, 2009; Levin & McEwan, 2001).

Research Synthesis and Systematic Reviews

The goal of a systematic review is to synthesize the existing research on a particular question. These questions have typically focused on interventions effectiveness, and hence quantitative studies, in particular experiments and quasi-experiments have been acceptable for synthesis (Dixon-Woods, Agarwal, Jones, Young & Sutton, 2005; Goldsmith, Bankhead & Austoker, 2007; Mays, Pope & Popay, 2005). Meta-analysis, the most developed form of quantitative synthesis – allowed researchers to aggregate findings of many experimental studies to determine how effective an intervention was on average (Bernard, 2014). By treating individual studies like participants in a primary study, the meta-analyst extracts "effect sizes" or estimates of the actual or standardized impact of the intervention. The effect sizes are averaged usually using some weighting system, to estimate the population effect size or "true" effect. In the same way the sample scores will be distributed normally around the mean, it is expected that study effect sizes will be distributed normally around the "true" effect. Additionally, using "moderator analysis," meta-analytic studies have been able to explain to a certain degree, why studies report varying degrees of effectiveness for the same intervention (Abrami and Bernard, 2006).

Meta-analysis is not always able to meet the needs of policy makers, however. First, questions of effectiveness may not always be answerable by experimental studies alone. Suppose for example, a meta-analysis of lab and clinical trials has discovered two effective forms of a new drug, oral and hypodermic, and shown the hypodermic version to act more quickly and effectively. Paradoxically, practicing doctors observe real patients on the oral version enjoying a more complete recovery. The seeming contradiction can be easily explained: many patients have “needle phobia,” and are likely to resist treatments involving frequent injections (Wertheimer, Santella, Finestone & Levy, 2005). Patients who do not adhere to the drug protocol were likely to have been excluded from the RCTs. Meta-analyzing these studies only gives information about the characteristics of the drug itself, but says nothing about the other factors that can have an impact on effectiveness. Similarly, evaluations of one-to-one computing programs use scores on standardized test as measures of impact on achievement. Several researchers disagree with this approach, arguing that both the test media, paper and pencil, and the design of the tests make them insensitive to the types of learning that may take place when a student has his or own computer at school and home (Davies, 2004; Russell & Higgins, 2003). They argue that other methods of assessing learning, including qualitative methods, would be better suited to this task.

Second, policy makers are rarely concerned only with questions of intervention effectiveness. More commonly, questions are much more complex and messy, including considerations of funding, cost-effectiveness, economic impact, political impact, differential impacts across social groups, and questions of significance in comparison with other potential interventions (Mays et al., 2005). These complex questions require the reviewers to explore more diverse types of evidence in their syntheses (Abrami, Bernard & Wade, 2006; Goldsmith et al., 2007; Mays et al., 2005). Again, one-to-one laptop computing programs provide numerous examples of multiple policy goals. The Michigan Freedom to Learn initiative provided laptop computers to all middle school students and extensive teacher professional development in select schools. The goals of the program, to which policy-makers were to be held accountable, included, in addition to improving student learning and achievement, goals related to technology access, professional development, empowerment, and school structural change (Lowther et al., 2005). Similarly, the Enhanced Learning Strategy of the Eastern Townships School Board, of Quebec, Canada, lists three main program goals and no fewer than twenty diverse sub-goals including improving attendance, decreasing attrition, improving student attitudes, and improving the presence of the Anglophone community in the Eastern Townships, in addition to the more traditional goals of improving numeracy and literacy (Eastern Townships School Board, 2003).

Challenges to the Synthesis of Diverse Evidence

Although meta-analysis is well-established, and methods of qualitative synthesis have gained some acceptance, diverse evidence synthesis is new, evolving and not universally accepted as legitimate or desirable (Abrami et al., 2006; Dixon-Woods et al., 2005; Goldsmith et al., 2007; Mays et al., 2005; Pope, Mays & Popay, 2007).

Epistemological Issues

The quantitative and qualitative approaches disagree on the very foundations of knowledge. In the quantitative approach, knowledge emanates from the *systematic* application of scientific procedures to ensure objectivity and minimize bias. By contrast, in the qualitative approach, knowledge emanates from *purposeful* exploration and interpretation of data in order to gain deeper understanding. Every step of the research process is governed by these *a priori* beliefs. In this regard the two approaches can be thought of as endpoints on a research design continuum, with the most purposeful methods approaching one end of the continuum and the most systematic approaching the other (Figure 1). Methods in the middle can be thought of as

“Mixed” approaches and will employ a combination of methods from both ends of the continuum. This matter is discussed more completely in Bethel and Bernard (2010).

Moreover, researchers on both sides doubt the validity of this type of inclusive synthesis. Qualitative researchers fear that synthesis is a blunt instrument that blurs the uniqueness of qualitative research, they worry about applying “quality” standards that have typically undervalued qualitative methods, and they doubt the ability of synthesis to capture the full diversity of qualitative research (Bethel & Bernard, 2010; Dixon-Woods et al., 2004; Evans, 2003; Freeman, Preissle, Roulston & Pierre, 2007; Maxwell, 1992; Petticrew & Roberts, 2003; Sandelowski, Docherty & Emden, 1997). On the other hand, quantitative researchers argue that reliable conclusions can only be drawn from reviews of studies from which all subjectivity and bias are removed (Bernard, 2014; Bernard, Borokhovski & Tamim, 2014; and Bernard, Borokhovski, Schmid & Tamim, 2014). They apply strict evidence hierarchies and include only those studies at the very top of the ladder, true experiments (Bethel & Bernard, 2010; Coalition for Evidence-Based Policy, 2012; Institute of Education Sciences, n.d.; Slavin, 2008).

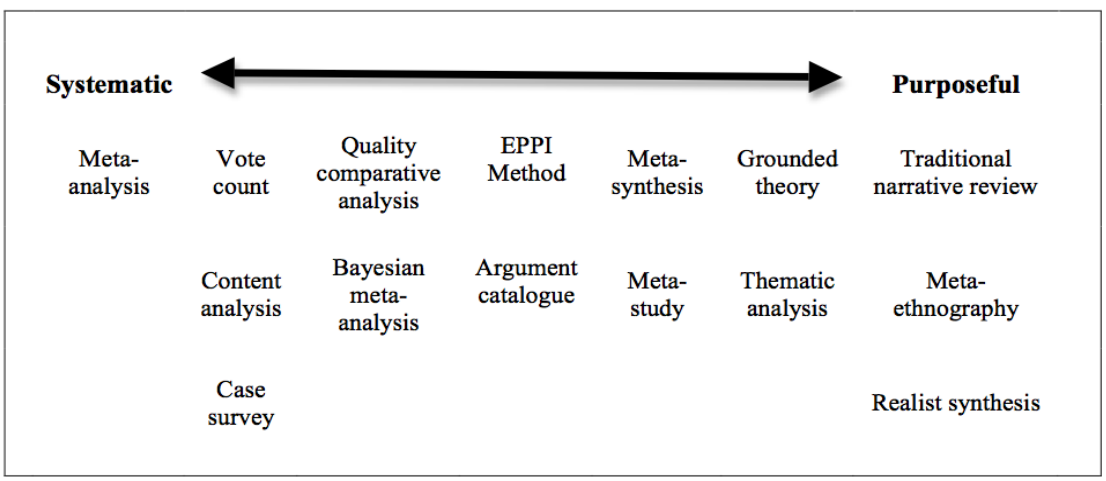

Figure 1. Continuum of synthesis methods (Bethel & Bernard, 2010)

At the same time, researchers on both sides of the divide have come to accept the need to marry the two approaches to expand and deepen understanding. Those on the qualitative side recognize the need for broader relevance while those on the quantitative side recognize the need for more detailed and insightful evidence. Synthesis methods can be chosen to suit the broader policy questions and available evidence. The marriage of both approaches greatly enhances the practicality and applicability of research findings (Abrami et al., 2006; Brunton et al., 2005; Dixon-Woods et al., 2004; Goldsmith et al., 2007; Gough, 2007; Harden et al., 2004; Petticrew & Roberts, 2003; Rees et al., 2006; Sandelowski, 2004; Sandelowski et al., 1997; Sandelowski, Barroso & Voils, 2007; Shadish & Myers, 2004; Thomas et al., 2004).

Methodological Challenges

Four main methodological issues challenge diverse evidence synthesis. First, synthesis methods are tailored to specific types of evidence. Evidence diversity challenges that very approach. Second, the notion of study "quality" is quite different from one approach to another, with some qualitative researchers rejecting the idea altogether. Third, as there is no agreement on an understanding of study quality, it is unclear how criteria can be applied to justify inclusion or exclusion of studies from the synthesis or review. Finally, because sampling techniques reflect the purposeful and systematic divide discussed above, qualitative and quantitative studies are not easily compared, particularly as some synthesis methods use sample size to weight the value of each study (Bethel & Bernard, 2010; Borenstein, Hedges, Higgins & Rothstein, 2011).

Despite the challenges, many approaches to the synthesis of diverse evidence have emerged. Some have been developed precisely for this purpose, while others extend primary methodologies to literature synthesis. Synthesis methods can be effectively characterized and compared using the systematic – purposeful continuum discussed above. All reviews share a common structure consisting of several steps (Gough, 2007):

1. Problem statement/statement of research question;

2. Search, retrieval, and selection of studies;
3. Analysis of studies;
4. Synthesis of studies.

The steps themselves can be characterized as systematic, purposeful, between the two, or a combination of the two. In Table 1, the steps of a variety of methodologies are compared (from Bethel & Bernard, 2010).

Table 1. Steps of different synthesis methodologies

Methodology	Search	Selection	Analysis of studies	Synthesis of studies	Discussion
Meta-analysis	S	S	S	S	P
Vote count	S	S	Depends	S	P
Case survey	S	S	S	S	P
Content analysis	S	S	P - S	S	P
Qualitative comparative Analysis	P	P	S	S	P
Bayesian meta-analysis	S	P	P	S	P
EPPI method	S	S	S	S	P
Argument catalogue	S	S	S	S	P
Thematic analysis	S-P	P	P	P	P
Grounded theory	P	P	P	P	P
Meta-study	S	S	S-P	S	P
Meta-synthesis	S	S	P	P	P
Realist Synthesis	P	P	P	P	P
Traditional narrative review	P	P	P	P	P
Meta-ethnography	P	P	P	P	P

P: Purposeful
S: Systematic
S-P: From systematic to purposeful
S&P Both systematic and purposeful
P-S: From purposeful to systematic

This breakdown helps locate each of these methodologies on the Systematic – Purposeful continuum (Figure 1), remembering that these are general guidelines not fixed classifications (Bethel & Bernard, 2010). Many of the qualitative methods have incorporated systematic search and selection methods in an attempt to minimize actual or potential bias. In this regard, the gap between the ends of the continuum is narrowing. Nonetheless, a clear distinction can be made between studies that use purposeful versus systematic synthesis methods. When the purpose is to explore and explain, the synthesis itself will be purposeful, even though all other steps may be systematic. For this reason, the synthesis step determines where studies were placed on the systematic or purposeful end of the continuum (Bethel & Bernard, 2010).

The continuum is also suggestive of appropriate methodologies for the synthesis of a body of evidence. If the evidence is predominantly quantitative, then more systematic approaches may be appropriate. Similarly, qualitative bodies of evidence may best be synthesized with the purposeful methods. It should be noted that Narrative Review and Realist Synthesis have been used to synthesize mixed bodies of evidence also. In both these methodologies quantitative evidence can and will be incorporated to answer specific questions (Bethel & Bernard, 2010).

A mixed approach is most suitable for this dissertation as it seeks to quantify the impact of one-to-one computing while at the same time drawing from a broader pool of studies from which effect sizes cannot be extracted but which may provide insights into the mechanisms underlying one-to-one programs. Specifically two methods listed above will be employed.

Case survey analysis. The case survey methodology is analogous to survey research. This approach treats each study as a survey participant and scores each according to a variety survey items. This approach is particularly useful for scoping studies and theory building and can be applied to large numbers of diverse studies (Bethel & Bernard, 2010). Results will be quantified, but will also serve to develop themes and moderator variables for the meta-analysis.

Mixed effects meta-analysis. As described elsewhere in this section, a meta-analysis involves selecting high quality quantitative studies, extracting from them effect sizes, then aggregating these effect sizes to estimate a population effect sizes. Themes and variables developed in the case survey are tested to determine the degree to which they moderate the general intervention effect.

Consolidating the Evidence

The need for a solid evidence base to inform policy on one-to-one computing implementations is apparent: including Penuel (2006), as many as forty literature reviews have been located that attempt to synthesize the evidence on one-to-one computing in K-12 settings. Of these, however, only Penuel (2006), Fleischer (2012) and Sell et al. (2012) describe systematic procedures for the identification, inclusion, and analysis of studies. Given the nature of the studies included in the Penuel (2006) review, effect size extraction was possible in too few cases for meta-analysis, so studies were synthesized by vote count. Fleischer (2012) and Sell et al. (2012) on the other hand are both narrative reviews and as such are not designed to quantify intervention impact. There is a need to move beyond a "does it work" type of analysis that looks for a causal result of giving each student a computer to a more integrative approach that accounts for the impact of context and timing on the intervention and vice versa, in other words an analysis that asks "does it work, how, why, when, where?" (Lei, Conway, & Zhao, 2008). Importantly, can we situate existing one-to-one implementations on the one-to-one continuum discussed above, and if so, does this classification tell us anything about how, when, or where these interventions have the most impact.

The one-to-one reviews are generally optimistic in their assessment of the progress of one-to-one computing. The most consistent findings highlight the increases in technology use, technology proficiency and positive attitudes toward technology (Belanger, 2000; Bethel, Bernard, Abrami & Wade, 2008; Fleischer, 2011; Holcomb, 2009; Loertescher, 2006; O'Hanlon, 2007; Penuel, 2006; Rockman, 2004; Valiente, 2010; Wambach, 2006). Many hail improvements student writing, engagement, behavior and attendance (Belanger, 2000; Holcomb, 2009; O'Hanlon, 2007; Rockman, 2004) although others caution that these findings are largely self-reported or anecdotal (Boyd, 2002; Maderthaner, 2007; Penuel, 2006; Sell, Cornelius-White, Chang, Mclean and Roworth 2012). Although there are self-reported findings of achievement gains, there is agreement that these finding of gains in student learning, at least as measured by standardized tests, was not supported by evidence (Belanger, 2000; Bethel et al., 2008; Boyd, 2002; Loertscher, 2007; Rockman, 2004; Sell et al., 2012; Warschauer & Matuchniak, 2010).

While success in standardized tests has not been demonstrated, many reviews question whether standardized tests are the appropriate measure for the kinds of learning that will take place in laptop classrooms (Boyd, 2004; Fleischer, 2011; Holcomb, 2009; Rockman, 2004; Warschauer & Matuchniak, 2010). Warschauer and Matuchniak (2010) in particular have proposed that we need to expand our conception of literacy in a digital world beyond reading and numeracy to include skills that are more appropriate for 21st century life, for example information search, retrieval and integration and the manipulation of information using digital tools. Whatever the measure used, monitoring and evaluation is seen as a key ingredient to program success (Bonifaz & Zucker, 2004; Camfield, Kobulsky & Paris, 2007; Hirji, Barry, Fadel & Shannon, 2010; Lento & Salpeter, 2007; Nugroho & Lonsdale, 2009; Valiente, 2010; Zucker, 2005).

Monitoring and evaluation faces challenges of its own, however. Clearly defined program goals are a pre-requisite for effective monitoring and evaluation, but in too many programs, goals are poorly defined or inadequately linked to program implementation (Bonifaz & Zucker, 2004; Boyd, 2002; Fleischer, 2011; Penuel, 2006; Severin & Capota, 2011; Spires, Oliver & Corn, 2011; Zucker, 2005). Added to which, policy makers may set goals based on anecdotal reports and political expediency rather than scientific research (Maderthaner, 2011; Severin & Capota, 2011).

One factor on which the reviews agree on is the role of teachers. The reviews consistently report that the role of teachers and hence also their preparation play a central role in program success (Bebell & O'Dwyer, 2010; Bonifaz & Zucker, 2004; Hirji et al., 2010; Holcomb, 2009; Lento & Salpeter, 2007; Nugroho & Lonsdale, 2009; O'Hanlon, 2007; Penuel, 2006; Severin & Capota, 2011; Spires, Oliver & Corn, 2011; Rockman, 2003; Wambach, 2006; Weston & Bain, 2010; Zucker, 2005). The degree of consensus on the importance of the role of the teacher is surprising because in some cases like the OLPC, the programs themselves do not emphasize the role of the teacher. At least three reviews of OLPC evaluations, including a review by the OLPC Foundation itself, report that more emphasis must be paid to the role and preparation of teachers (Hirji et al., 2010; Nugroho & Lonsdale, 2009; Severin & Capota, 2011). In fact, several of the reviews of the OLPC take note of the top-down, techno-centric approach common to many OLPC programs, arguing that more attention must be paid to integrating the laptop programs into the local contexts (Camfield, Kobulsky & Paris, 2007; Nugroho & Lonsdale, 2009). In general, though, the OLPC reviews are optimistic about the present and potential success of the program. They note, however, that the impact of the OLPC will be greatest when integrated within existing systems, otherwise local stakeholders will treat the program with distrust and rather than support.

OLPC, like many other one-to-one programs, emphasizes that the laptops will act as vehicle for social justice and equity as their use and impact will extend beyond the classroom. They propose that increased access to technology will bridge the digital divide (The Abell Foundation; 2008; Belanger, 2000; Camfield, Kobulsky & Paris, 2007; Chan et al., 2006; Hirji et al., 2010; Penuel, 2006; Severin & Capota, 2011; Valiente, 2010; Warschauer & Matuchniak, 2010). Increased access does not guarantee increased equity, however. Without carefully planned interventions that target specific ways that access can improve educational and life outcomes, equity issues will remain or worsen due to increased costs (Belanger, 2000; Boyd, 2004; Lento & Salpeter, 2007; Warschauer & Matuchniak, 2010). Finally, for all programs, costing information needs to be more carefully reported. Although technology costs are declining, some sort of cost benefit effectiveness metric needs to be developed to allow for fair comparisons with potentially competing programs (The Abell Foundation, 2008; Camfield et al., 2007; Sell et al., 2012; Severin & Capota; 2011).

In summary the existing reviews highlight many factors that may contribute to or inhibit the educational impact of one-to-one laptop computing in K-12 classrooms and summarize reports of success in technological, educational and social outcomes. In particular, they note that despite many reports of academic impact, only self-reports and anecdotes support this finding. Technology is being used, and technology skills are improving. They note the importance of monitoring and evaluation, but call for improved metrics to assess “21st century learning” and better reporting and standardization of program costs. Finally, the reviews emphasize the role of teachers in program success. This dissertation makes a unique contribution to the literature on one-to-one computing for several reasons:

1. It is the most comprehensive review of one-to-one programs in K-12 settings;
2. It is the first to measure quantitatively the impact of one-to-one programs using meta-analysis;
3. It measures the impact of one-to-one programs on the following outcomes: Technology Use, Technology Proficiency, Student Achievement, Attendance,

Student Engagement, Student Satisfaction;

4. It measures the impact of moderating variables related to study characteristics;
5. It measures the impact of moderating variables related to program context;
6. It refines the meta-analytic findings with reference to a case survey analysis of studies.

Summary

Since the first program in 1990, implementations of one-to-one laptop computing programs have spread globally, driven by an unflagging belief in the capability of technology to impact educational outcomes. Historically, lack of consistent access to technology has been a vexing barrier to realizing the hoped-for gains of classroom-based technology. As computers became more affordable and portable, continuous technology access for every teacher and student was possible through one-to-one laptop deployments, where every teacher and student would receive a laptop computer. One-to-one laptop program goals have included: developing 21st Century skills, bridging the “digital divide”; increasing technology use, increasing technology proficiency and literacy; improving student motivation, attendance and discipline, improving student achievement; enhancing problem-solving and critical thinking skills; and transforming learning by shifting the focus from teacher centered to student centered approaches.

There are two broad schools of the role that laptops will play in the transformation. In the first, laptops are seen as central mechanism for change that will in many ways supplant the traditional role of teachers and classrooms in a new student-centered, technology-enhanced learning paradigm. The second proposes that laptops will facilitate a broader school transformation process driven primarily by the changing but still central role of the teacher and learning support systems. Laptops are seen as an essential tool in this broader transformation process. While the broad visions of laptop programs are at odds, there is more agreement on the actual mechanisms that facilitate learning gains in laptop programs – the program theory. Technology-enhanced learning environments, technology-enhanced instruction, computers as mind tools or learning tools, computers as productivity tools, computers as tools for collaboration and communication, computers as links to online learning environments, computers as tools for information access, and the computer as a learning medium itself; are all cited as mechanisms through which laptops will enhance learning.

At the same time, program-level variables may also be at work impacting the success or otherwise of laptop deployments. Implementation fidelity, or the degree to which the program has been implemented as intended, if at all, will certainly impact program success. Moreover, implementation fidelity itself can only be seen as an indirect input if the ultimate goal is improving student learning and achievement. Implementation fidelity will involve putting in place all the necessary supports to ensure successful technology integration. Technology integration, though seen as a goal in its own right by some, is itself an indirect input that is intended to lead to increased technology use. Technology use of an appropriate sort is the input that can impact learning. The degree to which each input impacts the other and the degree to which they all impact student learning remains an open question.

The literature of one-to-one laptop implementations is broad including reviews, books, descriptive and opinion articles, and primary studies. While several of the reviews can be described as systematic (notably Penuel, 2006, Fleischman, 2011 and Sell et al., 2012), none have attempted to quantify the impact using quantitative synthesis techniques, whether meta-analysis or otherwise. At the same time, because of the diversity of approaches of the primary studies, meta-analysis is not always applicable. Methods for the systematic synthesis of diverse evidence are needed. This type of approach is fraught with controversy with quantitative opponents cautioning against introducing bias and subjectivity when including studies other than those that meet fairly stringent standards of quantitative research, while qualitative opponents caution that the very notion of research synthesis will always result in reductionism, robbing qualitative studies of their *raison d'être.*

From the literature several key issues present themselves for investigation. The grandest of these of course is whether one-to-one laptop programs work, that is, whether they impact intended outcomes. Several intervening mechanisms have been proposed that may moderate program impact. First, do the originally conceived program goals tell us anything about how the program was implemented and how it eventually worked? Second, does the program theory – the way program architects imagine laptops to have an impact on educational outcomes – impact outcomes? Third, do implementation characteristics impact one another and ultimately impact educational outcomes? Finally, are the proposed variables sufficiently explanatory to predict future program success?

Objectives of this Study

The proliferation of diverse, sometimes conflicting one-to-one computing research lends itself to systematic analysis. This dissertation sought to bring order to this diversity of information through a three-fold analysis. The first component was exploratory and employed the case study and methodology to categorize and draw general themes from as broad a category of studies as is possible. The second component was inferential and attempted to answer the following substantive questions regarding the impact of one-to-one computing in K-12 environments using meta-analytic methods:

1. Is there a general laptop effect on the variables of student achievement, technology use, technology proficiency, motivation, attendance, and discipline?
2. Are those general effects moderated by study characteristics: quality of design, type/level of measurement used, type of study in relationship to the program (internal, external or published study)?
3. Are the general effects moderated by other variables as predicted in the literature, namely:
    a. Does technology use moderate technology proficiency;
    b. Do any or all of the following moderate achievement: technology use, technology integration, program theory, program implementation?

The third component was explanatory and used the findings of the first component to attempt to explain the findings of the second component in a synthesis of syntheses.

In this study, one-to-one computing was defined as educational settings in which each student has a computer to use every day for no less than one half of an academic term (6 weeks). While there is fertile data for research in both K-12 and post-secondary schooling, this study focused on one-to-one computing in K-12 environments for the sake of limiting scope. A parallel study focusing post-secondary environments would be equally important. In some one-to-one programs students have full time access to the computers: that is they are allowed to take them home; in others, students can only use the computers at school. Though these two types of programs are unique, for the purpose of this study they were both classified as one-to-one programs. Given the need for portability, one-to-one computing initiatives usually involve students being issued with laptop computers. Some programs refer to portable computers as laptops, while some call them notebooks. This study used the term “laptops” to refer to laptop or notebook computers. Initiatives where students use handheld computers as opposed to laptops were not included in this study. This study attempted to determine how, to what extent, and under what circumstances does one-to-one computing in K-12 settings impact educational goals including but not limited to student achievement, student and teacher technology use, technology proficiency, and attitudes toward technology, through a systematic review of primary implementation and intervention studies and evaluation reports.

CHAPTER 3 – METHODOLOGY

The main purpose of a systematic review is to locate the research that is available about a particular research question or idea, and use systematic methods to determine what conclusions or inferences can be drawn reliably from this data (EPPI-Centre, 2009). Meta-analysis is perhaps the most well-known and well-developed of the review methodologies. Meta-analysis was developed as a systematic method to bring order to and reconcile varied research findings on a single research question. By treating individual studies like participants in a primary study, the meta-analyst extracts "effect sizes" or estimates of the actual or standardized impact of the intervention. The effect sizes are averaged to estimate the "true" effect of the intervention – the point estimate of the population effect size, formally. It is assumed that study effect sizes will converge around the point estimate, much the way that sample scores converge around the sample mean. When studies are similar in design, research question, and treatment, we can be confident that meta-analysis yields a robust estimate of intervention effect.

In educational research, interventions and studies of interventions rarely share this degree of similarity. There is always a concern that the studies and interventions are sufficiently different that it is unreasonable to expect that the effects will converge around a single population estimate. Effects are said to be heterogeneous in this case. A valid criticism of meta-analysis is that in the case of heterogeneous results, the point estimate of population effect size has no practical meaning – it is just a weighted mean of a set of unrelated numbers (Leech & Onwuegbuzie, 2004). Meta-analysts have developed tools for addressing heterogeneity: random-effects models, sub-group analysis, or moderator analysis (see below). For each of these methods, we use some study and intervention characteristics to help explain the distribution of effects. While the point estimate may not have any practical meaning, convincing explanations for variability can actually provide more useful information by revealing which contextual factors enhance and which hinder learning gains from an intervention.

In the case of one-to-one laptop computing, interventions are as diverse as the types of evidence reporting on them. Heterogeneity analysis plays an important role in determining contextual factors that contribute to program success. For this dissertation, extracting as much contextual data from studies was critical. With this in mind, the review was completed in three sections:

1. Case survey – Initially, all included studies were assessed according to a variety of survey items, like study feature coding in meta-analysis, and then the aggregate survey data were analyzed. In addition to extracting summary data this approach helped determine the development of group profiles. This section concluded with a discussion of themes emerging from the analysis with examples from specific studies.
2. Meta-analysis – Quantitative studies from which effect sizes could be extracted were meta-analyzed. The effect size used was standardized mean difference (Cohen, 1988), adjusted for small samples using Hedges *g* (Hedges & Olkin, 1985). The weighted mean effect size was used to estimate the population effect size. Given the diverse nature of even the quantitative studies random-effect models were used to calculate general effects for each outcome variable. Mixed models were used to explore and analyze data variability.
3. Synthesis of syntheses – In the discussion section, findings from the two syntheses were explored. Themes, categories, and profiles drawn from the case survey analysis in addition to quantitative findings from the meta-analysis

informed this step. In addition to using the data to propose typical or representative models this synthesis attempted to describe the processes that lead to apparently unique cases.

The study was arranged as follows:

1. Problem statement;
2. Search, retrieval, and selection of studies;
3. Case survey;
4. Meta-analysis;
5. Synthesis of syntheses (Discussion).

Problem Statement

Statement of the Research Question

As stated above, the research question was as follows: how, to what extent, and under what circumstances does one-to-one computing in K-12 settings impact educational goals including but not limited to student achievement, technology use, technology proficiency, engagement, attendance, and attitudes toward technology?

This dissertation sought to answer this multi-faceted question through a three-fold systematic review of diverse primary intervention studies and evaluation reports of one-to-one laptop computer implementations. The first component was exploratory and employed the case study methodology to categorize and draw general themes from as broad a category of studies as possible. The case survey asked the following questions: what variables or groups of variables provide insight into and allow for useful comparisons of the one-to-one programs being studied? Do any of the following frameworks apply: technology first – balanced approach continuum, technology integration, implementation fidelity, program goal or theory?

The second component was inferential and attempted to answer the following substantive questions regarding the impact of one-to-one computing in K-12 environments using meta-analytic methods:

1. Is there a general laptop effect on the variables of student achievement, technology use, technology proficiency, engagement, attendance, and attitudes toward technology?
2. Are those general effects moderated by study quality?
3. Are the general effects moderated by contextual variables, as predicted in the literature, namely: technology use, technology integration/program implementation, duration, program theory, year, age, program size, or gender?

The third component was explanatory and used the findings of the first component to explain the findings of the second component in a synthesis of syntheses.

Terms and Definitions

Key terms were identified for document searches. All key terms and definitions, search strategies, decisions and results, retrieval, inclusion/exclusion criteria are recorded in the study codebook. Key terms were defined as follows:

One-to-one computing. Educational settings in which each student has a unique laptop computer to use for educational purposes in every class, every day for no less than 6 weeks (Penuel, 2006). In some one-to-one programs students have full time access to the computers: that is they are allowed to take them home; in others, students can only use the computers at school. Though these two types of programs exhibit unique characteristics, for the purpose of this study they were both be classified as one-to-one programs and included in the study. This difference was noted in the case survey.

Student Achievement. The assessed performance on a standardized assessment, particular assignment, a group of assignments, or the composite or average score over a series of assignments. Achievement scores must be reported in both the laptop and comparison condition and be similar enough to be compared one to the other (Bernard et al., 2009). Both subjective and objective measures were included and coded in the case study.

Technology Use. The frequency that and purpose(s) for which the laptops (and other related technologies) were used. Technology use as an outcome variable refers to frequency of use only. Technology use as a moderating variable or study feature refers to both frequency and purpose.

Technology Proficiency. The ability of students to use the available technology, particularly laptops, including but not limited to productivity software, communication tools, search and retrieval tools, and cognitive tools (Schmid et al., 2014).

Technology Integration. The degree to which technology is incorporated into the teaching and learning process. Technology integration consists of four components: (a) access, (b) technological and pedagogical support, (c) professional development, and (d) teacher and student technology use (Shapley et al., 2006a).

Engagement. The degree to which the intervention has impacted the willingness of students to apply themselves to their studies. This category also includes the concepts of motivation, self-discipline, time on task, attention and interest (Shapley et al., 2006a).

Attendance. The degree to which the intervention has impacted the regularity with which students go to school.

Technology Attitudes. How and to what extent the intervention has impacted attitudes toward technology. By definition, this measure is self-reported.

Whether these variables were self-reported or measured was coded as a study feature.

Search, Retrieval and Selection of Studies

Search Strategy

The following keywords and descriptors were used for document searches: one-to-one, ubiquitous computing, laptop initiative, laptop computing, K-12, school, education, laptop, notebook, netbook, pda, handheld, mobile, portable, technology integration, personal digital assistant, computers, evaluation, technology uses in education, computer uses in education, handheld computer, lab, access to computers, computer assisted instruction, computer attitudes, computer centers, computer literacy, computer managed instruction, and integrated learning systems. The following databases were searched using a variety of combinations of the search terms: ERIC, ProQuest full text, ProQuest dissertations, ProQuest CBCA Canadian, Educational Technology Abstracts, and Academic Search Premier. In addition, using the same search terms, Internet searches were conducted using the Google and Google Scholar search engines. Additional web resources were accessed using several online one-to-one clearinghouses: One-to-One Information Resource (http://www.k12one2one.org/), Ubiquitous Computing Consortium – Literature Review and Resources (http://ubiqcomputing.org/lit_review.html), One-to-One Institute (http://sparty.crt.net/121/research.cfm), BC Ministry Education – Laptop Initiative (http://www.bced.gov.bc.ca/onetoone/resources.htm), Govt of Western Australia, Dept of Education and Training, Notebooks for students 1:1 (http://www.det.wa.edu.au/education/cmis/eval/curriculum/ict/notebooks/). When dead links were encountered, attempts were made to locate the documents using the Internet Archive's WayBackMachine (http://www.archive.org). Additional documents were located by two methods of pearling: first, additional documents would be identified from reference lists of documents already retrieved, and second, retrieved documents would be scanned for any mention of other school, district, or state laptop programs. The name of the school or district would then be used as search terms to attempt to locate documents relating to the referenced laptop initiative. Searches were first conducted in March 2007 and updated according to the following schedule: ERIC – March 2007, January 2008, March 2008, March 2009, April 2010, Jan 2014; other databases – March 2007, March 2008, April 2010, Jan 2014, hand searches (internet and paper based) – March 2007, March 2008, March 2009, April 2010, Jan 2014.

Finally, when there was evidence of the existence of a K-12 one-to-one program with no publicly available reports or evaluations, schools, school boards, school district offices, or other relevant governing bodies were contacted directly to request access to reports of any evaluation studies.

Selection of Studies: Inclusion/Exclusion Criteria

This review sought to be as inclusive of evidence diversity as possible. As such, minimal exclusion criteria were employed in the initial selection of studies for the Case Survey review. Studies should be evaluations or descriptions of one-to-one laptop computer implementations and as such describe implementation and outcome variables. In the first round of coding, study abstracts were coded for inclusion/exclusion. Note that studies were evaluated against all criteria from the outset, but only certain criteria were used as exclusion criteria for each of the reviews. To establish inter-rater reliability, all abstracts were coded for inclusion/exclusion by two independent coders. Ratings were compared to ensure consistency. For full-text inclusion/exclusion decisions inter-rater reliability will be established in two ways: (a) the author rated all documents two times, the second review at least one month after the other and compared the two sets of coding, and (b) a second coder rated a random sample of 10 percent of documents and then compared findings with the author's coding.

For the Case Survey, studies were excluded only for the following reasons:

- N121 (Not a One-to-One study): Conditions did not fit the One-to-One definition.
- DUR (Duration): The analysis did not consider studies in which the duration of one-to-one computing exposure lasted for less than six weeks.
- NSB (Not school based): One-to-one initiative not in K-12 school environment.
- OA (Opinion article): An article that reflected a personal opinion.
- RA (Review article): An article that included a general review of findings or studies in the field was excluded from the case study and meta-analysis steps.
- MA (Meta-analysis): Meta-analyses addressing one-to-one initiatives was excluded from the case study and meta-analysis.

For the meta-analysis, more stringent criteria were used. Studies had to compare one-to-one computing in K-12 with a control condition (one to many, computer lab time, no technology, a pre-treatment condition). One-to-one initiatives had to be school based and evaluate at least six weeks of the treatment. Outcomes had to include one or more of the following: Achievement, Technology use, Technology proficiency, Attendance, Engagement, Attitudes toward technology, or Behavior. Measures had to be reported in a way that enabled effect size extraction or estimation, including information on total and group sample sizes (quantitative data sufficiency criterion). Other reasons for exclusion are noted below. Studies that satisfied inclusion criteria were retrieved for full text review, regardless of the type of study design: experimental (randomly assigned group comparison), quasi-experimental (comparison of pre-existing groups) or pre-experimental (one group pre-test and post-test). Study design was coded in the Case Study. Studies were excluded from the quantitative analysis for the following reasons:

- DOA (Description or opinion article): An article that reflected personal opinion or a description of a specific implementation that did not report outcomes.
- QLR (Qualitative research): A qualitative study were excluded from the quantitative analysis but could be included in the narrative summary if the study reported one or more outcomes identified for this review.
- ISD (Insufficient Statistical Data): Articles that did not fit the quantitative data sufficiency criterion were not be included for quantitative analysis, but were eligible to be included in the narrative summary.

Studies not matching the criteria of the particular review step were excluded from that section. Studies were coded according to the level of confidence about the decision made using a 5 point scale: (1) almost definitely unsuitable; (2) probably unsuitable; (3) doubtful, but possibly suitable; (4) most likely suitable; and (5) almost definitely suitable. Abstracts rated (3) or higher were retrieved.

Analysis of Data

Case Survey Analysis

The purpose of the case survey tool was to evaluate each one-to-one laptop program according to a variety of survey items, thereby creating a comprehensive case profile of each program. The case survey sought to answer the how, under what circumstances, when, and for whom parts of the research question. More specifically, responses were used to evaluate whether the frameworks discussed above (technology first – balanced approach continuum, comprehensive school reform, technology integration, implementation fidelity, program goal or theory), could be usefully applied to the one-to-one programs analyzed. Data were aggregated and analyzed using descriptive statistics and correlations. Aggregated case survey data were used to develop themes and constructs for study. These constructs were used as grouping variables and moderators for the meta-analytic section.

Survey items were drawn from the literature and from iterative sample coding at the beginning of the case survey process and reflected themes discussed above – implementation fidelity, diffusion of innovation, technology adoption, one-to-one computing as comprehensive school reform – in addition to items reflecting study and intervention characteristics. Below is a list of survey items drawn from the literature grouped into five sections.

Study Variables. These included items that described the study itself, such as study design, publication information, and study orientation (what relationship the study authors have to the program).

- Type of study;
- Research design;
- Sample size;
- Treatment duration;
- Comparison group (Wozney et al., 2006).

Demographic Variables. These included items that described the program context, for example, size of implementation, ages of students, and location.

- Level of Program;
- Type of educational institution (public/private);
- Age of participants / Educational level;
- Gender;

- Location of program (urban, suburban, rural) (Wozney et al., 2006).

Implementation Variables. These included items that described program implementation such as delivery of machines, policy creation, professional development, and establishment of technical support.

- Laptops deployed and working;
- Educational design;
- Curriculum development;
- Professional Development;
- Wireless infrastructure;
- Tech support& maintenance;
- Relevant peripherals;
- Stakeholder buy in;
- Student laptop ownership;
- Staged implementation;
- Pilot studies;
- Planned evaluation;
- Professional development/in-service training on using computer technology in the classroom;
- Timing of Professional development exercises (Inan & Lowther, 2010a; Shapley, et al., 2010; and Warschauer, 2009).

Each implementation variable was scored and the implementation scores were combined into a single technology integration score from 1 to 4 as follows: 1 = minimal integration, 2 = partial integration, 3 = substantial integration, and 4 = full integration. This overall "technology integration score" was intended to reflect as closely as possible the various factors impacting technology integration discussed above. The score was used as a proxy for program implementation fidelity. Typically, programs with minimal integration (technology integration score = 1) could be best described as technology only programs, involving little more than hardware deployment. In these programs, teachers received very little professional development, very little technology and administrative support, little to no classroom guidance on how to integrate the laptops into teaching activities, and no guidance on how to adapt the curriculum to take advantage of a technology-rich environment. Classroom practices were not changed to take advantage of the technology affordances, in particular, technology was seldom used to support core learning.

In programs with full integration (technology integration score = 4) on the other hand, technology integration to support student learning was a consistent theme, receiving support from school leaders, teachers, students and parents alike. Teachers were supported through comprehensive and consistent professional development activities that strengthened their abilities and built their confidence in using technology to transform their teaching and their students' learning. Teachers were encouraged and shown how to use technology to support day-to-day classroom practices, in particular, those uses that promoted higher-order learning goals such as critical thinking, goal setting, self-monitoring, and developing critical research and inquiry skills. Technology was frequently used to communicate more closely with students and parents.

Where there was insufficient information to rate one or more of the factors, the aggregate included only the coded scores. In this way as many studies as possible were given integration scores. This approach, while expedient, introduced a potential threat. On the one hand, such detailed and fine-grained coding reduces subjectivity and catches many different facets of technology integration. On the other hand, the more specific and numerous the items to be coded, the less likely that many studies will have data on all the integration codes. With programs being scored only on the information present in the document, programs with quite different integration experiences could wind up with similar aggregate scores. This issue was discussed further in the Limitations section.

Program Variables. These included items that described the degree to which (if at all) technologies were integrated in the ways described. These were used to infer or confirm program theory; that is how the computers were expected to impact student learning, such as intended and actual uses of technology, and policy statements of intended technology impact.

- Teacher centered instruction (PowerPoint presentations, electronically posted notes, online lectures);
- Student centered learning (problem/project-based learning, individualized learning programs, electronic enrichment activities);
- Expansive (simulations, modeling, virtual experiments);
- Expressive (electronic writing – word processor, blog, etc);
- Organizational/Administrative (electronic grade book/plan book, record keeping);
- Communicative (emails, websites, bulletin boards, web forums, discussion boards);
- Evaluative (electronic assessment, electronic portfolios);
- Informative (electronic research);
- Creative (art, music, design, creative writing);
- Specific general literacy applications;

- Specific technology literacy applications (Wozney et al., 2006).

Outcome Variables. These included items that described outcomes that could be or were attributed to the intervention, such as attendance, achievement, and discipline. These variables are evaluated in terms of whether they were stated as goals (1 = yes, 0 = no), whether they were in fact measured (1 = yes, 0 = no), and whether they were attained (+1 = improvement, 0 = no change, – 1 = no change). Items were drawn from the literature, and supplemented with items drawn from iterative sample coding of a random sample of documents.

- Achievement;
- Problem-solving skills;
- Attendance;
- Motivation;
- Discipline;
- Retention;
- Graduation;
- College-bound graduates;
- Collaboration;
- Student-centered learning;
- Technology deployment;
- Technology use;
- Technology literacy;
- Information literacy;
- Just-in-time professional development;
- Community outreach;

- Media literacy;
- Closing the digital divide;
- 21st Century skills.

Outcome measures. These included items that described how outcomes were measured. Both qualitative and quantitative measures were included. Items are scored as 1 = yes or 0 = no.

- Observation;
- Interview;
- Focus groups;
- Document analysis;
- Survey;
- Course grades;
- GPA;
- Teacher-made measure;
- Researcher-made measure;
- Standardized measure.

Mixed Effects Meta-analysis

The purpose of the meta-analysis was to estimate the population effect size by aggregating effect sizes reported in or calculated from individual studies. The questions that were being investigated derive from the broader research question:

- Did students with continual access to laptop computers (the one-to-one condition) outperform students with more limited access on measures of achievement, technology use, and technology proficiency?
- Did students with continual access to laptop computers (the one-to-one condition) behave

differently than students with more limited access in terms of attendance and engagement?

- Did students with continual access to laptop computers (the one-to-one condition) have more positive attitudes towards technology than students with more limited access?

The “limited access” of comparison groups ranged from no access at all to use of laptop carts for some parts of the day or week (part time one-to-one computing). In the initial analysis, this diversity of access was coded as a study feature. Unfortunately, too few studies described the comparison condition explicitly enough to provide sufficient data for analysis. The questions above all refer to the general effects, in other words, the effects that were measured across all studies within a subset, regardless of quality or study features. In addition, however, these general effects were also tested to see whether they were impacted by study quality or by any one of or combination of contextual variables coded as study features. As stated before, the study questions became:

1. Is there a general laptop effect on the variables of student achievement, technology use, technology proficiency, engagement, attendance, and attitudes toward technology?
2. Are those general effects moderated by study quality?
3. Are the general effects moderated by contextual variables, as predicted in the literature, namely: technology use, technology integration/program implementation, duration, program theory, year, age, program size, or gender?

Retrieved studies were read for final inclusion decisions and for effect size coding. In effect size coding, statistical data from which effect sizes could be extracted according to outcome type was identified and coded (standardized measure, researcher-produced test, teacher-produced test) and type of statistics that allow for effect size extraction. The unit of analysis was independent effect size rather than study, so it was possible that one study could yield more than one effect size. By the same token, because several included studies were annual evaluation reports of the same program, care was taken to ensure that effect sizes from each of these studies were in fact independent in the sense that they did not include the same participants' scores. In some cases, effect sizes from multiple year studies were excluded when independence could not be confirmed. An argument could be made that scores from different samples of the same program cannot be considered to be completely independent and should be counted only once (either by aggregation or exclusion). While independent scores from the same program were often aggregated, in some cases independent scores were retained if they differed from one another sufficiently on one or more of the study feature variables, for example by age or duration.

As a body of research expands the need for reliable methods to summarize and synthesize grows accordingly. The techniques of meta-analysis arose from this need to summarize in an unbiased, systematic and quantifiable way, the plurality of quantitative research on a given research question, particularly in education. Meta-analysis offered the most reliable method of drawing general conclusions about population effects from groups of similar studies (Bernard, 2014).

Effect sizes and effect size extraction. The main unit of interest in a meta-analysis is the *effect size*. Simply put, the effect size is a measurement of the impact of an intervention or the strength of the relationship between two variables. Effect sizes are useful particularly because they are independent of measure and other study-based peculiarities, and hence allow for reasonable comparisons among study outcomes (Borenstein, Hedges, Higgins, & Rothstein, 2009; Hedges, 2009; Lipsey & Wilson, 2001; Shadish & Haddock, 2009). Effect sizes can be of several types, depending on the outcomes compared, for example, standardized mean difference, odds or risk ratios, and a variety of metrics to compare variable relationships (*r, R* squared, eta squared). In addition, the *common language effect size* (CL) has been developed to provide a metric that is more easily understandable to non-scientists (McGraw & Wong, 1992). Methods have been developed to convert from one effect size to another (Wilson, n.d.).

The effect size used for this dissertation was the standardized mean difference. Effect sizes were calculated from data given in studies using formulas developed in Lipsey & Wilson (2001), and the Wilson online effect size calculator (Wilson, n.d.). Reported mean differences were used only when original research data from which effect sizes could be extracted or estimated were not reported. Formulas for converting more unusual effect sizes were found in Nakagawa, S., & Cuthill, I. C. (2007), H. S. Steyn, (2012); and Fritz, Morris, Richler, (2012).

The earliest attempts to calculate an effect size based on mean difference were introduced by Gene Glass (1977). Mean difference is easily calculated by subtracting control from experimental means (or pretest from posttest for pre-experimental studies), but this simple formula will result in a mean difference that is unique to the measure and units used in the given study. Glass proposed dividing by the standard deviation of the untreated (control) group in order to obtain a standardized value that would be comparable across studies:

$$\Delta = \frac{\bar{Y}_E - \bar{Y}_C}{SD_C} \quad (1)$$

Glass's methods meant not only that one study could be compared to another, but more importantly, the standardized measures could be aggregated to give a mean effect size that would estimate a "true" underlying effect size. Glass's effect size had one problem though. The effect size estimation was only reliable if variances of the two groups were similar. Cohen proposed a modification - Cohen's *d* that uses the pooled standard deviation of the two groups as the denominator instead, thus overcoming the issue of differing variances (Cohen, 1988):

$$d = \frac{\bar{Y}_E - \bar{Y}_C}{SD_{pooled}} \quad (2)$$

where the pooled standard deviation is calculated as follows:

$$SD_{pooled} = \sqrt{\frac{(n_E-1)SD_E^2+(n_C-1)SD_C^2}{(n_E-1)+(n_C-1)}} \quad (3)$$

Hedges noticed that Cohen's *d* tended to overestimate the effect for small samples, so to account for this small sample bias, he proposed Hedges *g* (unbiased estimator) which is calculated by multiplying *d* by a coefficient obtained by subtracting the inverse of the sample size from 1. This gives us the following (Hedges & Olkin, 1985):

$$g \simeq d\left(1 - \frac{3}{4N-9}\right) \quad (4)$$

Note that when sample sizes get large *g* approaches *d*, so *g* is suitable for estimating effect sizes for studies with large and small sample sizes. Wherever possible, *g* is used as the effect size metric in this study.

Standard error. Sampling and study sample sizes play important roles in meta-analysis. Studies with larger sample sizes tend to have smaller variances and hence are thought to be better estimates of the "true" effect size (Lipsey & Wilson, 2001). In a meta-analysis it is important to reflect these differences when aggregating effect sizes. Hedges and Olkin (1985) propose using weights derived from the standard error of the effect size. Standard error is calculated as follows:

$$SE_g = \sqrt{\frac{1}{n_e} + \frac{1}{n_c} + \frac{d^2}{2(n_e+n_c)}}\left(1 - \frac{3}{4N-9}\right) \quad (5)$$

The standard error can then be squared to calculate the variance *v*:

$$v_g = se^2 \quad (6)$$

The 95% confidence interval for the effect size estimate is calculated using the following:

$$CI = g \pm 1.96(SE_g) \quad (10)$$

$$CI\ Upper\ Boundary = g + \left(1.96 * SE_g\right) \text{ (10a)}$$

$$CI\ Lower\ Boundary = g - \left(1.96 * SE_g\right) \text{ (10b)}$$

We can use this confidence interval as a test of significance – if zero falls within the confidence interval, our point estimate effect size does not differ significantly from 0 ($\alpha = .05$). Alternatively, we can calculate the *z* value for *g* and evaluate significance from the Unit Distribution table:

$$z_g = \frac{g}{se_g} \quad (11)$$

For the two-tailed test of z_g ($\alpha = .05$), if z_g is between –1.96 and +1.96 then *g* is not significantly different from zero and the null ($g = 0$) must be retained:

For $g = 0$: $-1.96 < z_g < 1.96$ (11a)

Note that the interpretation of the tests of significance using the Confidence Interval (Eq. 10) and z_g (Eq. 11) should match.

Fixed effect vs. random effects models. In this study, the degree to which the studies were, in fact, similar determined the meta-analytic model used. Similarity of studies was judged on two levels, construct and context. Construct similarity is the minimum standard for meta-analysis. The construct is the underlying phenomenon being measured in studies, in this case, one-to-one laptop computing. For example, to aggregate the findings from studies investigating the impact of guided reading programs in K-3 classrooms, there must be a clear definition of "guided reading" and what reading programs fit that definition. While this may seem a trivial matter, this very issue has been one on which meta-analysis has endured persistent criticism (Sharpe, 1997). Unless construct similarity can be clearly established, the studies should not be combined using meta-analysis at all.

Context similarity on the other hand, refers to the degree to which program elements that may influence program impact are similar from one program to another. These contextual elements might include program size, duration, participant ages, socio-economic status, prior learning, among many others. Where studies with similar constructs and contexts are being compared, we might reasonably expect them to be estimating a common "true" effect and that study effects will form a normal distribution around this true effect. If on the other hand, contexts differ from study to study, we might each context to have its own "true" effect and that studies in that context to be estimating the contextual "true" effect. If we could find several studies for each of these unique contexts, we might expect each of these groups of studies to form a normal distribution around a true effect unique to that context. Together, all of these contextually unique true effects themselves form a normal distribution around a grand true effect.

Construct and context similarity determined whether the Fixed Effect or the Random Effects model was used for this meta-analysis. If studies were similar in both construct and context, the mean effect size would have estimated a common true effect, or fixed effect, and the Fixed Effect model would have been used. In this meta-analysis, studies were similar in construct, but not context. Studies were assumed to estimate a variety of true effects around each of which there was a distribution of study effects, so the Random Effects model was used. For this model, even though each study was approximating a unique true effect, these unique effects themselves approximated the grand true mean.

As explained above, there are two main models for meta-analysis, the fixed effect model and the random effects model. For both models we assume that all studies share a similar construct, otherwise it would make no sense to meta-analyze them. For the fixed or common effect model, we assume that all studies also share the same context so that all studies are approximating one common population mean effect size. In this model, there is only one source of variance – analogous to within study variance in primary studies. That is the variance due to the distance of the study effect size from the common effect size. In order to approximate the common or "true" effect size we calculate a weighted mean of study effect sizes. For any of the i studies the weights W_i we use are given by:

$$W_i = \frac{1}{V_i} \quad (12)$$

where V_i is the within-study variance. This means that studies with smaller variances (larger sample sizes) are weighted more heavily and hence have a larger effect on the estimation of the common mean. Note that since the variance is a squared term, the weight will always be positive (Bernard, Borokhovski & Abrami, 2014).

For the random effects model, we remember that there are two sources of variance: the within-study variance as discussed above, but also a "between-study" variance that is the result of the distance between each contextually unique sample mean and the grand population mean. These between-study variances are averaged over the entire distribution of effect sizes to give τ^2, the average between-study variance. The equations for τ^2 are complex. An in depth discussion on their derivation can be found in Borenstein, Hedges, Higgins & Rothstein, (2009). So for any of the i studies in a mixed effects meta-analysis, the total variance is:

$$\text{Total variance} = v_i + \tau^2 \quad (13)$$

The weights for each study in the random effects model are therefore calculated by taking the inverse of the total variance or:

$$W_i = \frac{1}{v_i + \tau^2} \quad (14)$$

Again, both the within- and the between-study variance are squared terms, so the weights for the random effect will always be positive. For both models, to calculate the weighted mean effect size we use the sum of the weights as the denominator:

$$\sum_{i=1}^{k} W_i = W_1 + W_2 + \cdots + W_k \text{ (15)}$$

Because each individual weight is positive, this sum (the denominator) is always positive (Bernard, Borokhovski & Abrami, 2014).

To calculate the numerator for the mean effect size in both the fixed effect and the random effects model, we sum the weighted effect sizes. The weighted effect sizes are obtained by multiplying the weights (fixed: Eq. 12, random: Eq. 14) by the study effect size (Eq. 4):

$$\text{Weighted Effect Size} = W_i g_i \text{ (16)}$$

Note that the weighted effect size can be positive or negative depending on whether the experiment outperforms the control (positive) or the control outperforms the experiment (negative). The sum of these weighted effect sizes is the numerator of the weighted average effect size and can also be positive or negative depending on the direction of the individual weighted effect sizes:

$$\sum_{i=1}^{k} W_i g_i = W_1 g_1 + W_2 g_2 + \cdots + W_k g_k \text{ (17)}$$

To calculate the weighted average effect size called $\overline{g}+$ or *ES,* for the fixed or random models we divide Equation (17) by Equation (15):

$$g+= \frac{\sum_{i=1}^{k} W_i g_i}{\sum_{i=1}^{k} W_i} \text{ (18)}$$

Because the denominator is always positive, the sign of the numerator will determine whether the weighted average effect size is positive or negative (Bernard, Borokhovski & Abrami, 2014).

The variance of the average effect size, V_{g+}, is the inverse of the weights and is the same for both models:

$$V_{g+} = \frac{1}{\sum_{i=1}^{k} W_i} \quad (19)$$

From the variance in both models we can then calculate the standard error by taking the square root:

$$SE_{g+} = \sqrt{V_{g+}} \quad (20)$$

As for *g*, the 95% confidence interval for the *g* +, average effect size estimate, is calculated using the following:

$$CI = g^{+} \pm 1.96(SE_{g+}) \quad (21)$$

$$CI\ Upper\ Boundary = g^{+} + \left(1.96 * SE_{g^{+}}\right) \quad (21a)$$

$$CI\ Lower\ Boundary = g^{+} - \left(1.96 * SE_{g^{+}}\right) \quad (21b)$$

We can use this confidence interval as a test of significance - if zero falls within the confidence interval, our point estimate effect size does not differ significantly from 0 ($\alpha = .05$). Alternatively, we can calculate the *Z* value for *g*+ and evaluate significance from the Unit Distribution table:

$$z_{g^{+}} = \frac{g^{+}}{SE_{g^{+}}} \quad (22)$$

As before, for the two-tailed test of Z_{g+} ($\alpha = .05$), if Z_{g+} is between –1.96 and +1.96 then *g*+ is not significantly different from zero and the null (*g*+ = 0) must be retained:

For $g+ = 0$: $-1.96 < Z_{g+} < 1.96$ (22a)

Note that the interpretation of the tests of significance using the Confidence Interval (Eq. 21) and Z_{g+} (Eq. 22) should match (Bernard, Borokhovski & Abrami, 2014).

Random effects, meta-regression and the mixed effects model. Even when assuming random effects, where each study is estimating a unique “true” effect, we may be able to predict the cause of some of the variation between studies; we may know some of the contextual variables that produce different sets of outcomes. These contextual variables or moderators can be used to produce a more fine-grained analysis of our set of effect sizes in three ways.

1. Categorical moderators – subdivide into subgroups then meta-analyze independently with separate variances (τ^2). This can be done when the levels of the categorical moderators are sufficiently different and when there are sufficient effect sizes to conduct separate meta-analyses at each level. For this dissertation, the set of effect sizes was grouped into outcome type: technology use, technology proficiency, student achievement, attendance, engagement, and school outcomes. The set was large enough to allow for this subdivision and the effect sizes are sufficiently different to warrant it.
2. Categorical moderators – subdivide into subgroups then meta-analyze together with shared or pooled variance (τ^2). This is done when moderators differ by degree rather than type. This approach was taken when determining the impact of coded study features such as program theory.
3. Continuous or quasi-continuous moderators – continuous or quasi-continuous moderators are treated as covariates to build regression models similar to normal regression but using effect sizes instead of scores as dependent variables. This regression of meta-analyses is called *meta-regression.* The variance-explained term R^2 is modified for meta-regression to incorporate the variance terms discussed here (v and τ^2). In this meta-analysis, several variables including study quality, technology integration and duration were treated as quasi-continuous using meta-regression techniques.

For each of these methods we can use Q-tests as omnibus tests to determine the amount of variability explained by our grouping or meta-regression models. The Q value can be evaluated for significance using the Chi-squared distribution. The Calculations for Q and the methods for building the meta-regression models are complex. Detailed discussions can be found in Borenstein et al (2009), and Raudenbush (2009). All calculations and modeling for the meta-analysis were performed using The metafor package: A meta-analysis package for R (Viechtbauer, 2014). A detailed description of the software and its applications can be found in Viechtbauer (2010). The moderators used for the meta-analysis are described below.

Moderators (categorical). The categorical moderators used for the mixed-effects meta-analysis are described below.

- Gender. Programs were coded as F = all-female school or program, M = all male school or program, CE = co-educational school or program or gender not specified).
- Program size. Programs were coded as follows: 1 = Class(es) w/in single school, 2 = Grade(s) w/in single school, 3 = School-wide program, 4 = Selected Schools w/in Board, 5 = Board-wide program, 6 = Selected Schools w/in District, 7 = District-wide, and 8 = State/Province-wide. Although this moderator is ranked numerically in ascending order, the categories overlapped considerably. For example there may have been more schools in a particular board participating (category 4) in one program than schools in a district (category 6). Similarly, in certain large jurisdictions a district wide program may be larger than a state or province-wide program in a smaller jurisdiction. As a result the moderator was treated as categorical and findings were interpreted carefully.

- Program theory. Program theory was open-coded in the Case Survey. From this process, three broad program theory themes were developed: technology-enhanced learning environment (TLE), technology-enhanced instruction (TEI), and use of computers as mind tools or learning tools (CMT). These three program theory categories were used to recode the studies for the meta-analysis.
- Type of outcome. The complete set of effect sizes contained six different types of outcomes. The categorical moderator Type of Outcome therefore had six levels: Technology Use, Technology Proficiency, Student Achievement, Attendance, Student Engagement, and Student Satisfaction. For this moderator the dataset was partitioned into six subsets which were then meta-analyzed separately.
- Subject area. The achievement subset was further subdivided to reflect the academic subject or area of study from which the effect sizes were extracted. The following subject codes were used: reading, writing, mathematics, English/language arts, cognitive skills, and other academic subjects.

Moderators (categorical/quasi-continuous). Several of the categorical moderators were numerically ranked. As such they were also treated as quasi-continuous moderators and analyzed using meta-regression.

- Age. Participant age was coded using the following ranked categorical scale: 1 = elementary school (K-6), 2 = middle school (5-8), 3 = all-ages (K-12), 4 = secondary (7-12), 5 = high school (9-12). Ranks were determined by the median grade level for each category.
- Duration. Program duration codes reflected the elapsed time between the commencement of the program and the program evaluation. Duration codes were

as follows: 1 = < 1 academic year, 2 = 1-2 academic years, 3 = 3-4 academic years, 4 = > 4 academic years.

- Study quality. Study quality was coded using a quality index. The quality index was created by adding together two quality variables: design quality (1=one group pre-experiment, 2=intact groups quasi experiment, and 3=randomized true experiment), and effect size quality (1=low: estimated from p or dichotomous data, 2=medium: estimated from beta weights, adjusted means, and 3=high: direct calculations). Quality index scores ranged from 2 to 6.
- Student/teacher centered learning. Studies were coded on the frequency of teacher-centered instruction and student-centered learning. Each variable (teacher-centered, student-centered) was coded separately on a scale of 1 – 4 as follows: 1 = never, 2 = sometimes, 3 = often, and 4 = almost always.
- Technology integration/program implementation. Programs were rated on a scale of 1 (minimal integration) to 4 (full integration) by combining scores on individual integration items as described in the methodology section.
- Technology use. Although technology use was an outcome (dependent) variable, it was also treated as a moderator variable to determine the impact of technology use on achievement, technology proficiency and other variables. Technology use was coded according to the following scale: 1 = low (less than once a week), 2 = medium (greater than once a week, but not daily), and 3 = high (daily or more frequently). For those studies with technology use effect sizes, Cohen's groupings were used to rank effect sizes: small effects (~0.2) mapped onto the low category, medium effects (~0.5) mapped onto the medium category, and large effects (~0.8)

mapped onto the high category. For those studies without numerical data, codes were extracted from program descriptions.

- Year. Studies were coded for year according to the year that the study was released. The year code categories were as follows: 1 = before 2000; 2 = 2000 - 2004 (5 years); 3 = 2005 - 2009 (5 years); 4 = 2010 - present (5 years).

CHAPTER 4 – RESULTS

This chapter is divided into three sections, Searches, Case survey and Meta-analysis.

Searches

In total, searches yielded 1701 titles for review. Before coding for inclusion, this dataset was analyzed for duplicate and closely similar entries, and for studies reporting the same findings in separate documents. When duplications were removed, the dataset was reduced to 1351 unique studies. Abstracts or short summaries of each document were compiled for coding for inclusion. To establish coding reliability, the author coded the abstracts dataset on two occasions, one month apart, then a second coder coded a random sample of 135 of the documents (ten percent of the complete dataset). Each coding comparison yielded an 85 percent agreement rate. Disagreements were re-examined and discussed (in the case of the independent coder) and a moderated code was accepted. Of the original 1351 documents, 165 were coded for inclusion in the case study and 101 for the meta-analysis. During the effect size extraction process of the meta-analysis fifteen studies were excluded for insufficient statistical data or because they reported the same findings as other included studies, leaving 88 studies for the meta-analysis, from which 231 effect sizes were extracted. These included studies were distributed between evaluation reports, conference proceedings, journal articles, books or book sections and dissertations. As can be seen in Figure 2 below, the largest group by far is evaluation reports. Of the various study types, reports are the only groups that do not have to meet certain quality standards as a matter of course. This lack of quality control in the largest group of included studies places even greater emphasis on coding for study quality, given the potential for low quality studies to skew meta-analysis findings (Bernard, Abrami, & Borokhovski, 2014).

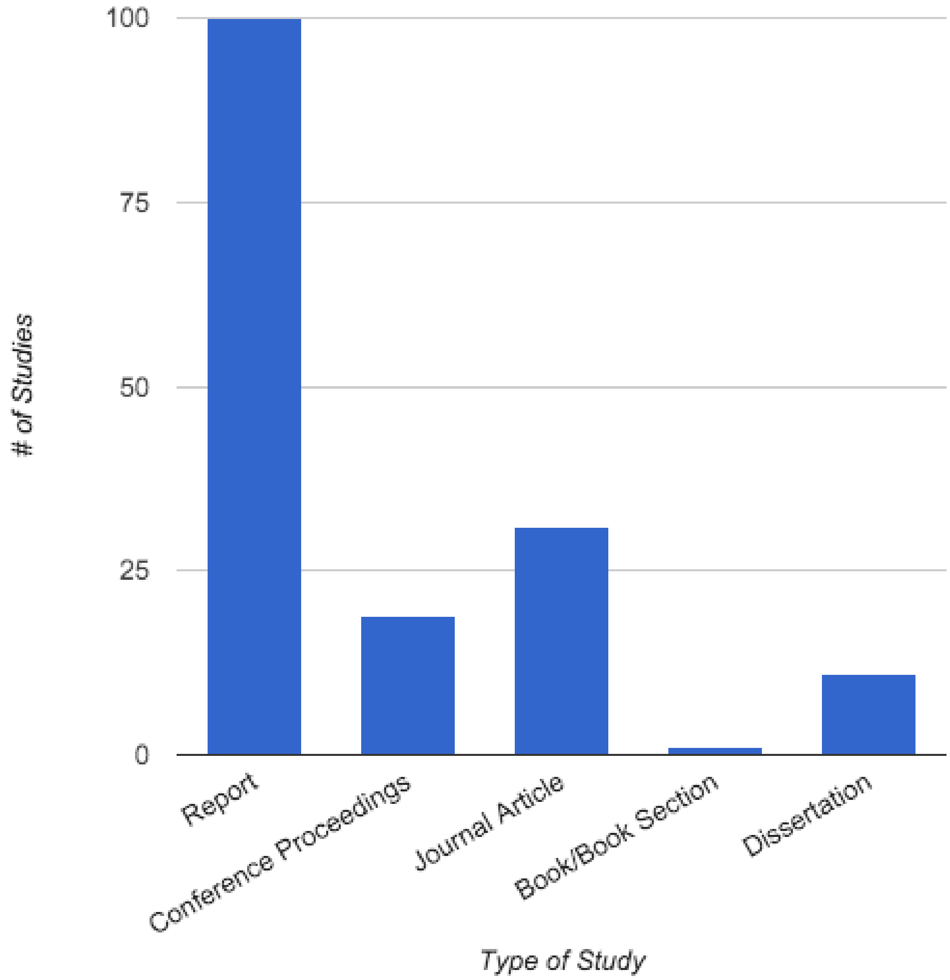

Figure 2. Case survey included studies by type

Case Survey

Documents were coded for the following categories of variables: demographics, program theory, outcomes (goals), outcomes (attained), outcome measures, types of learning, implementation, and technology integration.

Demographics

Two of the demographic variables were not described sufficiently in most studies to provide useful data: socio-economic status and whether the setting was urban, suburban or rural. For the most part, studies were gender neutral. One hundred fifty-seven out of 162 studies described co-educational programs or did not refer to the students' gender at all. Only five studies were conducted in girls-only schools and none in all-boys schools (Table 2).

Table 2. Gender of program participants

All Female	All Male	Co-ed or unspecified
5	0	157
3%	0%	97%

The category "Type of Institution" was similarly one-dimensional. Most programs (128 out of 162 - 82%), were conducted in public schools as shown in Table 3.

Table 3. Types of educational institutions implementing laptop programs

Public	Private	Independent / Charter	Private & Public
129	17	3	6
82%	11%	2%	4%

Although there is more diversity in the category "Levels of Learners" (grade level groupings) and the category "Program Size", in both of these categories one grouping stood out. For levels of learners (Figure 3), the modal grouping was middle school/junior high (grades 5-9) while for program size, multi-school programs were most common (Figure 4).

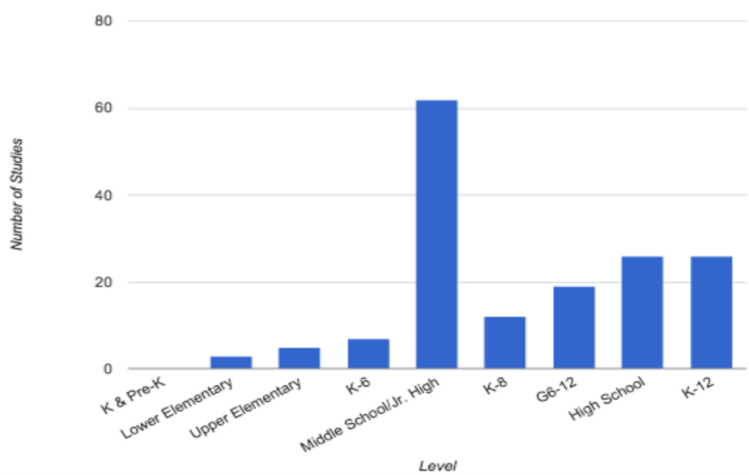

Figure 3. Grade levels of learners in laptop programs

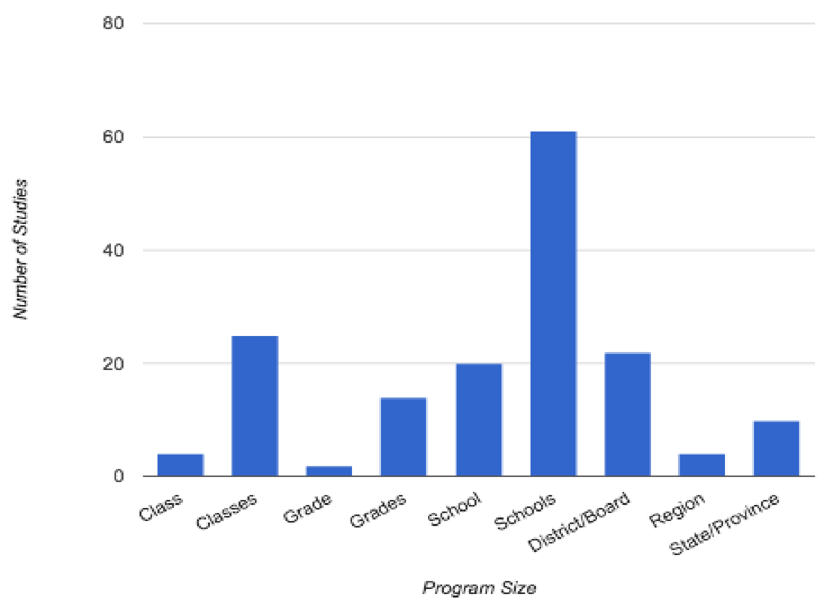

Figure 4. Size of laptop program

Program Theory

As noted above, for this study program theory was defined as a set of beliefs about (a) how laptops in the hands of each student worked to effect the desired changes and (b) the mechanisms through which students' laptops impacted their achievement, motivation, technology proficiency, or any of the other outcomes. In essence, program theory was the reasoning that provided the justification for one-to-one laptop programs over (a) whatever was already happening in classrooms or (b) any other proposed intervention. Surprisingly, few programs made any reference to a theoretical foundation for one-to-one computing, and for those that did, the references were usually vague and non-specific. Of the 162 studies, only 28 or 17% explicitly referenced the theoretical basis for choosing one-to-one laptops (see Table 4). Moreover, though an additional 42 studies made some reference to program theory, these references were vague. Half (81 of 162) of the studies made no direct references to program theory, though inferences could be drawn from other program information. These inferences, however, may be unreliable, depending as they did on the program evaluators' descriptions, and this author's interpretations.

Table 4. Articulation of program theory

	Explicit	Vague	Inferred	No theory evident
Theory articulated	28	42	81	11
Percentage	17%	26%	50%	7%

The apparent lack of importance given to program theory is challenging on two levels. First, without ideas about how the learning tools actually impacted learning, there were no clear criteria to determine what implementation models are most appropriate. At best, programs based decisions on prior experience or the experience of other programs without reference to whether those other programs actually shared the same ideas about how the program will work. At worst, program decisions appeared capricious, even random. Second, without a clear indication of program theory, researchers decided which program goals to measure and upon which to base their evaluations. These decisions were usually made with reference to the literature on technology in education in general, and one-to-one computing in particular. These decisions may not have accurately reflected the intentions of program architects, however. In their recommendations, one evaluation stated clearly that the most important next step is for program administrators to clarify program intentions and goals (Woodbridge, 2000). Perhaps even more surprising, another evaluation was actually tasked with determining what were the benefits of one-to-one computing and what were the ideal implementation strategies by studying the implemented program (Alberta, Alberta Education, Stakeholder Technology Branch, 2009). In other words, the program was launched with the understanding that one-to-one computing can be beneficial, but without any clear understanding of how, when, or why it may be beneficial.

As noted in Table 5, in most of the studies (151 of 162) a program theory was identifiable, even though in many, references underlying theory were vague or had to be inferred. Table 5 lists the numbers of studies ascribing to various program theories.

Table 5. Program theories

Program Theory	Number of Studies	Percentage
TLE - Technology enhanced learning environment	68	45%
TEI - Technology enhanced instruction	42	28%
CMT - Computers as mind tools or learning tools	34	23%
Computer as learning medium (CMT)	4	3%
Learning of computers (programming, comp. sci., development) (CMT)	2	1%
Computers as productivity tools (CMT)	1	1%
Online learning environments (TLE)	0	0%
Information access (TLE)	0	0%
Computer as collaborative/ communication tools (TEI)	0	0%
Total	151	100%

The three most popular theoretical frameworks in many ways reflected the debate discussed earlier over how one-to-one programs impact learning. Moreover, the other categories were collapsed into the first three as indicated by the annotations on the table, resulting in Table 6.

Table 6. Program theories collapsed

Program Theory	Number of Studies	Percentage
TLE – Technology-enhanced learning environment	68	45%
TEI – Technology-enhanced instruction	42	28%
CMT - Computers as mind tools or learning tools	41	28%
Total	151	100%

Technology-enhanced learning environment (TLE), the most generic of the three broad program theories, was found in almost half the studies, while the other two a quarter each. Unsurprising, perhaps, as TLE was the most likely of the three to be inferred where no explicit theory is given. Generally, programs that were designed around either computers as mind tools/learning tools (CMT) or technology-enhanced instruction (TEI) had one or more direct references to these theories, or more commonly, an extended explanation of how the computers would impact learning explained in terms of either of these two theories.

Program theory impacted program outcomes in one of two ways. First, program theory articulation led to better planning, goal setting, monitoring and presumably program impact. We can learn more about this by exploring relationships between program theory articulation and several program variables. Second, the program theories themselves were evaluated for their differential impact on outcomes in the meta-analysis section using moderator analysis. The degree to which a program theory was clearly articulated is related to several important variables. In Table 7, program theory was correlated with Technology integration scores, whether student achievement was set as a goal, whether student achievement was measured, and whether improvement in student achievement was attained. All variables were found to be positively correlated with Program Theory articulation and all *r*'s were significant, though the correlation with Technology Integration was small (0.17, $p < 0.05$).

Table 7. Program theory correlations

	ptartic	techint	achset	achmeas	achatt
ptartic	1.00				
techint	0.17 *	1.00			
achset	0.30 ***	0.14	1.00		
achmeas	0.29 **	0.04	0.31 ***	1.00	
achatt	0.30 ***	0.09	0.19 *	0.62 ***	1.00

$n = 162$ * $p < 0.05$ ** $p < 0.001$ *** $p < 0.0001$

ptartic = Program theory articulated
techint = Degree of technology integration
achset = Achievement goal set
achmeas = Achievement goal measured
achatt = Achievement goal attained

These relationships may have reflected more deliberate planning and more sophisticated understanding of the role of technology in programs where program theory was well articulated.

Program goals

While for many one-to-one implementations program theories are poorly articulated if at all, the opposite was true for program goals. Table 8 shows the abundance and diversity of program goals, whether they showed improvement, no change, regression, or whether they were measured at all.

Table 8. Program goals

Outcomes	Goals	Improvement	No Change	Regression	Not Measured
Technology use	155	143	4	0	8
Technology Deployment	151	146	2	0	3
Achievement	143	53	44	3	43
Technology literacy	122	101	5	0	16
Student Engagement	121	97	14	0	10
Student-centered learning	112	69	33	0	10
21st Century Skills	109	73	4	0	31
Technology as delivery tool	106	82	7	0	17
Motivation	99	73	13	0	13
Information literacy	88	59	5	0	24
Technology as a tool for collaboration	83	53	14	0	16
Student Satisfaction with Technology	70	57	9	0	4
Higher Order Thinking (Problem Solving, Critical Thinking, Creative Thinking)	62	30	11	0	21
Media literacy	62	41	3	0	18
Closing Digital Divide	51	25	7	2	17
JIT Professional development	48	12	4	0	14
Discipline	40	18	9	0	13
Community Outreach	38	25	5	0	8
Student Satisfaction with School	37	16	10	0	11
Attendance	29	9	8	1	11
Retention	8	2	0	0	6
College-Bound Graduates	7	0	1	0	6
Graduation	3	1	0	0	2

Program goals were collapsed into eight themes echoing the variables under study: technology goals, achievement goals, cognitive goals, instructional goals, attitudinal goals, engagement goals, social goals, and school outcome goals. The frequency with which each of the goals in these categories was cited is shown in Figure 5.

The most frequently cited program goals were no real surprise: technology use, technology deployment and student achievement, technology literacy, student engagement, student centered learning, 21st century skills, and technology as a delivery tool. Equally unsurprising was the fact that many of the technology-related goals were attained. More surprising though was the number of times goals were cited but not measured. Chief among these was student achievement. Clearly one of the most important goals (only technology deployment and use were stated as goals more frequently), studies citing student achievement did not report achievement in 43 of 143 cases or 30% of the time. Further, in those studies where achievement was measured in some form, gains were reported in only 53 of the cases (37%).

Apparently there is a gap between the expectations of achievement gains and the reality that achievement is not an automatic outcome of one-to-one programs. Moreover, while many programs touted the potential of one-to-one computers to realize transformational change in teaching and learning, the variables that would seem to be associated with these changes, for example student-centered learning, 21st century skills, information and media literacy, higher order thinking/critical thinking and technology as a tool for collaboration, experienced improvement in only a minority of cases and in many others were not even measured at all.

Broader goals such as discipline, attendance and retention have received less attention than reported in earlier reviews (Penuel, 2006), with fewer than a quarter of studies listing them as goals and fewer still attempting to measure these outcomes. Finally, closing the digital divide was not as important a technology goal as imagined, and an even more difficult one to realize.

Out of the 51 studies that set this goal, only 25 reported improvements and 17 did not measure it at all.

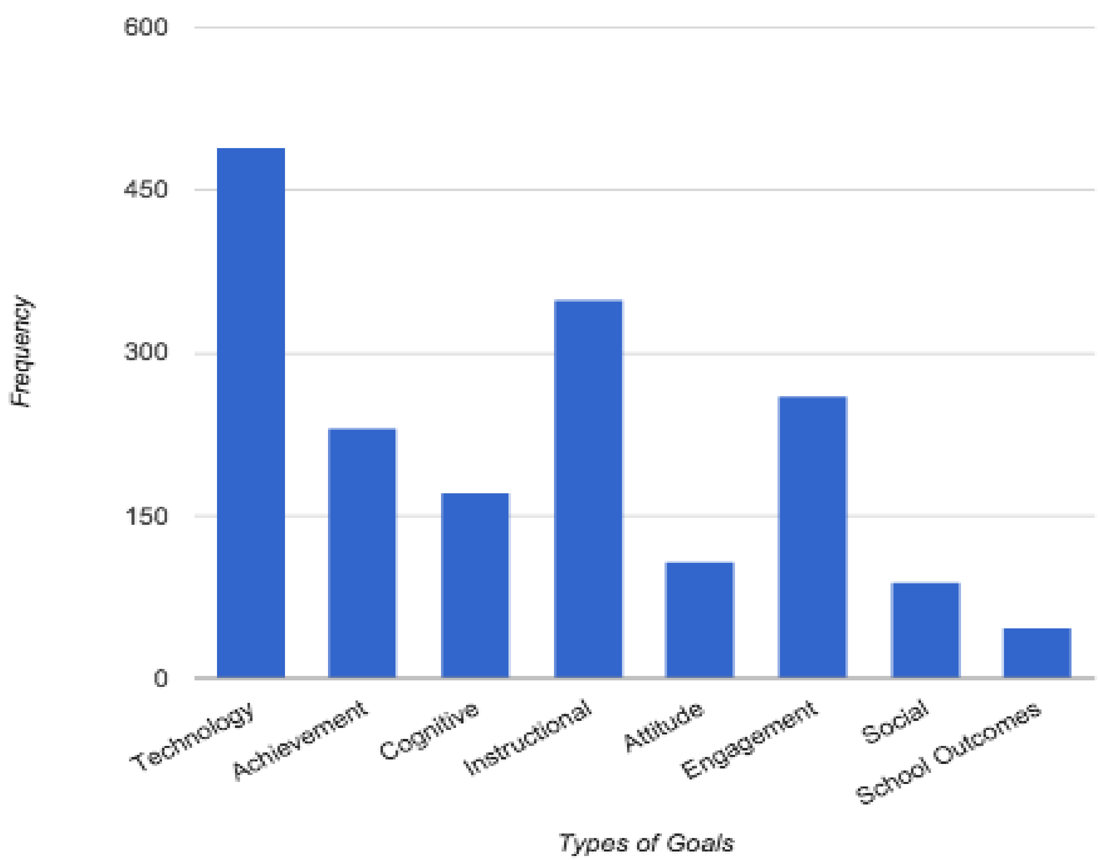

Figure 5. Frequency of program goal categories

Types of Learning

The types of learning activities can tell us several things about the program itself. First, learning activities reflected the program theory and program goals of an implementation. A program based on a theory of computers as learning tools or mind tools focused on learning that was directed by the students themselves and assisted by their technology. Conversely, a program based on a theory of technology-enhanced instruction focused on learning directed and guided by teachers with the assistance of technology. Second, learning activities described the degree to which learning is actually happening "anywhere, anytime." Frequencies of learning activities are recorded in Table 9 below.

Table 9. Frequencies of types of learning activities

	Type of Learning			
Observed?	**Autonomous**	**Mentored**	**In-school**	**Out of school**
Yes	76	61	149	92
No	61	75	4	41
Not Reported	25	26	9	29

The first two types of learning activities, Autonomous and Mentored reflected an emphasis on student-centered and teacher-centered learning respectively. If we assume that CMT is linked to student-centered approaches and TEI is linked to teacher-centered approaches, we would expect to see a fairly equal distribution of autonomous and mentored learning activities, given that the two theories were equally frequent. From Table 9, autonomous and mentored learning were not equally distributed. The results of a goodness of fit test comparing autonomous and mentored learning are reported in Table 10. 26. Cases where either category was not reported were omitted. Of these, 25 did not report both categories and one did not report on Mentored only. This case was also dropped, meaning the cell Autonomous (yes) count was reduced by one.

Table 10. Chi-squared goodness of fit test for Autonomous v Mentored learning

	Type of Learning	
Observed?	**Autonomous**	**Mentored**
Yes	75	61
No	61	75

Chi-square = 2.88, $df = 1$, $p = .09$

The Chi-squared goodness of fit test was significant at the $\alpha = .10$ level.

The second pairing of types of learning compared in-school learning with out of school learning. Both were found to be prevalent, not surprisingly with in-school learning being mentioned in almost all cases. Out of school learning was also common, though not as common as in-school learning. Several programs did not allow students to take laptops home, contributing to the lower numbers of programs reporting at-home learning.

Instrumentation and Measurement of Goals

A variety of methods were used to measure those goals that were in fact measured. Figure 6 below shows the frequency with which each measurement method was used. Echoing earlier reviews, self-report measures were frequently used to measure program impact, with surveys, interviews, and focus groups all among the most frequent methods. All the same, the use of standardized measures was sufficiently common to allow for effect size extraction and hence meta-analysis, in contrast to the data available to earlier reviews.

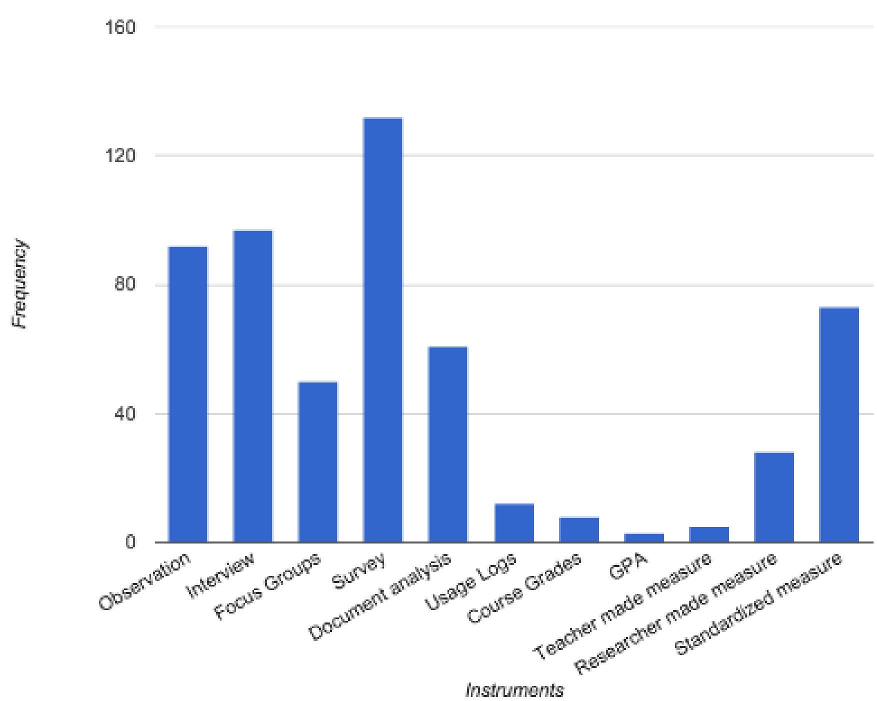

Figure 6. *Frequencies of measurement instruments*

Program Preparation

Several factors have been cited as important to program implementation success including teacher technology beliefs (Inan & Lowther, 2010a & 2010b), community and stakeholder buy in (Nugroho & Lonsdale, 2009), Teacher preparation and support (Severin & Capota, 2011), and monitoring and evaluation (Hirji et al., 2010). Programs were very successful in getting teacher buy in: 120 studies reported positive teacher technology beliefs, 14 reported teachers as neutral (or some positive and some negative), while none reported an overall negative perception of technology. As Table 11 below shows, with the exception of student laptop ownership, all of the other factors measured had good success rates.

Table 11. Degree of program preparation

Implementation	Yes	No	Not Reported
Stakeholder buy in	138	5	19
Student laptop ownership	65	89	8
Staged implementation	108	23	31
Pilot studies	93	36	33
Planned evaluation	131	12	19

Program Implementation/Technology Integration

Program implementation is critical for program success. Our vernacular is filled with witticisms about how good plans are undermined by poor execution (for example "there's many a slip 'tween cup and lip", "good intentions pave the road to hell"), for a reason. Table 12 shows the degree of implementation of a variety of program factors. Of interest in Table 12 is the fact that few of the programs implemented any of the factors extensively. Professional development as a necessary pre-requisite to program success was mentioned frequently in the one-to-one reviews. Clearly several programs were paying attention as most (72) arranged for PD activities to some degree.

Few programs focused extensively on their teachers, however. At the same time, this table may reflect more generally on the difficulty of executing any K-12 programs or reforms. After all, these are laptop programs and only a minority (59) reported that laptops are deployed and working extensively. Of all the implementation factors this was the one that would have to be given the most attention. If many programs were unable to get working machines into the hands of students effectively, then there was likely a bigger implementation issue.

Implementation and preparation scores were aggregated into a single metric: Degree of Technology Integration with scores ranging from 1 – 4 (1 = Minimal, 2 = Somewhat, 3 = Substantial, 4 = Full) as described above in the methodology section. This score was used as a potential moderator in the Mixed Effects Meta-analysis. Figure 7 shows the distribution of Technology integration scores. The results were somewhat encouraging: in more programs integration was rated as "Substantial" than all other groups combined. At the same time, only 22 out of 162 studies were rated as "Full" integration.

Table 12. Degree of program implementation and technology integration

Implementation	**Extensive**	**Somewhat**	**Minimal**	**Not Implemented**	**Not Reported**
Laptops deployed and working	59	85	6	0	12
Educational design	26	60	48	10	18
Curriculum development	25	40	68	7	22
Professional Development	44	72	13	2	31
Teachers' Computer proficiency	12	99	20	0	31
Teacher readiness	32	72	27	0	31
Wireless infrastructure	41	63	6	18	34
Relevant peripherals	22	20	14	3	103
Tech support & maintenance	20	75	13	0	54
Overall support	50	73	7	0	32

The Case Survey revealed that in general, programs were on the right track. More attention needed to be paid to Program Theory to facilitate more efficient goal setting and planning. More focused goal setting would have allowed programs to focus on a smaller set of targeted goals and plan accordingly. That said, programs were able to stakeholder buy-in, both within schools and in the wider communities. It is not surprising that programs achieved some degree of implementation success, though work still needed to be done for more programs to have been rated at full implementation.

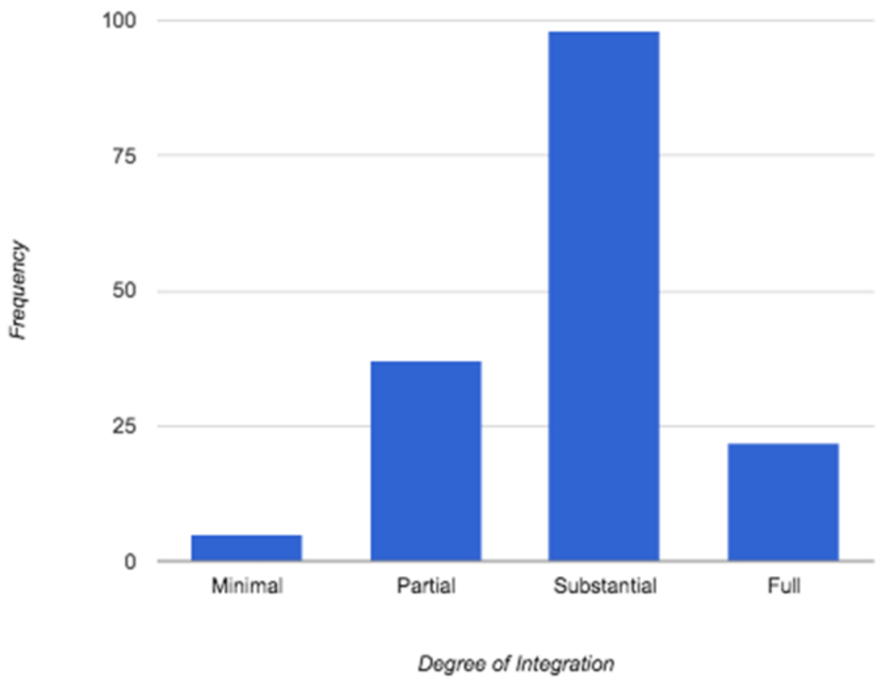

Figure 7. Distribution of degree of technology integration scores

Summary of Case Survey Results

The case survey yielded several interesting findings. Evaluation reports were by far the most numerous type of included document, outnumbering all other types combined. Because of a lack of built in quality controls, particular attention was paid to coding for study quality. Most programs were implemented in public co-educational schools at the middle school level.

Programs implemented in selected schools in a district or board, were most frequent though programs implemented in selected classes, school-wide or district-wide were also popular.

Program theory was the first substantive variable studied. Few studies made explicit or even vague references to program theory, though it was possible to infer a program theory from many others. From the program theories that were identified either directly or indirectly, they could be grouped into three broader theories: technology-enhanced learning environments (TLE), technology-enhanced instruction (TEI), and computers as mind tools or learning tools (CMT). These three broad theories were compared with other program outcomes. TLE was identified most frequently, particularly among studies from which the program theory was inferred. TEI and CMT were equally frequent.

Program goals were numerous and varied. Eight broad categories of goals were identified: technology, achievement, cognitive, instructional, attitudinal, engagement, social, and school outcome related goals. Unsurprisingly, technology related goals were most frequent, and were measured in most reports. Engagement, instruction and achievement were the next three most popular categories, though not as frequently evaluated. In particular, engagement goals were frequently mentioned (discipline, motivation, student engagement) but infrequently measured. Goals related to school outcomes (attendance, graduation, retention) were least evaluated of all. Types of learning activities revealed much about explicit or implicit program theories or goals. Activities were fairly equally distributed between autonomous (student-driven) and mentored (teacher-driven) activities, though the small difference was significant (Chi-Squared = 2.88, p = .09). Though both in-school and out of school learning activities were common the number of programs (41 out of 162) that did not incorporate out of school learning was higher than expected.

Reviews of one-to-one programs noted that much of the evidence of program success is based on self-report measures and anecdotes (Boyd, 2002; Maderthaner, 2007; Penuel, 2006; Sell et al., 2012). Self-report measures were by far the most numerous measures in this group of studies also, but observation and standardized measures were also common.

Program preparation and program implementation contributed directly to program success. Program preparation indices were largely positive. Particularly encouraging was the overwhelmingly positive attitudes of teachers, communities and the commitment to incorporating monitoring and evaluation. Actual implementation indices while still positive, painted a slightly less rosy picture. Encouragingly, the majority of programs achieved "substantial" implementation, but too few have moved to the "full" implementation category.

Mixed Effects Meta-Analysis

Included Studies

As described above, the included studies were expected to be diverse and hence random effects and mixed effects models were used to analyze extracted effect sizes. Of the original 1351 unique studies, 88 studies were included for the meta-analysis, just over a 6% inclusion rate. Similar to the case study, the largest included group for the meta-analysis was evaluation reports that lack the in-built quality controls of the other three groups (Figure 8). Study quality was recorded as a study feature and investigated for systematic influence on meta-analytic findings.

General Effects

The 88 included studies yielded a total of 231 unique effect sizes. Any attempt to meta-analyze the entire set may have been useful to explore bias, but would have run the risk of comparing completely unlike constructs – comparing apples to oranges.

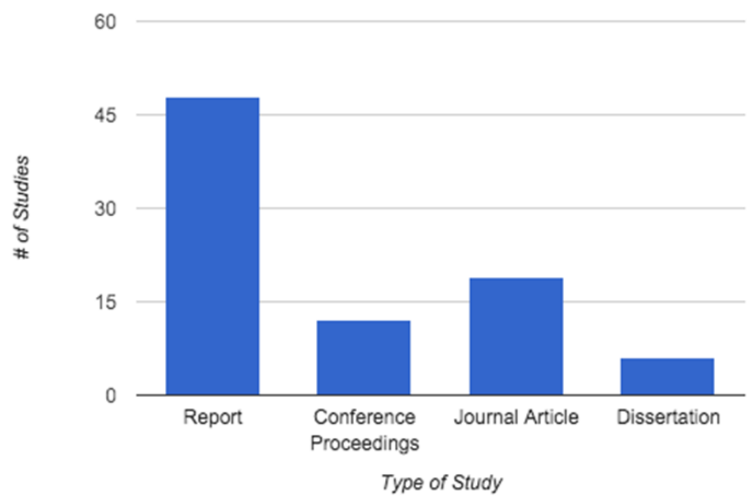

Figure 8. Meta-analysis included studies by type

These effect sizes fell into six broad categories and the dataset was partitioned accordingly: Technology Use (k = 39), Technology Proficiency (k = 22), Student Achievement (k = 112), Attendance (k = 8), Student Engagement (k = 21), and Student Satisfaction (k = 29), the distribution of which is shown in Figure 9. Note that too few studies identified discipline as a unique variable for meta-analysis, so that category was collapsed into student engagement.

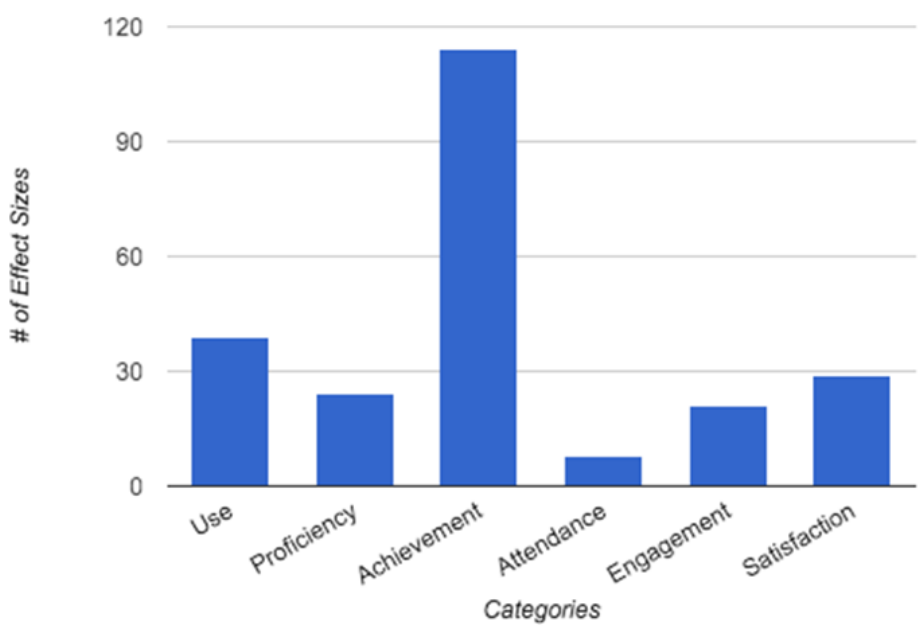

Figure 9. Effect size Categories

The dataset was partitioned in to six subsets of effect sizes corresponding to each of the categories. Each subset was meta-analyzed separately. The results of those meta-analyses are shown in Table 13, with significant average ES estimates in bold. With the exception of attendance, all categories were found to have significant general effects, though of varying magnitudes.

Table 13. General effect by categories

Category	*k*	ES Estimate (*g+*)	Standard Error	*z*	*p*	CI lower	CI Upper	tau-squared	I- squared
Technology Use	39	**0.53**	0.08	6.67	<.0001	0.38	0.69	0.14	64.0%
Technology Proficiency	22	**0.29**	0.08	3.73	.0002	0.14	0.44	0.05	38.1%
Student Achievement	112	**0.23**	0.03	7.38	<.0001	0.17	0.29	0.02	17.2%
Attendance	8	0.00	0.07	-0.03	.97	-0.14	0.13	0.00	0.0%
Student Engagement	21	**0.15**	0.07	2.20	.03	0.02	0.29	0.02	24.9%
Student Satisfaction	29	**0.26**	0.09	3.02	.003	0.09	0.44	0.12	58.7%

Significant findings at $p < .05$ in **boldface.**

Cohen (1988) offered an oft-quoted scale for judging effect size impact: small = 0.2, medium = 0.5, large = 0.8. By Cohen's metrics, one-to-one laptop programs had significant, though small, positive effects on Technology Proficiency (*g*+ = 0.29), Student Achievement (*g*+ = 0.22), Student Engagement (*g*+ = 0.15), and Student Satisfaction (*g*+ = 0.26), and a medium impact on Technology Use (*g*+ = 0.53). Care must be taken when interpreting effect sizes in this manner as in some instances large effect sizes may have little real world impact, and vice versa. It is always necessary to look at the context of the effect size as well. Nonetheless, on the surface these findings may be interpreted as a justification for one-to-one programs.

Study Quality

As noted above, inconsistent study quality can skew effect sizes. Poor quality studies introduce variability into analysis. Included studies in this meta-analysis were from four categories of documents only two of which, dissertations and journal articles have built-in quality control mechanisms. While some conferences make it quite clear that there are peer review processes involved in the acceptance of papers, others are not so discerning. Added to which, even if we argued that those three categories of documents (conference proceedings, dissertations and journal articles) were quality-controlled, evaluation reports outnumbered the other three categories combined. Quality was tested for its impact on overall effect size estimates.

Quality index. A quality index was created by adding together two quality variables: design quality and effect size quality as described in the methodology section. Quality index scores ranged from 2 to 6. The relationship between quality index scores and effect sizes was tested using meta-regression (random-effects model) for the complete set of effect sizes, and for each of the subsets, treating the quality index scores as quasi-continuous variables. For the complete set of effect sizes no relationship was found ($b_Y = 0.006$, $p = .78$, $Q_{\text{Regression}} = 0.08$, $p = .78$) indicating that study quality had no systematic impact on effect size for the entire set of effect sizes.

Similar results were found for all the subsets with the exception of Technology Use. For this subset, ($b_Y = 0.18$, $p = .03$, $Q_{\text{Regression}} = 4.57$, $p = .03$) indicating that the quality index score had a positive relationship with technology use effect sizes. To gain clarity on the source of this relationship, the meta-regression was repeated, this time treating the quality scores as categorical moderators. The highest quality category (6) was the only one that significantly moderated the intercept, so this category was omitted and the quasi-continuous meta-regression was repeated. This time without the highest quality studies, no significant relationship was found between quality and effect size (Technology Use) ($b_Y = 0.07$, $p = .57$, $Q_{\text{Regression}} = 0.32$, p=.57). All the same, the decision was taken to retain the highest quality studies for two reasons: 1) dropping the highest quality studies would be a perverse way to solve this issue; 2) none of the studies in this category individually distorts the Technology Use general effect (see Sensitivity Analysis below).

Publication Bias

Publication bias originally referred to publication or non-publication of studies in journals depending on the significance and the direction of the findings (Rothstein, Sutton & Borenstein, 2005). The result was that the collection of studies available in the published literature was unrepresentative of the complete set of studies on a particular question because non-significant findings and findings the reverse of what was expected were left unpublished. If the published studies were the only ones meta-analyzed, the resulting effect size estimate would be biased toward significant, desirable findings. More recently, publication bias covers any factors that systematically omit studies on a particular question including but not limited to: language bias, cost bias and availability bias (Rothstein, Sutton & Borenstein, 2005). In this study care was taken to search for studies that would not be found in the published literature in order to minimize the possibility of publication bias.

In order to test for publication bias, Rosenthal's fail-safe N tells us how many missing null-effect studies it would take to render non-significant the computed average effect size (Rosenthal, 1979), while Orwin's fail-safe N tells us how many missing null-effect studies it would take to render the computed average effect size trivial (Orwin, 1983). The fsn command in the metafor package for R enables the exploration of publication bias using the Rosenthal, Orwin or Rosenberg method (Viechtbaur, 2010). For the complete set of effect sizes (k = 231), 16,591 additional null-effect sizes would need to be added to nullify the computed average effect size ($g+$) at the α = .05 level. Using the Orwin method, 231 null effect sizes would be needed to reduce $g+$ to a trivial level of 0.15. The funnel plot of the effect sizes was largely symmetrical and so the likelihood of publication bias was negligible. This process was repeated with similar results with each of the subsets save attendance, which had a non-significant $g+$. No studies were needed to nullify or trivialize the result for attendance as it was already a null result. Note that the numbers of studies needed for each of the subsets varied with k for that subset, but was sufficiently large in comparison to the k for that subset to confirm the absence of bias.

Sensitivity Analysis

Because weighting is related to sample size, a large study with a large effect size is going to have a big impact on the average effect size. This may or may not be a desirable result, but certainly the meta-analyst needs to be aware of any single studies contributing disproportionately to $g+$. The purpose of sensitivity analysis is to determine whether any individual studies impact the estimation of $g+$ unduly. Metafor has several methods to explore study influence including the leave1out command that repeatedly fits the model leaving out one study at a time. The resulting dataset can be inspected for outliers – individual studies whose addition or removal has a large effect on $g+$ – and these can be removed if needed. The leave1out command was performed for the complete set of effect sizes and for the subsets and no studies were found to exercise undue influence in the complete set or the subsets.

Technology Use

The histogram of 39 Technology Use effect sizes is shown in Figure 10. The distribution was vaguely normal, right skewed (skewness = 0.78) and somewhat leptokurtic (kurtosis = 0.83). The unweighted mean was 0.58, moderately close to the random effects mean of 0.53, with a standard deviation of 0.59. The median was 0.48. The small sample size may have contributed to the lack of normal symmetry.

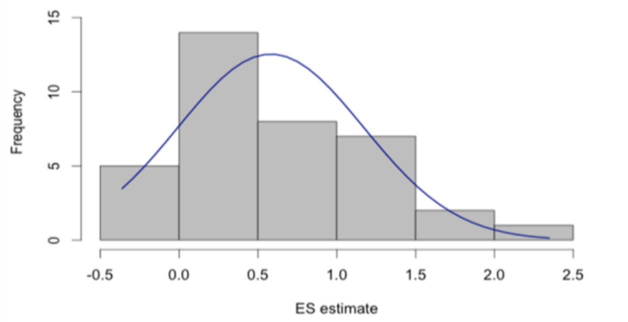

Figure 10. Histogram of technology use effects

First and foremost and in order to impact any other variables, one-to-one programs must have a positive impact on technology use. As predicted in the literature (Penuel, 2006), not only was there a positive effect size for technology use, but technology use enjoyed the largest impact of all the subsets ($g+ = 0.53$, $k = 39$).

Factors moderating technology use. The subset of technology use outcomes was meta-analyzed using mixed models with the following categorical moderators: year code, size of program, age of participants, duration, implementation/technology integration code, and program theory. Significant effects were found for only two of them, year code and program theory. For year code, studies were grouped together according to the year that the study was released (Table 14). The year codes were as follows: 1 = before 2000; 2 = 2000 - 2004 (5 years); 3 = 2005 - 2009 (5 years); 4 = 2010 - present (5 years). Note that for technology use, there were no studies in category 4 = 2010 – present (5 years), from which an effect size could be extracted.

Table 14. Technology use by year code (categorical)

Category	k	ES Estimate ($g+$)	Standard Error	z	p	CI lower	CI Upper
1 - before 2000	3	-0.19	0.29	-0.66	.51	-0.76	0.38
2 - 2000 - 2004	12	**0.52**	0.16	3.23	.0012	0.20	0.83
3 - 2005 - 2009	21	**0.63**	0.09	6.73	<.0001	0.45	0.82

$\tau^2 = 0.12$, $I^2 = 60.01\%$

Moderators were found to be significant (Q_M (df = 2) = 7.31, p = 0.03). Year code was treated as quasi-continuous and tested in a meta-regression (Table 15).

Table 15. Technology use by year code (continuous)

Category	Estimate	Standard Error	z	p	CI lower	CI Upper
Intercept	-0.36	0.31	-1.16	.25	-0.97	0.25
β (Year code)	**0.35**	0.12	2.94	.003	0.12	0.58

$\tau^2 = 0.10$, $I^2 = 60.17\%$

The model is significant, but there still remains much of the variability unexplained (I^2 = 60.17%). At least in terms of technology use, programs are getting better as time passes. The reasons for this may be numerous - transfer of knowledge between programs, program implementers making use of lessons learned, technology becoming more user-friendly, programs taking more time to train teachers how to integrate technology use in their classrooms.

Program theory was the second moderator that was found to be significant (at least at the $p < 0.1$ level). Table 16 details the differences in use ES between each of the Program theories (Technology-enhanced learning environment (TLE), Technology-enhanced instruction (TEI), and Computers as mind tools or learning tools (CMT)).

Table 16. Technology use by program theory (categorical)

Category	k	ES Estimate	Standard Error	z	p	CI lower	CI Upper
TLE	17	**0.44**	0.12	3.82	.0001	0.21	0.67
TEI	11	**0.52**	0.16	3.29	.0010	0.21	0.83
CMT	8	**0.91**	0.19	4.89	<.0001	0.54	1.27

$\tau^2 = 0.14$, $I^2 = 64.89\%$

Significance tests yielded the following: Q_M (df = 2) = 4.64, p =.098. While not significant at the 0.05 level, the p value is still smaller than 0.1. As a result, program theory should not be ruled out entirely as a potential moderator of technology use. The moderating impact of program theory should not be entirely surprising as the two categories reporting larger effect sizes, TEI and CMT, were the two that involved more intentional use of technology either for instruction or as a cognitive tool. That those two categories saw more technology use was not unexpected.

Technology Proficiency

The histogram of 22 Technology Proficiency effect sizes is shown in Figure 11. The distribution was vaguely normal, right skewed (skewness = 0.53) and somewhat platykurtic (kurtosis = -0.93). The unweighted mean was 0.35, moderately close to the random effects mean of 0.28, with a standard deviation of 0.33. The median is 0.25. The small sample size may have contributed to the lack of normal symmetry.

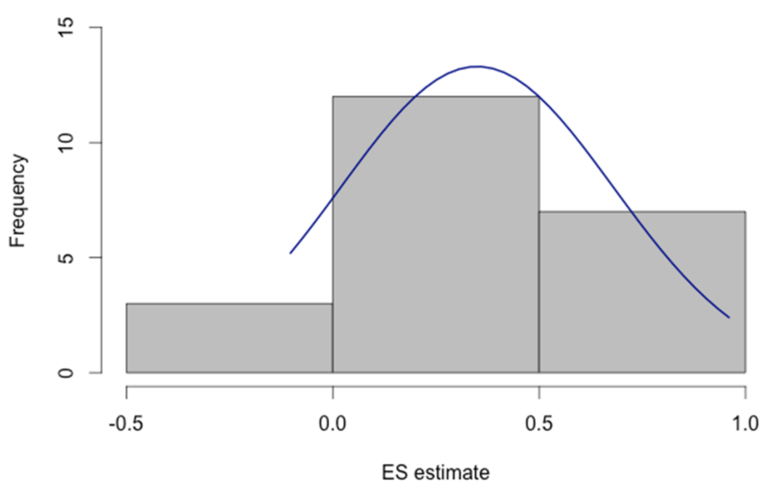

Figure 11. Histogram of technology proficiency effects

Factors moderating technology proficiency. Whatever the program theory behind one-to-one programs, the common expectation was that increased use should lead to improvements in the other outcomes. In this regard, while technology use was a measured outcome it also was tested as moderator of other program outcomes as described in the methodology section. Only two moderators were found to be significant moderators of technology proficiency: technology use and duration (Tables 17 and 18 respectively). The number of studies reporting technology proficiency was small and hence statistical power was low. With a larger sample size, a more sensitive analysis would be possible. The relationship between technology use and proficiency was straightforward and expected: proficiency improved with frequent use, though it should be noted that proficiency gains were significant only with daily use.

Table 17. Technology proficiency by technology use (categorical)

Category	k	ES Estimate (g+)	Standard Error	z	p	CI lower	CI Upper
1 = Low (< once a week)	1	0.16	0.28	0.59	.56	-0.38	0.70
2 = Medium (>once a week, < daily)	14	**0.12**	0.07	1.75	.08	-0.01	0.26
3 = High (daily or more frequently)	7	**0.70**	0.11	6.37	<.0001	0.48	0.91

$\tau^2 = 0.00$, $I^2 = 0.00\%$

Technology use was treated as quasi-continuous and tested in a meta-regression (Table 18):

Table 18. Technology proficiency by technology use (continuous)

Category	Estimate	Standard Error	z	p	CI lower	CI Upper
Intercept	**-0.73**	0.25	-2.85	.004	-1.23	-0.23
β (Technology Use)	**0.45**	0.11	4.05	<.0001	0.23	0.67

$\tau^2 = 0.00$, $I^2 = 0.00\%$

The results of the regression model suggested that almost all of the improvement in proficiency was due to increased technology use, though the strength of the findings was possibly an artifact of the small sample size (k = 22).

The relationship between proficiency and duration was more unexpected: technology proficiency was *inversely* related to program duration (Tables 19 and 20). This finding can be explained for comparison studies by noting that the control group in the studies was not a no-technology condition but rather a less-technology condition. Proficiency may have a plateau more quickly attained by laptop students. Comparison groups with less exposure eventually attained those same levels of proficiency as well, but it took them longer. The group differences will tend to decline over time as comparison groups close the gap. While this explanation is plausible, it does not seem entirely consistent with the findings for technology use, where only daily exposure seemed to improve proficiency.

Table 19. Technology proficiency by duration (categorical)

Category	*k*	ES Estimate (*g*+)	Standard Error	*z*	*p*	CI lower	CI Upper
1 - < 1 academic year	7	**0.69**	0.12	5.88	<.0001	0.46	0.92
2 - 1-2 academic years	12	**0.17**	0.08	2.26	.02	0.02	0.32
3 - 3-4 academic years	3	0.10	0.13	0.75	.45	-0.16	0.35

$\tau^2 = 0.00$, $I^2 = 0.00\%$

An alternative explanation might be that over time, teachers became more familiar with technology and more comfortable adapting it to their preferred methods rather than those proscribed by the program. Technology use would continue to rise, but not necessarily technology proficiency. More research is needed to clarify this finding.

Duration was treated as quasi-continuous variable and tested in a meta-regression (Table 20). Not only was the model significant, but duration was found to be a strong negative predictor of technology proficiency.

Table 20. Technology proficiency by duration (continuous)

Category	Estimate	Standard Error	*z*	*p*	CI lower	CI Upper
Intercept	**0.87**	0.20	4.43	<.0001	0.48	1.25
β (Duration)	**-0.30**	0.10	-3.15	.001	-0.49	-0.11

$\tau^2 = 0.00$, $I^2 = 0.00\%$

The two predictors of proficiency, technology use and duration were combined in a meta-regression model (Table 21).

Table 21. Technology proficiency by technology use and duration

Category	Estimate	Standard Error	*z*	*P*	CI lower	CI Upper
Intercept	-0.13	0.43	-0.31	0.76	-0.97	0.71
β (Technology Use)	**0.34**	0.13	2.60	.01	0.08	0.59
β (Duration)	-0.17	0.10	-1.72	0.09	-0.37	0.02

$\tau^2 = 0.00$, $I^2 = 0.00\%$

Again, the model is significant and in the combined model, technology use was still a strong positive predictor. Duration remains significant albeit at the $p = .10$ level. Interestingly, the two strong moderators pulled in opposite directions and between them were responsible for the lion's share of the variability of the mean effect size.

Achievement

The histogram of 112 Achievement effect sizes is shown in Figure 12. The distribution was somewhat normal, somewhat right-skewed (skewness = 0.53) and leptokurtic (kurtosis = 2.54). The unweighted mean is 0.23, approximates to the random effects mean of 0.23, with a standard deviation of 0.31. The median was 0.20.

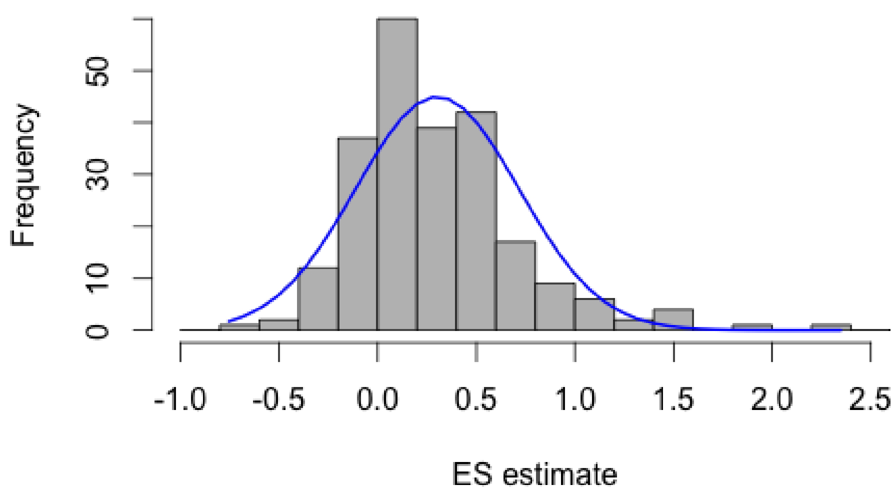

Figure 12. Histogram of achievement effect size estimates

Achievement was subdivided into six subject areas: Reading, Writing, Mathematics, English/Language Arts, Cognitive Skills, and Other Academic Subject(s). The results of this partitioning are shown in Table 22:

Table 22. General effects (achievement) by subject area

Category	k	ES Estimate ($g+$)	Standard Error	z	p	CI lower	CI Upper
Reading	21	**0.23**	0.07	3.26	.001	0.09	0.37
Writing	15	**0.33**	0.09	3.72	.0002	0.16	0.51
Mathematics	35	**0.17**	0.05	3.16	.002	0.06	0.27
English/Language Arts	20	**0.21**	0.07	3.03	.003	0.07	0.35
Cognitive Skills	10	**0.29**	0.12	2.44	.01	0.06	0.52
Other Academic Subject	11	**0.30**	0.12	2.55	.01	0.07	0.53

$\tau^2 = 0.02$, $I^2 = 17.72\%$

All of the achievement subsets were significant including writing ($g+ = 0.33$), described in the literature as the discipline most likely to be impacted by increased access to technology (Russel et al., 2003). Interestingly of the six subsets, the core areas of Reading ($g+ = 0.23$), English/Language Arts ($g+ = 0.21$) and Mathematics ($g+ = 0.17$) had the smallest effects, but each was still statistically significant.

Factors moderating achievement. The subset of achievement outcomes was meta-analyzed using mixed models with the following categorical moderators: year code, size of program, age of participants, duration, implementation/technology integration code, program theory, technology use, teacher-centered instruction and student-centered instruction. Significant effects were found for size of program, age of participants, and implementation/technology integration code at the $p < 0.05$ and for year code, duration and teacher-centered instruction at the $p < 0.1$ level. Interestingly, no significant effects were found for technology use, program theory or student-centered instruction.

Achievement was moderated by a number of program variables significant at the 0.05 and the 0.1 levels. Program size was the first variable with a significant impact (see Table 23). Although a clear pattern was not discernible, in general, larger programs produced larger impacts, though there was a considerable drop between the two largest categories (District-wide, $g+$=0.51 and State/Province-wide, $g+$=0.16; both significant).

Table 23. Achievement by size of program (categorical)

Category	*K*	ES Estimate ($g+$)	Standard Error	*z*	*p*	CI lower	CI Upper
1 - Class(es) w/in single school	18	**0.25**	0.10	2.46	.01	0.05	0.44
2 - Grade (s) w/in single school	7	0.28	0.15	1.84	.07	-0.02	0.57
3 - Schoolwide	12	0.18	0.10	1.81	.07	-0.02	0.38
4 - Selected Schools w/in Board	31	**0.17**	0.05	3.09	.002	0.06	0.27
5 - Board-wide	3	-0.28	0.20	-1.44	.15	-0.67	0.10
6 - Selected Schools w/in District	14	**0.22**	0.06	3.72	.0002	0.11	0.34
7 - District-wide	15	**0.51**	0.08	6.38	<.0001	0.36	0.67
8 - State/Province-wide	12	**0.16**	0.08	2.01	.04	0.004	0.32

$\tau^2 = 0.01$, $I^2 = 9.05\%$

A vexing issue with program size moderator was the variability in program size within each category. Because of regional demographic differences and differences in definitions of governing bodies, there was some overlap between categories. For instance a district-wide program in Texas was as big in terms of numbers of students and schools as state- or province-wide programs in smaller jurisdictions.

Age was found to be a more consistent moderator of achievement in one-to-one programs (Table 24). Programs with younger participants tended to yield better results. These students, less exposed to traditional methods of instruction may be more receptive and responsive to innovative technology rich methodologies.

Table 24. Achievement by participant age (categorical)

Category	*k*	ES Estimate (*g+*)	Standard Error	*z*	*p*	CI lower	CI Upper
1 - Elementary school (K-6)	17	**0.49**	0.09	5.44	<.0001	0.31	0.66
2 - Middle School (5-8)	63	**0.23**	0.04	5.85	<.0001	0.15	0.30
3 - All-Ages (K-12)	15	**0.16**	0.07	2.36	.02	0.03	0.30
4 - Secondary (7-12)	13	0.06	0.09	0.65	.52	-0.12	0.25
5 - High School (9-12)	4	0.13	0.19	0.70	.48	-0.24	0.49

$\tau^2 = 0.01$, $I^2 = 12.62\%$

Age was treated as a quasi-continuous moderator and meta-regression was performed (Table 25) with similar results: age was inversely related to program impact. On the one hand, this finding could be expected: younger students tend to respond better to interventions for a number of reasons: more controlled environments, fewer pedagogical distractions, fewer disciplinary issues. Alternatively, these findings could also be interpreted to lend support to the "digital native" narrative proposed by Prensky (2001). Because younger students are born and raised in a digital world, they will by nurture be more suited to technology-rich learning environments.

Table 25. Achievement by participant age (continuous)

Category	Estimate	Standard Error	*Z*	*p*	CI lower	CI Upper
Intercept	**0.46**	0.08	5.52	<.0001	0.30	0.62
β (Age)	**-0.10**	0.03	-3.01	.003	-0.17	-0.03

$\tau^2 = 0.01$, $I^2 = 12.40\%$

Program year was also a significant moderator of student achievement. Programs in the first decade of the 2000's experienced significant impacts on achievement, while prior to 2000 program impact was negligible and not significant. Effect sizes decreased toward the end of the decade and were no longer significant in the 2010's (Table 26). Whether there were systematic reasons for this pattern of program effectiveness was unclear (meta-regression using year as a quasi-continuous variable was not significant). More data would help clarify the relationship between program year and achievement.

Table 26. Achievement by year category (categorical)

Category	*k*	ES Estimate (*g*+)	Standard Error	*z*	*p*	CI lower	CI Upper
1 - before 2000	13	0.09	0.11	0.77	.44	-0.13	0.31
2 - 2000 - 2004	23	**0.41**	0.09	4.71	<.0001	0.24	0.59
3 - 2005 - 2009	61	**0.23**	0.04	6.24	<.0001	0.16	0.30
4 - 2010 - present	15	0.13	0.08	1.58	.11	-0.03	0.29

$\tau^2 = 0.01$, $I^2 = 13.83\%$

One of the key study features coded was implementation fidelity/technology integration. Programs were rated on a scale of 1 (minimal integration) to 4 (full integration) by combining scores on individual integration items as described in the methodology section. As predicted technology integration was a significant moderator of student achievement (Table 27) - greater effect sizes were observed in programs with more complete technology integration.

Of interest was the fact that the biggest increase was between the minimal and partial implementation categories. Programs rated as only having minimal integration paid little attention to supporting teachers in transforming their teaching and learning activities through technology us. Classroom practices were much as they were without technology. In programs rated as having partial integration typically there was evidence that teachers were given some support in using technology to enhance their instruction and student learning and that support translated into changed classroom practices. These results indicated that even a small amount of attention paid to implementation yielded significant gains.

Table 27. Achievement by implementation/technology integration (categorical)

Category	k	ES Estimate ($g+$)	Standard Error	z	p	CI lower	CI Upper
1 - Minimimal	7	0.06	0.11	0.56	.58	-0.15	0.27
2 - Partial	15	**0.26**	0.09	3.07	.002	0.09	0.43
3 - Substantial	60	**0.19**	0.04	4.77	<.0001	0.11	0.27
4 – Full	30	**0.37**	0.07	5.57	<.0001	0.24	0.50

$\tau^2 = 0.01$, $I^2 = 15.18\%$

Strictly speaking, technology integration scores were categorical as they represented perceived amounts of integration over several variables. Because the categories were ranked numerically, it was possible to treat technology integration as a quasi-continuous variable and attempt meta-regression (Table 28). As noted in Table 28, once again technology integration was a significant positive predictor of achievement.

Table 28. Achievement by implementation/technology integration (continuous)

Category	Estimate	Standard Error	z	p	CI lower	CI Upper
Intercept	-0.01	0.11	-0.14	.89	-0.23	0.20
β (Tech Integration)	**0.08**	0.04	2.26	.02	0.01	0.15

$\tau^2 = 0.01$, $I^2 = 11.15\%$

This is an important finding and contrasts with technology use. Technology integration was not a significant moderator of technology use, nor was technology use, when coded as a categorical factor, a significant moderator of achievement. Again we must be careful in our interpretation, but one explanation is that while deeper integration does not guarantee more frequent use, it may promote use that is more pedagogically effective.

Duration was also a significant moderator of achievement (Table 29), lending support to the argument that it takes several years to see the impact of a laptop program as teachers and students take time to get used to new routines incorporating laptop use (Lane, 2003; Hill & Reeves, 2004). Technology integration also deepens over time, and as demonstrated above, technology integration is also a positive moderator of student achievement. In this light, duration was an expected moderator of achievement.

Table 29. Achievement by duration (categorical)

Category	k	ES Estimate ($g+$)	Standard Error	z	p	CI lower	CI Upper
1 - < 1 academic year	31	**0.12**	0.06	2.05	.04	0.01	0.23
2 - 1-2 academic years	61	**0.24**	0.04	5.64	<.0001	0.16	0.33
3 - 3-4 academic years	19	**0.29**	0.06	4.81	<.0001	0.17	0.41
4 - > 4 academic years	1	**0.35**	0.15	2.38	.02	0.06	0.63

$\tau^2 = 0.01$, $I^2 = 10.47\%$

Although categorical moderators were used to code duration, because the ranked categories map directly onto a numerical value (years) we can treat this variable as quasi-continuous and attempt meta-regression with duration as the moderator (Table 30).

Table 30. Achievement by duration (continuous)

Category	Estimate	Standard Error	z	p	CI lower	CI Upper
Intercept	0.06	0.08	0.71	0.48	-0.10	0.21
β (Duration)	**0.08**	0.04	2.30	.02	0.01	0.15

$\tau^2 = 0.01$, $I^2 = 9.67\%$

Program duration and implementation/technology integration were likely to be correlated because implementation and integration will tend to increase over time, provided that teachers stick to the intervention as they become more comfortable with the technology. In some cases, as teachers become more comfortable with the technology, they may start customizing the intervention to suit their preferred teaching approaches. Teachers and students become more accustomed to using technology as pedagogical tools and technology routines will become normal rather than novel. With this in mind, a meta-regression model combining these two moderators was tested (Table 31). As predicted the model was significant and both moderators were significant (albeit at the $p < .10$ level).

Table 31. Achievement by technology integration and duration

Category	Estimate	Standard Error	*z*	*p*	CI lower	CI Upper
Intercept	-0.08	0.11	-0.73	.47	-0.31	0.14
β (Tech Integration)	0.06	0.04	1.63	.10	-0.01	0.14
β (Duration)	0.06	0.04	1.67	.10	-0.01	0.14

$\tau^2 = 0.006$, $I^2 = 7.10\%$

The last moderators of achievement that were tested were student-centered instruction and teacher-centered instruction. While student-centered instruction was not a significant moderator of achievement, teacher-centered instruction was (Table 32).

Table 32. Achievement by teacher-centered instruction (categorical)

Category	*k*	ES Estimate	Standard Error	*z*	*p*	CI lower	CI Upper
1 - Never	7	**0.32**	0.16	2.00	.05	0.01	0.64
2 - Sometimes	30	**0.20**	0.06	3.58	.0003	0.10	0.31
3 - Often	21	0.11	0.07	1.75	.08	-0.01	0.24
4 - Almost always	11	**0.42**	0.06	6.59	<.0001	0.30	0.55

$\tau^2 = 0.01$, $I^2 = 6.88\%$

For the first three levels (Never, Sometimes and Often) it appears that teacher-centered instruction is inversely related to student achievement. The ES estimate is the highest for the highest of teacher-centered levels (almost always), an indication that the relationship is not quite so straightforward.

Student Attendance, Engagement and Satisfaction

With only eight studies reporting attendance data and an average effect size of 0.00, further analysis of this category was not warranted. The lack of attention paid to this and other school outcome variables is surprising though as so many studies list them as program goals. The histograms of 21 Student Engagement and 29 Student Satisfaction effect sizes are shown in Figures 13 and 14 respectively. For Student Engagement, the distribution is vaguely normal, right skewed (skewness = 1.00) and slightly leptokurtic (kurtosis = 0.22). The unweighted mean is 0.21, moderately close to the random effects mean of 0.15, with a standard deviation of 0.59. The median is 0.11. The small size may contribute to the lack of normal symmetry. For Student Satisfaction, the distribution is vaguely normal, right skewed (skewness = 0.76) and slightly leptokurtic (kurtosis = 1.52). The unweighted mean is 0.22, reasonably close to the random effects mean of 0.26, with a standard deviation of 0.43. The median is 0.14. The small size may contribute to the lack of normal symmetry.

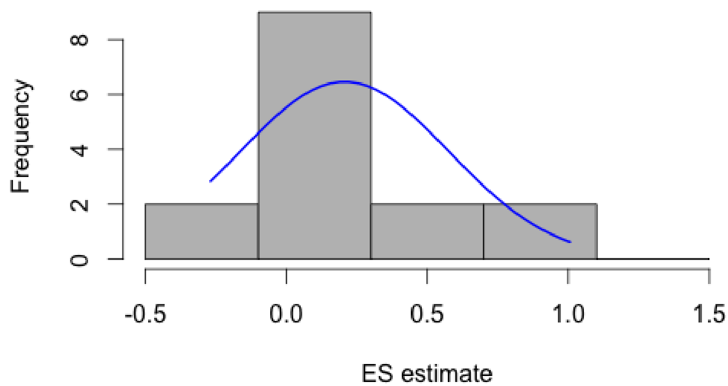

Figure 13. Histogram of engagement effect size estimates

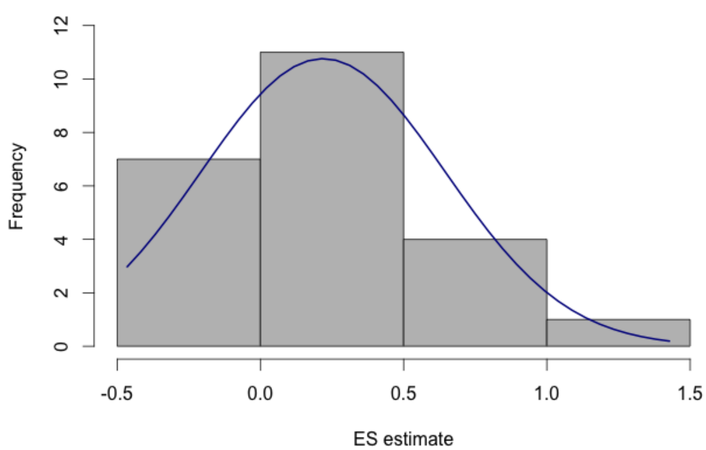

Figure 14. Histogram of satisfaction effect size estimates

Factors Moderating Student Engagement and Satisfaction With Technology

Moderator analysis was performed for both student engagement and technology satisfaction. None of the moderators tested were found to be significant for student engagement or technology satisfaction.

Summary Of Mixed Meta-Analysis Results

In the mixed effects meta-analysis general effects were found for all categories of effects except for attendance. One-to-one computing had a medium impact on technology use and small impacts on technology proficiency, student achievement, student engagement, and student satisfaction. Moderators were tested for their impact on general effects. Two moderators were found to impact technology use: program year and program theory. Student Achievement was further subdivided into subject areas, all of which were found to have significant general effects save for cognitive skills. Significant moderators of achievement were size of program, age of participants, program implementation/technology integration, program duration, program year and teacher centered instruction. Only two moderators were found to be significant moderators of technology proficiency: technology use and duration. As expected, increased use leads to increased technology proficiency. Duration, on the other hand was found to have an inverse impact on proficiency: the longer the program the less the impact on proficiency. No variables were found to moderate student engagement or technology satisfaction.

CHAPTER 5 – DISCUSSION

The purpose of this study was to determine how, to what extent, and under what circumstances does one-to-one computing in K-12 settings impact educational goals including but not limited to student achievement, technology use, technology proficiency, engagement, attendance, and attitudes toward technology. The case survey was exploratory and asked the following questions: what variables or groups of variables provide insight into and allow for useful comparisons of the one-to-one programs being studied? Do any of the following frameworks apply: technology first – balanced approach continuum, technology integration, implementation fidelity, program goal or theory?

The mixed effects meta-analysis was inferential and answered the following questions:

1. Are there general laptop effects on the variables of student achievement, technology use, technology proficiency, engagement, attendance, and attitudes toward technology?
2. Are those general effects moderated by study quality?
3. Are the general effects moderated by contextual variables, as predicted in the literature, namely: technology use, technology integration/program implementation, duration, program theory, year, age, program size, or gender?

These findings were evaluated against the backdrop of earlier criticisms of technology interventions that technology in classrooms is not sufficiently used to justify the intervention (Cuban, 2001) and that when used the outcomes are not sufficiently different or unique to justify the intervention (Clark, 1994). To a degree, these questions have been answered by Tamim et al. (2011) and other studies, even though the specifics of one-to-one programs may not have been addressed. In this light, this dissertation went beyond those basic questions and sought to explore the degree to which contextual variables impact outcomes, and the degree to which outcome variables impact one another.

General Effects

One-to-one computing was found to have a significant effect on all outcomes save attendance. As predicted, technology use increases with the introduction of one-to-one programs ($g+ = 0.53$) (Bethel et al., 2008; Fleischer, 2011; Penuel, 2006), answering the first of the criticisms of school technology implementations that technology is “oversold and underused” (Cuban, 2001). In fact technology use is the only significant effect in Cohen’s (1988) “medium effect” range, all other significant effects are small. Surprisingly, the impact of technology proficiency is considerably smaller ($g+ = 0.29$), and while dependent on technology use, declines over the life of the program (see discussion on the impact of program duration below).

The small positive impact on achievement ($g+ = 0.23$) would seem to vindicate the technology advocates claiming the positive impact of one-to-one laptop programs on academic achievement, despite numerous reports claiming otherwise. These results must be interpreted with caution however, as few reports controlled for the impact of instructional method. As Clark (1994) and others have pointed out, an instructional effect is easily confused with a technology effect. Achievement gains can only be definitively attributed to the laptops if the laptop and the non-laptop groups used similar instructional methods. At the same time, the size of the impact raises questions about efficiency: are there more affordable programs with similar impact? Moreover, the impact of one-to-one computing on achievement is somewhat smaller than the summary technology effect found in Tamim et al. (2011). Careful attention must be paid to the impact of the various moderating variables. As mentioned above, attendance was the one general effect that was not significant. While this may be an artifact of sample size ($k = 8$), it is instructive that only eight studies report quantitative data on school outcome variables (attendance, attrition, graduation rates, college-bound graduates). Perhaps the inclusion of school outcomes as program goals expresses a more general idea that any positive intervention that results in more successful and engaged students will automatically lead to improvement in attendance and persistence and all the other school outcome variables. Finally, small improvements were observed in student engagement and student satisfaction. Once again, effect sizes were smaller than may have been predicted, but positive nonetheless.

General Effects - Achievement

As reported above, all of the achievement subsets were significant. Consistent with previous findings writing effects were the largest ($g+ = 0.33$) (Goldberg et al. 2003; Russell, 2003; and Russell et al., 2002). Core areas of Reading ($g+ = 0.23$), English/Language Arts ($g+ = 0.21$) and Mathematics ($g+ = 0.17$) had the smallest effects, but were still statistically significant. These findings likely reflect types of technology use in laptop classrooms. Given the ease with which laptops can be used for writing and writing practice, and the well-documented history of successful technology-assisted writing (Goldberg et al., 2003), we might expect technology-assisted writing and editing to be implemented successfully in laptop classes. In contrast, integrating laptops into other areas of learning may be more complicated and certainly less well documented. More finely grained analysis of laptop implementation could help clarify the differential achievement effects.

Demographics

Programs were predominantly conducted in coeducational, public middle school settings. While programs varied in size from single class to state- or province-wide most were conducted in selected schools throughout a district or board. Insufficient data were reported to compare urban, suburban and rural programs or programs with differing socioeconomic profiles. The latter was particularly regrettable given the stated goal of reducing the digital divide: these data would have been useful to quantify progress toward that goal. One program that did record SES data specifically mentions that there remains a gap after program implementation. Rather than the one-to-one intervention acting as an ameliorating force on digital inequality, SES acted as a catalyst for one-to-one impact. Higher SES schools experienced deeper integration and broader one-to-one impact than did lower SES schools. Certainly this is an area that should be studied further.

Demographic factors played a larger role in moderating outcomes than expected. Program size, student age and program year were all significant moderators of outcomes. Although the most frequent size of program was selected schools, district-wide programs were the most successful in impacting achievement scores. It is difficult to draw conclusions from this as board-wide and state-wide programs did not experience the same success, so size alone does not seem to be the determining factor. One suggestion might be that these programs seemed the most consistently committed to monitoring and evaluation, a variable linked to program success. More detailed analysis of these programs is warranted.

Program year moderated both technology use and achievement. For technology use, more recent programs enjoyed greater use. Several explanations can be proposed to explain this trend. First, technology has become more ubiquitous throughout society and as such technology use has increased in all areas; it is not surprising to see similar trends in education. Second, prior to 2000, schools were still focusing their technology efforts on desktops and computer labs. Laptop programs were still new and the smaller effects may be a result of this being a trial and error period. Later programs would have been able to build on the successes; failures and lessons learned of these earlier programs, so we should anticipate improved performance over time. Third, as technology becomes cheaper, schools are more likely to have more technology to use. The relationship between year and academic achievement is less simple. Performance increased in the early 2000's but declined in the latter 2000,s and was not significant in the 20-teens. More study is needed to decode this relationship, if there is indeed one.

Participant age was also found to moderate achievement either as a categorical or continuous variable. In both models, as students got older, the intervention impact declined. Most programs were conducted in middle schools. These programs enjoyed a larger impact that studies with older students, but our model suggests that even bigger gains would have been observed with younger, elementary students. Younger students may respond better to this type of intervention as they are still developing school routines and can more easily integrate radical changes to their learning milieu than older students who have established routines and practices. As mentioned above this finding could also be read to lend support to the idea of "digital natives" (Prensky, 2001). The younger the student, the more technology-saturated the environment they grow up in and hence the more that student is a digital native. Yet another explanation may be that technology integration is easier in elementary and middle schools as students spend significant time as a class group with the same teacher. Teacher and student routines arising out of the intervention will be more quickly internalized as they all spend more time together in the same environment. In high school students move from class to class on individualized timetables. Each student will experience different teachers in groups of different class groups each class period. Achieving consistent implementation becomes a much larger, more complicated task. The explanation for this finding is certainly an area to be studied further.

Study Features

Program Theory

Few programs had clearly articulated program theories. Few clear links to research or learning theory were established, rather program justification was based on program goals such as improving student achievement, widening access to technology, enhancing instruction and economic development (Penuel, 2006). At the same time, program theory articulation was correlated with technology integration (weakly), and the setting, measurement and attainment of academic goals.

Where program theories were either explicitly stated or were inferred from the article or report, they clustered around three main themes, technology-enhanced learning environment, technology-enhanced instruction and computers as mind tools or learning tools. When explicitly stated, the goals were usually one of the latter two, technology-enhanced instruction or computers as mind tools or learning tools. The program theory that emphasizes computers as mind tools or learning tools imagines technology as a sort of “cognitive add-on”. The technology is working to extend the student’s capacity for learning, cognition and productivity and in this sense is a student-centered tool. In its most radical formulation, this approach focuses exclusively on the ability of the technology to present new learning opportunities for the students and spends little time on teacher activities and technology integration. This program theory fits best with the school of thought that computers are the learning tool that will revolutionize education. Technology-enhanced instruction on the other hand, emphasizes the role of the instructor in bringing about learning gains. In this theory, much emphasis is placed on instructor readiness, technology proficiency, and capacity development. This approach relies on teachers to spearhead the technology revolution. Change is seen as being primarily the result of improved instructional approaches and teacher technology integration.

The most popular theory, technology-enhanced learning environment, can be seen either as a compromise between the two other theories, or a reluctance to commit to a theoretical prescription for technology integration. This is reflected in vague or missing references to program theory in the majority of studies. These studies present little in the way of program indicators other than reports of technology use and student attainment. Studies of programs with a clearly articulated program theory on the other hand, present a more detailed, thought out approach. One example discussed above, the Texas Immersion Pilot lists several criteria by which a technology-rich environment can be judged and uses specially developed instruments to measure technology integration (Shapley et al., 2006a, 2007, 2008, & 2009). One of the studies even compares technology immersion and its impacts in a district of high immersion versus one of low immersion. Their findings are important and instructive, particularly with regard to claims that unlimited access will help bridge the digital divide. They found that the main variable separating the two districts was socio-economic status. Although both districts received the same technical support in terms of machines, professional development, peripheral support and technical support, technology immersion was considerably more successful in the medium income district than in the lower income district (Shapley et al., 2009).

Program theory as a moderator of outcomes. Using the three broad themes discussed above, program theory was found to be a significant moderator of technology use, with computers as mind tools or learning tools outperforming the other two categories. This may be explained by the nature of this particular program theory: of the three theories, this is the only one that requires continuous student use of technology. Interestingly, program theory was not found to be a significant moderator of any of the other outcomes including achievement. Given that the whole purpose of the program theory is to explain how the technology intervention will impact achievement, one would expect to see some sort of link between the two variables. On the other hand, this non-significant finding may imply that each of the theories has a similar impact on outcomes. This finding must be interpreted with caution, however, given that program theory was for a large part an inferred rather than explicit variable. Program theory needs to be evaluated more directly to begin to clarify these findings somewhat.

Program Goals

While program theories collapsed easily into three broad categories, program goals on the other hand were multiple and diverse with twenty-three different goals articulated. Program goals clustered around eight main themes: technology goals, achievement goals, cognitive goals, affective goals, behavioral goals, social goals, and school outcome goals. Of these, technology goals were the most common, followed by instructional, behavioral and achievement goals. This multiplicity of goals makes the evaluation and comparison of programs challenging. While most studies reported progress on technology goals, many did not even measure some of the other stated goals. The impact of one-to-one computing on student achievement is clearly an important program goal, but often this goal was not even measured. Interestingly, a relationship was established between those programs with a clearly stated program theory and the measurement and attainment of achievement goals.

Program Preparation, Implementation and Technology Integration

Implementation and planning scores were aggregated into a single technology integration index. Although the modal category was 3 = substantial integration, relatively few studies were classified as 4 = full integration. Several authors have proposed a link between technology integration and program success (Inan & Lowther, 2010a; Shapley et al., 2006a; and Wozney et al., 2006). Of particular concern is the need to provide frequent, extensive ongoing professional development to help teachers integrate the technology most effectively (Bebell & O'Dwyer, 2010; Bernard et al., 2008; Bonifaz & Zucker, 2004; Lento & Salpeter, 2007; O'Hanlan, 2007) The proposed link between technology integration and program success was investigated using the degree of technology integration variable as a categorical and quasi-continuous moderator. Surprisingly, technology integration only had an impact on student achievement scores, not on technology use, nor on technology proficiency. For achievement, the impact was as expected: the deeper the integration the larger the effect size. This impact is contrasted with that of technology use: technology integration did not moderate technology use. Furthermore, when treated as a moderator of the other effect sizes, technology use was not found to moderate achievement though it did have an impact on proficiency. As noted earlier, deeper integration may not promote more use, but it may promote more pedagogically effective use. Read another way, this can be interpreted to mean that technology use alone is not enough to promote achievement, unless that use is designed to be pedagogically effective (Maderthaner, 2007).

Program Duration

One of the complaints of early one-to-one implementation was that "change takes time" and program impacts would only be experienced after several years of program continuation (Hill & Reeves, 2004; Lane, 2003). This idea was tested by treating program duration as a moderator of outcome variables. Duration was a significant moderator of technology proficiency and academic achievement but not of technology use. One explanation for the lack of a connection between technology use and duration may be that the use is dependent primarily on the level of technology. When a one-to-one program is implemented, the level of technology is raised immediately compared to a comparison group without one-to-one, and use increases accordingly. Over time, the level of technology remains constant, so use remains constant as well. The surprising result was that duration negatively moderated technology proficiency. Moreover, the relationship was found to be robust, exceeded only by the impact of technology use on proficiency.

One possible explanation is that the effect size is an effect size compared to a control group, but that control group is not a no-technology group, rather it is a limited-technology group. Proficiency gains appear to manifest themselves quite rapidly with one-to-one access, then level off. This means that over time, students in a limited access group can catch up over time. The effect size – the proficiency difference between the two groups – will become smaller as the limited technology group improves proficiency, while the laptop group remains constant. This may also reflect a progression to more ubiquitous access to technology in general, so that the limited technology group may have comparable access outside of the school setting. An alternative explanation may be that as teachers become more comfortable with the technology and take ownership of the intervention, they may be more willing to adapt it in their own ways as opposed to those suggested by the program theory. Although technology use may even increase, because the technology is not being used as attended, the relevant gains may not be observed. The finding is certainly contrary to projections of one-to-one programs and should be studied further to understand it better.

In contrast to technology proficiency, duration was a significant moderator of achievement, confirming the conventional wisdom (The Abell Foundation, 2008; Bonifaz & Zucker, 2004; Hill & Reeves, 2004; Lane, 2003; Penuel, 2006). Moreover, when meta-regression is performed combining technology integration and duration into a single model, the model is a more robust predictor than either technology integration or duration alone. In other words, this finding confirms the conventional wisdom that to achieve success in any educational intervention, one must plan, execute well, and be persistent (The Abell Foundation, 2008; Bonifaz & Zucker, 2004; Hill & Reeves, 2004).

Technology Use as a Moderator

Technology use was recoded as a moderating study feature and tested against the other outcomes. The fact that technology use was only found to be a significant moderator of technology proficiency is instructive. First of all, technology use was a robust predictor of technology proficiency, unsurprisingly: the more you practice, the better you get. In fact the relationship was so strong that it accounted for almost all the variation in technology proficiency. Given the two significant moderators of proficiency, technology use and duration, a new model was built using both these variables. Again both were found to be significant (though duration was now only significant at the $p < .10$ level). Second, technology use alone was not sufficient to produce achievement gains. For many this is not a surprise (Bonifaz & Zucker, 2004; Bernard et al., 2008; Fleischer, 2011; Warschauer & Matuchniak, 2010; Warschauer, 2004), but this flies in the face of the premise of the One Laptop per Child program, that through increased access to technology student learning will increase. It appears that the premise is true, but that the only learning that increases is learning of the technology itself as predicted in Warschauer (2002). For technology use to promote learning it must be applied in pedagogically appropriate ways. In some cases, when not used appropriately, technology use has been linked to a slowing rather than an acceleration of learning (Bernard et al., 2008).

Teacher-Centered and Student-Centered Instruction

The final moderators explored were the degree to which the programs incorporated teacher-centered and student-centered instruction. The results should be read with two caveats: first, very few of the programs were coded as being completely one or the other, most programs had some of each; second, many programs did not report the type of instruction at all and so for these moderators, results were from limited sample sizes (student centered instruction $k = 66$, teacher-centered instruction $k = 69$, compared to achievement $k = 112$). Student-centered instruction was not found to be a significant moderator, while teacher-centered instruction was a significant moderator. This finding appeared to vindicate the critics of the technology first approach, and to confirm that the role of the teacher is central in the success of implementations of this sort.

CHAPTER 6 – CONCLUSION

Several general messages can be drawn from the findings of this dissertation. The research questions asked: how, to what extent, and in what context does one-to-one laptop computing impact educational goals in K-12 settings including but not limited to student achievement, technology use, technology proficiency, engagement, attendance, and attitudes toward technology? This study answered these questions quantitatively using the case survey approach and mixed effects meta-analysis. The results validate the use of such an attempt to mix qualitative synthesis techniques with meta-analysis. At the same time, case survey is still a quantitative approach to qualitative synthesis. The bigger test will be when more purposeful methods of qualitative synthesis are combined with meta-analysis.

This study reliably quantified, for the first time, the positive impacts of one-to-one computing on student achievement, technology use, technology proficiency, engagement, and attitudes to technology, but found no effects for attendance or any of the other school outcomes. Moreover, the study quantified the impacts of several moderating variables on the primary outcomes and the impacts of the outcomes on one another. The two variables that had the deepest impact on technology use, proficiency and achievement were technology integration and program duration. Unsurprisingly, the degree of technology integration impacted both technology use and student achievement. In fact technology integration was more important moderator of student achievement than technology use. The impact of program duration was not as straightforward, however. Duration also had a positive impact on achievement, meaning that one-to-one computing programs are just like any other interventions: for success they require proper implementation (technology integration) and persistence (program duration). At the same time, duration had no effect on technology use and a negative effect on technology proficiency.

While explanations for these unusual findings have been proposed, further study may provide more definitive answers.

Several demographic factors were found to influence program success. One-to-one computing works best with younger students and program impact dwindles as students get older. More recent programs seem to be more successful, though this needs more study to clarify the relationship. Finally, the size of a program seems to be a moderator – districts were by far the most successful – but this needs to be studied more closely to learn what it is about programs of this size that makes them so successful. Economies of scale alone cannot explain the success, as larger state and provincial programs were the least successful. Perhaps the combination of being large enough to enjoy economies of scale, yet not too large to maintain consistency among implementers may be the source of districts' success.

One-to-one computing access for educationally underserved students improves the resources available to those students. This is important in and of itself, as those technological resources often have unintended social impacts, particularly in technology-poor societies. There is little evidence, however, that the increased access to technology is closing the digital divide, when we use a much broader definition that goes beyond improved access and incorporates usage patterns. This is not to underestimate the potential impact that one-to-one computing can have on impoverished student communities, but the impact on achievement has not been demonstrated to date save in unique programs where more emphasis has been placed on pedagogically and culturally appropriate technology integration.

Limitations of This Study

Quality

The quality of any systematic review will always be dependent on the quality of the studies under review. For this review, quality was an issue not only at the level of the studies, but also at the level of the interventions themselves. Programs vary from passing out computers and getting out of the way (Warschauer, 2009), to carefully designed, piloted and implemented technology-intensive school reforms where student and teacher laptops are but one component of a systemic overhaul. Similarly, studies varied from one intact group pretest posttest pre-experiments to randomized controlled true experiments. While one would normally expect that the low quality design studies would tend to overestimate the population effect size, this was not the case. Low to medium quality studies clustered together, predicting a common population effect. The high quality studies on the other hand were the outliers, predicting a larger effect size than the other. One explanation for this may be that the high quality studies evaluated high quality programs. Larger impacts are expected from well-planned, theory-based, carefully implemented programs. In particular, given the relationship between technology implementation and achievement and use, further investigation into the relationship (if there is one) between study and program quality is needed.

This study was faced with a bigger issue of study quality. Despite widening the set of included studies by using a mixed systematic review (case study and meta-analysis), there were still only 165 of 1351 studies included for review in total, representing a 12% inclusion rate. To a degree, this reflects a liberal search strategy as of the 1351 studies: 848 were rated as N121 – not one-to-one studies at all. Nonetheless, there were still 338 studies that *were* one-to-one studies but were not suitable for inclusion in the review, in addition to the many low-quality studies that were included in the review. The one-to-one literature as a whole is diverse not only in type but in quality, increasing the potential for statistical noise. An argument can be made for analyzing only the highest quality studies reporting on the highest quality intervention to understand the true potential of one-to-one programs.

Coding and Technology Integration

As noted earlier, technology integration is a complex, multi-faceted construct. Coding for technology integration as a single case survey item or study feature had the potential of introducing significant coder bias give the many possible interpretations of "technology integration." In order to limit subjectivity in coding, technology integration was subdivided into several much simpler, more specific categories, each of which was coded. From these a composite score representing overall technology integration was calculated similar to the approach taken in Shapley et al. (2006). Rarely were descriptions detailed and comprehensive enough for studies to enable coding on every one of these items, however. Technology integration scores were only calculated for information that was actually found in the studies; so two studies could both be rated similarly on the composite score while describing very different ideas of technology integration. This challenge aside, the granular approach used still holds promise to deepen understanding if sufficient studies can be found to analyze technology integration components for differential impact on the measured outcomes.

Final Remarks

After twenty-five years of one-to-one computing in K-12 school we can claim with confidence positive impacts on an array of educational outcomes. As tablets and other portables become the mobile computing options of choice, the findings here can inform practitioners and program planners alike to ensure that technology impact is maximized. Like so many others this study is limited as it does not account for program cost. In that regard, continued research is warranted. This study can serve as a both a springboard and a signpost, pointing to new questions to be answered, but providing a solid base from which to depart.

REFERENCES

Abrami, P. C., & Bernard, R. M. (2006). Research on distance education: In defense of field experiments. *Distance education*, *27*(1), 5-26. doi: 10.1080/01587910600653116

Abrami, P.C., Bernard, R.M. & Wade, C.A (2006). Affecting policy and practice: Issues involved in developing an argument catalogue. *Evidence & Policy: A Journal of Research, Debate and Practice, 2*(4), 417-437. doi: http://dx.doi.org/10.1332/174426406778881737

Abrami, P., Bernard, R., Wade, A., Schmid, R., Borokhovski, E., Tamin, R., Surkes, M., Lowerison, G., Zhang, D., Nicolaidou, I., Newman, S., Wozney, L., & Peretiatkowicz, A. (2008). A Review of e-learning in Canada: A rough sketch of the evidence, gaps and promising directions. *Canadian Journal Of Learning And Technology / La Revue Canadienne De L'Apprentissage Et De La Technologie, 32*(3). Retrieved from http://cjlt.csj.ualberta.ca/index.php/cjlt/article/view/27/25

Abrami, P. C. (2001). Understanding and promoting complex learning using technology. *Educational Research and Evaluation*, *7*(2), 113-136. doi: 10.1076/edre.7.2.113.3864

Alberta, Alberta Education, Stakeholder Technology Branch. (2009) *Emerge one-to-one laptop learning initiative: year one report*. Edmonton, AB: The Metiri Group and the University of Calgary. Retrieved from http://education.alberta.ca/media/933510/emerge%20year%20one%20report%20final.pdf

Bagui, S. (1998). Reasons for increased learning using multimedia. *Journal of Educational Multimedia and Hypermedia*, *7*(1), 3-18. doi: 10.1076/edre.7.2.113.3864

Bangert-Drowns, R. L. (1993). The word processor as an instructional tool: A meta-analysis of word processing in writing instruction. *Review of Educational Research*, 63(1), 69-93. doi: 10.3102/00346543063001069

Bebell, D., & O'Dwyer, L. M. (2010). Educational outcomes and research from 1:1 computing settings. *Journal of Technology, Learning, and Assessment*, *9*(1), n1. Retrieved from http://ejournals.bc.edu/ojs/index.php/jtla/article/view/1606/1463

Belanger, Y. (2000). Laptop computers in the K-12 classroom. ERIC Digest. Retrieved from http://files.eric.ed.gov/fulltext/ED440644.pdf

Bernard, R. M., Borokhovski, E., Schmid, R. F., Tamim, R. M. & Abrami, P. C. (2014). A meta-analysis of blended learning and technology use in higher education: From the general to the applied. *Journal of Computing in Higher Education. 26(*1), 87-122. doi: http://dx.doi.org/10.1007/s12528-013-9077-3

Bernard, R. M. (2014). Things I have learned about meta-analysis since 1990: Reducing bias in search of "The Big Picture." *Canadian Journal of Learning and Technology*, *40*(3). Available from http://www.cjlt.ca/index.php/cjlt/issue/current

Bernard, R. M., Abrami, P. C., Borokhovski, E., Wade, C. A., Tamim, R. M., Surkes, M. A., & Bethel, E. C. (2009). A meta-analysis of three types of interaction treatments in distance education. *Review of Educational Research*, *79*(3), 1243-1289. doi:10.3102/0034654309333844

Bernard, R., Bethel, E., Abrami, P., & Wade, C. (2008). Introducing laptops to children: An examination of ubiquitous computing in Grade 3 reading, language, and mathematics. *Canadian Journal Of Learning And Technology / La Revue Canadienne De*

L'Apprentissage Et De La Technologie, 33(3). Retrieved from http://cjlt.csj.ualberta.ca/index.php/cjlt/article/view/158/152

Bernard, R. M., Borokhovski, E., & Abrami, P. C. (2014). *Statistical applications in meta-analysis: Extracting, synthesizing and exploring variability in effect sizes***.** Montreal, QC: Concordia University and Centre for the Study of Leaning and Perfromance.

Bernard, R. M., Borokhovski, E., Schmid, R. F., & Tamim, R. M. (2014). An exploration of bias in meta-analysis: the case of technology integration research in higher education. *Journal of Computing in Higher Education*, *26*(3), 183-209. doi: 10.1007/s12528-014-9084-z

Bernard, R. M., Borokhovski, E., & Tamim, R. M. (2014). Detecting bias in meta-analyses of distance education research: big pictures we can rely on. *Distance Education*, *35*(3), 271-293. doi: 10.1080/01587919.2015.957433

Bethel, E.C., Bernard, R.M., Abrami, P.C., & Wade, A.C. (2008). Ubiquitous computing in K-12 classrooms: A systematic review. The Eighth Annual Campbell Collaboration Colloquium, Vancouver, BC. 12-14 May 2008. Retrieved from http://ecbethel.com/Edward_C_Bethel/research_files/Betheletal08onetooneC2.pdf

Bethel, E. C. & Bernard, R. M. (2010). Developments and trends in synthesizing diverse forms of evidence: Beyond comparisons between distance education and classroom instruction. *Distance Education, 31*(3), 231-256. http://dx.doi.org/10.1080/01587919.2010.513950

Bonifaz, A., & Zucker, A. (2004). *Lessons learned about providing laptops for all students*. Newton, MA: Education Development Center. Retrieved from http://perkinselementary.pbworks.com/f/LaptopLessonsRprt.pdf

Borenstein, M., Hedges, L. V., Higgins, J. P., & Rothstein, H. R. (2011). *Introduction to meta-analysis* (2nd ed.). Chichester, UK: John Wiley & Sons.

Borman, G. D., Hewes, G. M., Overman, L. T., & Brown, S. (2003). Comprehensive school reform and achievement: A meta-analysis. *Review of Educational Research*, *73*(2), 125-230. doi: 10.3102/00346543073002125 Retrieved from http://rer.sagepub.com/cgi/content/abstract/73/2/125

Borman, K. M., Carter, K., Aladjem, D. K., & LeFloch, K. C. (2004). Challenges for the future of comprehensive school reform. In C. T. Cross (Ed.), *Putting the pieces together: Lessons from comprehensive school reform research,* 109-150. Washington, DC: The National Clearinghouse for Comprehensive School Reform. Retrieved from http://www.centerforcsri.org/PDF/PTPTLessonsfromCSRResearch.pdf

Boyd, S. (2002). Literature review for the evaluation of the digital opportunities projects. Wellington: New Zealand Council for Educational Research. Retrieved from http://www.educationcounts.govt.nz/__data/assets/pdf_file/0005/6989/digopps.pdf

Bransford, J. D., Brown, A. L., & Cocking, R. R. (1999). *How people learn: brain, mind, experience, and school*. Washington, DC: National Academy Press.

Brunton, G., Thomas, J., Harden, A., Rees, R., Kavanagh, J., Oliver, S., Shepherd, J. & Oakley, A. (2005). Promoting physical activity amongst children outside of physical education classes: a systematic review integrating intervention studies and qualitative studies. *Health Education Journal*, *64*(4), 323-338. doi:10.1177/001789690506400404

Camfield, J., Kobulsky, A., & Paris, J. (2007). A report card for One Laptop per Child closing the digital divide via ICTs and education: Success and failures. In *Annual Meeting of the*

Multidisciplinary Seminar in Science Technology and Global Affairs, Washington, DC. Retrieved from http://joncamfield.com/writing/Camfield_Report_Card_for_OLPC.pdf

Canuel, R. (2009, October 9). Technology in education integration: People not laptops. OLPC//News. Retrieved October 20, 2009, from http://www.olpcnews.com/countries/canada/technology_in_education_integr.html

Caplan, D. & Graham, R. (2008). The development of online courses. In T. Anderson (Ed.) *Theory and practice of online learning 2nd ed.* Athabasca, AB: Athabasca University Press. Retrieved 18 July 2014 from: http://www.aupress.ca/books/120146/ebook/99Z_Anderson_2008-Theory_and_Practice_of_Online_Learning.pdf

Caswell, T., Henson, S., Jensen, M. & Wiley, D. (2008) “Open content and open educational resources: Enabling universal education.” *The International Review of Research in Open and Distance Learning* 9, no. 1 (February 7, 2008). http://www.irrodl.org/index.php/irrodl/article/view/469

Clark, R. E. (1983). Reconsidering research on learning from media, *Review of Educational Research, 53*(4), 445–459. doi:10.3102/00346543053004445

Clark, R. E. (1994). Media will never influence learning. *Educational Technology Research and Development*, *42*(2), 21-29. doi:10.1007/BF02299088

Clark, R. E., & Sugrue, B. (1995). Research on instructional media, 1978-1988. *Instructional technology*, 348-364.

CMEC. (2001). Education ministers call upon federal government to invest in connectivity in budget. *Council of Ministers of Education, Canada/Conseil des ministres de l'Education (Canada)*. Retrieved April 3, 2007, from http://www.cmec.ca/releases/20011115.en.asp

Coalition for Evidence-Based Policy (2012). Home. Retrieved from http://coalition4evidence.org/

Cobb, T. (1997). Cognitive efficiency: Toward a revised theory of media. *Educational Technology Research and Development*, *45*(4), 21-35. doi:10.1007/BF02299681

Coley, R., Cradler, J., & Engel, P. (1997). *Computers and classrooms: The status of technology in US schools*. Princeton, NJ: Policy Information Center, Educational Testing Service. Retrieved from http://www.etsliteracy.com/Media/Research/pdf/PICCOMPCLSS.pdf

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences*. Hillsdale, NJ: Erlbaum.

Craig, D. V. (2001). View from an electronic learning environment: perceptions and patterns among students in an online graduate education course. *Journal of Educational Technology Systems*, *30*(2), 197-219. doi: 10.2190/2xpj-a3br-0ujt-26ht

Creemers, B., & van der Werf, G. (2000). Economic viewpoints in educational effectiveness: cost-effectiveness analysis of an educational improvement project. *School Effectiveness and School Improvement*, *11*(3), 361-84. doi:10.1076/0924-3453(200009)11:3;1-g;ft361

CRF & Associates. (2003). *The impact of Plato Learning, Inc. technology in East Rock Magnet School* (Evaluation). New Haven, CT: East Rock Magnet School. Retrieved from https://09intelvisionaryconferenceoto.wikispaces.com/file/view/East+Rock+Impact+Study+final.pdf

Cuban, L. (1986). *Teachers and machines: Classroom use of technology since 1920*. New York: Teachers College Press.

Cuban, L. (2001). *Oversold and underused: Computers in the classroom*. Harvard University Press.

Dalgarno, N. (2009). Compulsory laptop programs: Teachers' responses to the adoption and implementation process. Retrieved from QSpace at Queen's University http://hdl.handle.net/1974/1966

Davies, A. (2004). *Finding proof of learning in a one-to-one computing classroom*. Courtenay, BC: Connections Publishing.

Davis, D., Garas, N., Hopstock, P., Kellum, A., & Stephenson, T. (2005). Henrico County Public Schools iBook survey report. *Development Associates, Incorporated, Arlington, VA*. Retrieved from http://www.henrico.k12.va.us/pdf/technology/hcreport.pdf

DiMaggio, P., & Hargittai, E. (2001). From the 'digital divide'to 'digital inequality': Studying Internet use as penetration increases. *Princeton: Center for Arts and Cultural Policy Studies, Woodrow Wilson School, Princeton University*. Retrieved from https://www.princeton.edu/~artspol/workpap/WP15%20-%20DiMaggio%2BHargittai.pdf

DiMaggio, P., Hargittai, E., Celeste, C., & Shafer, S. (2004). Digital Inequality: From unequal access to differentiated use: A literature review and agenda for research on digital inequality. In K. Neckerman (Ed.), *Social Inequality* (pp. 355-400). New York, NY: Russell Sage Foundation. Retrieved from http://webuse.org/pdf/DiMaggioEtAl-DigitalInequality2004.pdf

Diodato, M. (2007). Innovative age: Technology for education in the developing world. *Harvard International Review*, *28*(4). Retrieved from http://hir.harvard.edu/index.php?page=article&id=1519&p

Dixon-Woods, M., Agarwal, S., Jones, D., Young, B., & Sutton, A. (2005). Synthesising qualitative and quantitative evidence: a review of possible methods. *Journal of health services research & policy*, *10*(1), 45-53B.

Eastern Townships School Board (2003). *Dennis McCullough Initiative Enhanced Learning Strategy: Goals and expectations.* Retrieved from http://www.etsb.qc.ca/en/enhanced_learning_strategy/obj_goals_expectations.html

Educational Technology Debate. (2009). Assessing ICT4E evaluations: Educational technology debate: Exploring ICT and learning in developing countries. [Web log] Retrieved from http://edutechdebate.org/archive/assessing-ict4e-evaluations/

EPPI-Centre. (2009). EPPI-Centre Home. Retrieved from http://eppi.ioe.ac.uk/cms/Default.aspx

Ertmer, P. A. (2005). Teacher pedagogical beliefs: The final frontier in our quest for technology integration? *Educational technology research and development*, 53(4), 25-39. doi: 10.1007/BF02504683

Ertmer, P. A., Ottenbreit-Leftwich, A. T., Sadik, O., Sendurur, E., & Sendurur, P. (2012). Teacher beliefs and technology integration practices: A critical relationship. *Computers & Education*, *59*(2), 423-435. doi:10.1016/j.compedu.2012.02.001

Evans, D. (2003). Hierarchy of evidence: a framework for ranking evidence evaluating healthcare interventions. *Journal of clinical nursing*, *12*(1), 77-84. doi: 10.1046/j.1365-2702.2003.00662.x

Fitz-Gibbon, C. T., & Morris, L. L. (1996). Theory-based evaluation. *Evaluation Practice*, *17*(2), 177-184. doi:10.1177/109821409601700211

Fleischer, H. (2012). What is our current understanding of one-to-one computer projects: A systematic narrative research review. *Educational Research Review*, *7*(2), 107-122. doi:10.1016/j.edurev.2011.11.004

Freeman, M., Preissle, J., Roulston, K., & Pierre, E. A. S. (2007). Standards of evidence in qualitative research: An incitement to discourse. *Educational researcher*, *36*(1), 25-32. doi: 10.3102/0013189X06298009

Fritz, C. O., Morris, P. E., & Richler, J. J. (2012). Effect size estimates: current use, calculations, and interpretation. *Journal of Experimental Psychology: General*, *141*(1), 2. http://dx.doi.org/10.1037/a0024338

Fuchs, T., & Wößmann, L. (2005). *Computers and student learning: Bivariate and multivariate evidence on the availabilityand use of computers at home and atschool* (Working Paper No. 8). Ifo Working Papers. Munich, Germany: Ifo Institute for Economic Research at the University of Munich. Retrieved from http://www.cesifo.de/pls/guest/download/Ifo%20Working%20Papers%20(seit%202005)/IfoWorkingPaper-8.pdf

Gladwell, M. (2007). Open secrets. *New Yorker*, *8*.

Glass, G. V. (1976). Primary, secondary, and meta-analysis of research. *Educational researcher*, 3-8. Retrieved from http://www.dataschemata.com/uploads/7/4/8/7/7487334/glass_1976_primarysecondarymetaanalysis.pdf

Goldberg, A., Russell, M., & Cook, A. (2003). The effect of computers on student writing: A meta-analysis of studies from 1992 to 2002. *Journal of Technology, Learning, and Assessment*, *2*(1), 1-24. Retrieved from http://www.staff.ucsm.ac.uk/rpotter/ict/research/effects-writing.pdf

Goldsmith, M. R., Bankhead, C. R., & Austoker, J. (2007). Synthesising quantitative and qualitative research in evidence-based patient information. *Journal of epidemiology and community health*, *61*(3), 262-270. doi:10.1136/jech.2006.046110

Gough, D. (2007). Weight of evidence: a framework for the appraisal of the quality and relevance of evidence. *Research papers in education*, *22*(2), 213-228. doi: 10.1080/02671520701296189

Gravelle, P. B. (2003). *Early evidence from the field–the Maine Learning Technology Initiative: Impact on the digital divide* (Evaluation No. 2). Early evidence from the field (p. 21). University of Southern Maine. Retrieved from http://www.usm.maine.edu/cepare/pdf/mlti/Iimpact%20on%20the%20digital%20divide%20as%20OCCASIONAL%20PAPER%202.pdf

Great Maine Schools Project. (2004). *One-to-one laptops in a high school environment: Piscataquis Community High School study final report*. Portland, ME: Mitchell Institute. Retrieved from http://www.greatschoolspartnership.org/pdf/One-to-OneComputing_Report.pdf

The Greaves Group, The Hayes Connection. (2006). *America's digital schools - mobilizing the curriculum: A five-year forecast*. The Greaves Group, The Hayes Connection. Retrieved from http://www.ads2006.net/ads2006/pdf/ADS2006KF.pdf

Grimes, D., & Warschauer, M. (2008). Learning with laptops: A multi-method case study. *Journal of Educational Computing Research*, *38*(3), 305-332. doi:10.2190/ec.38.3.d

Gulek, J., & Demirtas, H. (2004). Learning with technology: The impact of laptop use on student achievement. *Journal of Technology, Learning, and Assessment*, *3*(2). Retrieved from http://webdev.shorelineschools.org/instruction/tech/pdf/jtla(1-1impact).pdf

Hannafin, M. J., & Land, S. M. (1997). The foundations and assumptions of technology-enhanced student-centered learning environments. *Instructional Science*, *25*(3), 167-202. doi: 10.1023/A:1002997414652

Hanushek, E. A. (1997). Assessing the effects of school resources on student performance: An update. *Educational evaluation and policy analysis*, *19*(2), 141-164. doi: 10.3102/01623737019002141

Harasim, L., Hiltz, S., Teles, L., & Turoff, M. (1995). *Learning networks: A field guide to teaching and online learning*. MIT Press.

Harden, A., Garcia, J., Oliver, S., Rees, R., Shepherd, J., Brunton, G., & Oakley, A. (2004). Applying systematic review methods to studies of people's views: an example from public health research. *Journal of Epidemiology and Community Health*, *58*(9), 794-800. doi:10.1136/jech.2003.014829

Harel, I., & Papert, S. (1991). *Constructionism.* Norwood. NJ: Ablex Publishing.

Hargittai, E. (2002). Second-level digital divide: Differences in people's online skills. *First Monday*, *7*(4-1).

Hargittai, E. (2003). The digital divide and what to do about it. In D. C. Jones (Ed.), *New economy handbook* (pp. 821-839). San Diego, CA: Academic Press.

Harris, D. N. (2009). Toward policy-relevant benchmarks for interpreting effect sizes: Combining effects with costs. *Educational Evaluation and Policy Analysis*, *31*(1), 3-29. doi:10.3102/0162373708327524

Hattie, J. (2009). *Visible learning: A synthesis of over 800 meta-analyses relating to achievement*. New York, NY: Routledge.

Healy, J. M. (1998). *Failure to connect: How computers affect our children's minds for better and worse*. New York, NY: Simon & Schuster.

Hedges, L. V. (2009). Statistical considerations. In H. Cooper, L. V. Hedges and J. C. Valentine (Eds.), *The handbook of research synthesis and meta-analysis* (2nd ed.) (pp. 7-47). New York, NY: Russell Sage Foundation.

Hedges, L. V., & Olkin, I. (1985). *Statistical methods for meta-analysis*. Orlando, FL: Academic Press.

Helmersen, P. (2006, March). Human factors in emerging markets: First world solutions addressing third world needs. In *HFT, 20th International Symposium*. Retrieved from http://www.hft.org/HFT06/paper06/04_Helmersen.pdf

Hill, J., & Reeves, T. (2004). *Change takes time: The promise of ubiquitous computing in schools. A report of a four year evaluation of the laptop initiative at Athens Academy*. Atlanta, GA: Department of Instructional Technology, University of Georgia. Retrieved from http://lpsl.coe.uga.edu/projects/aalaptop/pdf/finalreport.pdf

Hirji, Z., Barry, B., Fadel, R., & Gavin, S. (2010). Assessment overview of One Laptop per Child projects. *One Laptop per Child Foundation. Learning Group*. Retrieved from http://wiki.laptop.org/images/2/24/OLPCF_M%26E_Publication.pdf

Hmelo-Silver, C. E., Duncan, R. G., & Chinn, C. A. (2007). Scaffolding and achievement in problem-based and inquiry learning: A response to Kirschner, Sweller, and Clark (2006). *Educational Psychologist*, *42*(2), 99-107. doi:10.1080/00461520701263368

Holcomb, L. B. (2009). Results & lessons learned from1:1 laptop initiatives: A collective review. *TechTrends: Linking Research & Practice to Improve Learning*, *53*(6), 49-55. doi: 10.1007/s11528-009-0343-1

Hole-in-the-Wall Education Ltd. (2009). Hole-in-the-Wall. *Hole-in-the-Wall*. Retrieved April 7, 2010, from http://www.hole-in-the-wall.com/

Inamdar, P. (2004). Computer skills development by children using 'hole in the wall' facilities in rural India. *Australasian Journal of Educational Technology*, *20*(3), 337-350.

Inamdar, P., & Kulkarni, A. (2007). 'Hole-in-the-Wall' Computer kiosks foster mathematics achievement - A comparative study. *Educational Technology & Society*, *10*(2), 170-179. Retrieved from http://www.hole-in-the-wall.com/docs/Paper11.pdf

Inan, F. A., & Lowther, D. L. (2010a). Factors affecting technology integration in K-12 classrooms: a path model. *Educational Technology Research and Development*, *58*(2), 137-154. doi: 10.1007/s11423-009-9132-y

Inan, F. A., & Lowther, D. L. (2010b). Laptops in the K-12 classrooms: Exploring factors impacting instructional use. *Computers & Education*, *55*(3), 937-944. doi:10.1016/j.compedu.2010.04.004

Institute of Education Sciences (n.d.). What Works Clearinghouse. Home. Retrieved from http://ies.ed.gov/ncee/wwc/

Inter-American Development Bank. (2009, September 24). Lessons learned and future challenges [video file]. Retrieved from http://www.youtube.com/watch?v=RH94FSWsp5U&feature=youtube_gdata

Jarboe, K. P. (2001). *Inclusion in the information age: Reframing the debate*. Washington, DC: Athena Alliance.

Johnstone, B. (2003). Never mind the laptops: Kids, computers, and the transformation of learning. Iuniverse Inc.

Jonassen, D. H. (2007). Engaging and supporting problem solving in online learning. In R. Luppicini (Ed.), *Online learning communities*: *Perspectives in instructional technology and distance education* 109-128. Charlotte, NC: Information Age Publishing.

Jonassen, D. H., Carr, C., & Yueh, H. (1998). Computers as mindtools for engaging learners in critical thinking. *TechTrends*, *43*(2), 24-32. doi:10.1007/BF02818172

Jonassen, D. H., Howland, J., Moore, J., & Marra, R. M. (2003). *Learning to solve problems with technology: A constructivist perspective, 2nd Ed.* Columbus, OH: Prentice-Hall.

Kirschner, P. A., Sweller, J., & Clark, R. E. (2006). Why minimal guidance during instruction does not work: An analysis of the failure of constructivist, discovery, problem-based, experiential, and inquiry-based teaching. *Educational Psychologist*, *41*(2), 75-86. doi: 10.1207/s15326985ep4102_1

Korman, K. (2007). Lessons learned. *netWorker*, *11*(1), 3. doi:10.1145/1231827.1231831

Kozma, R. B. (1994a). The influence of media on learning: The debate continues. *School Library Media Research*, *22*(4).

Kozma, R. (1994b). Will media influence learning? Reframing the debate. *Educational Technology Research and Development*, *42*(2), 7-19. doi:10.1007/BF02299087

Kraemer, K. L., Jason D., and Prakul S. (2009). One Laptop per Child: Vision vs. reality." *Communications of the ACM*, June 1, 2009. http://pcic.merage.uci.edu/papers/2008/OneLaptop.pdf.

Kuh, G. D., & Vesper, N. (2001). Do computers enhance or detract from student learning? *Research in Higher Education*, *42*(1), 87-102. doi: 10.1023/A:1018768612002

Kuhn, D. (2007). Is direct instruction an answer to the right question? *Educational Psychologist*, *42*(2), 109-113. doi: 10.1080/00461520701263376

Kulik, J. A. (2003). *Effects of using instructional technology in elementary and secondary schools: What controlled evaluation studies say*. Arlington, VA: SRI International. Retrieved from http://www.ssa.sri.com/policy/csted/reports/sandt/it/Kulik_ITinK-12_Main_Report.pdf

Kulik, J. A., & Kulik, C. L. C. (1989). Meta-analysis in education. *International Journal of educational research*, *13*(3), 221-340.

Lane, D. (2003). *Early evidence from the field: The Maine Learning Technology Initiative: Impact on students and learning. Occasional Paper* 1.Gorham, ME: Center for Education Policy, Applied Research, and Evaluation, University of Southern Maine. Retrieved from https://usm.maine.edu/sites/default/files/Center%20for%20Education%20Policy,%20Applied%20Research,%20and%20Evaluation/MLTI_Impact_Students_Learning.pdf

Laurillard, D. (2002). *Rethinking university teaching: a framework for the effective use of educational technology* (2nd ed.). Oxon, UK: Falmer Press.

Leech, N. L., & Onwuegbuzie, A. J. (2004). A proposed fourth measure of significance: The role of economic significance in educational research. *Evaluation and Research in Education*, *18*(3), 179-198. doi: 10.1080/09500790408668317

Lei, J., Conway, P. F., & Zhao, Y. (2008). *The digital pencil: One-to-one computing for children*. New York: Routledge.

Leinhardt, G. (1980). Modeling and measuring educational treatment in evaluation. *Review of Educational Research*, *50*(3), 393-420. doi:10.3102/00346543050003393

Lento, E. & Salpeter, J. (2007). *But does it work? Evaluating our nation's one-to-one initiatives*. K-12 Computing Blueprint. Retrieved from http://www.k12blueprint.com/content/does-it-work-evaluating-our-nations-one-one-initiatives

Levin, H. M., & McEwan, P. J. (2001). *Cost-effectiveness analysis: Methods and applications* (2nd ed.). Thousand Oaks, CA: Sage Publications, Inc.

Lipsey, M. W., & Wilson, D. (2001). *Practical Meta-Analysis*. Thousand Oaks, Calif: SAGE Publications, Inc.

Loertscher, D. (2006). Towards one-to-one computing – the research. *Teacher Librarian. 34*(1), 38.

Lou, Y., Abrami, P. C., & d'Apollonia, S. (2001). Small group and individual learning with technology: A meta-analysis. *Review of Educational Research*, *71*(3), 449-521. doi: 10.3102/00346543071003449

Lowes, S. & Luhr, C. (2008). *Evaluation of the teaching matters One Laptop per Child (XO) pilot at Kappa IV*. New York, NY: Institute for Learning Technologies, Teachers College, Columbia University. Retrieved from http://www.teachingmatters.org/files/olpc_kappa.pdf

Lowther, D. L., Inan, F. A., Daniel Strahl, J., & Ross, S. M. (2008). Does technology integration "work" when key barriers are removed? *Educational Media International*, *45*(3), 195-213. doi: 10.1080/09523980802284317

Lowther, D., Ross, S., & Morrison, G. (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. doi: 10.1007/BF02504551

Lowther, D., Ross, S., Strahl, J. D., Inan, F. A., & Pollard, D. (2005). *Freedom to Learn program: Michigan 2004-2005 evaluation report*. Memphis, TN: Center for Research in Educational Policy, The University of Memphis. Retrieved from http://www.ftlwireless.org/upload_3/FTL%20Year%201%20Evaluation%20Report%20FINAL%20cr.pdf

Maderthaner, P. (2007). Laptop classrooms as ‚catalysts of change'? A review of international research on the effects of laptop classrooms. In *Conference ICL2007, September 26-28, 2007*. Villach, Austria: Kassel University Press. Retrieved from https://hal.archives-ouvertes.fr/file/index/docid/257122/filename/204_Final_Paper.pdf

Maxwell, J. A. (1992). Understanding and validity in qualitative research. *Harvard educational review*, *62*(3), 279-301.

Mayer, R. E. (2004). Should there be a three-strikes rule against pure discovery learning?. *American Psychologist*, *59*(1), 14. doi: 10.1037/0003-066X.59.1.14

Mays, N., Pope, C., & Popay, J. (2005). Systematically reviewing qualitative and quantitative evidence to inform management and policy-making in the health field. *Journal of health services research & policy*, *10*(suppl 1), 6-20. doi: 10.1258/1355819054308576

McCombs, B. L. (2001). What do we know about learners and learning? The learner-centered framework: Bringing the educational system into balance. *Educational Horizons*, *79*(4), 182-193.

McKinsey & Co. (2014). *Offline and falling behind: Barriers to internet adoption*. McKinsey & Co. Retrieved from http://www.mckinsey.com/Insights/High_Tech_Telecoms_Internet/Offline_and_falling_behind_Barriers_to_Internet_adoption

Mitra, S. (2000). Minimally invasive education for mass computer literacy. Presented at the CRIDALA 2000 Confernce, Hong Kong. Retrieved from http://www.hole-in-the-wall.com/docs/Paper01.pdf

Mitra, S., Dangwal, R., Chatterjee, S., Jha, S., Bisht, R. S., & Kapur, P. (2005). Acquisition of computing literacy on shared public computers: Children and the "Hole in the Wall". *Australasian Journal of Educational Technology*, *21*(3), 407-426. Retrieved from http://www.ascilite.org.au/ajet/ajet21/mitra.html

Mitra, S., & Rana, V. (2001). Children and the Internet: Experiments with minimally invasive education in India. *British Journal of Educational Technology*, *32*(2), 221-232. Retrieved from http://hole-in-the-wall.com/docs/paper02.pdf doi:10.1111/1467-8535.00192

Monk, D. H., & King, J. A. (1993). Cost analysis as a tool for education reform. *Reforming education: The emerging systemic approach*, 131-150.

Morrison, G., Ross, S., & Lowther, D. (2009). Technology as a change agent in the classroom. In L. Moller, J. B. Huett, & D. M. Harvey (Eds.), *Learning and instructional technologies for* *the 21st century,* 1–23. Springer US. Retrieved from http://dx.doi.org/10.1007/978-0-387-09667-4_9

Mowbray, C. T., Holter, M. C., Teague, G. B., & Bybee, D. (2003). Fidelity criteria: Development, measurement, and validation. *American Journal of Evaluation*, *24*(3), 315-340. doi: 10.1177/109821400302400303

Nakagawa, S., & Cuthill, I. C. (2007). Effect size, confidence interval and statistical significance: a practical guide for biologists. *Biological Reviews*,*82*(4), 591-605. doi: 10.1111/j.1469-185X.2007.00027.x

Negroponte, N. (2005). Laptop for every kid. *Wired*, *2005*(November). Retrieved from http://www.wired.com/techbiz/people/news/2005/11/69615

Negroponte, N. (2006a). *Nicholas Negroponte: One Laptop per Child* [video file]. Retrieved from http://www.ted.com/talks/nicholas_negroponte_on_one_laptop_per_child.html

Negroponte, N. (2006b). One Laptop per Child. *Innovate, 2006*(1). Retrieved 18 July 2014 from http://web.up.ac.za/sitefiles/file/EBIT-Innovate/One_Laptop_per_child.pdf.

Neill, A. S. (1960). Summerhill: A radical approach to child rearing. New york: Hart Publishing Company.

Noble, D., Schneiderman, B., Herman, R., Agre, P., & Denning, P. J. (1998). Technology in education: The fight for the future. *EDUCOM Review*, *33*(3), 22-34.

Nugroho, D., & Londsale, M. (2009). Evaluation of OLPC programs globally: A literature review. *Melbourne, Australia: Australian Council of Educational Research. Mimeographed document*. Retrieved from http://wiki.laptop.org/images/a/a5/OLPC_Lit_Review_v4_Aug2010.pdf

O'Donnell, C. L. (2008). Defining, conceptualizing, and measuring fidelity of implementation and its relationship to outcomes in K-12 curriculum intervention research. *Review of Educational Research*, *78*(1), 33-84. doi:10.3102/0034654307313793

O'Hanlon, C. (2007). 1-to-1 computing: A measure of success. *THE Journal*,*34*(2), 26-32. Retrieved from http://thejournal.com/articles/2007/02/01/1to1-computing--a-measure-of-success.aspx

Orwin, R. G. (1983). A fail-safe N for effect size in meta-analysis. *Journal of Educational Statistics*, 8, 157-159. doi: 10.2307/1164923

Palloff, R. M., & Pratt, K. (2005). *Collaborating online: Learning together in community*. San Francisco, CA: Jossey-Bass.

Papert, S. (1980). *Mindstorms: Children, computers, and powerful ideas*. New York, NY: Basic books.

Papert, S. (1993). *The children's machine: Rethinking school in the age of the computer*. New York, NY: Basic Books.

Papert, S. (n.d.). Constructionism vs. instructionism. Retrieved from http://www.papert.org/articles/const_inst/const_inst1.html

Penuel, W. R. (2006). Implementation and effects of one-to-one computing initiatives: A research synthesis. *Journal of Research on Technology in Education*, *38*(3), 329-348. doi:10.1080/15391523.2006.10782463

Petticrew, M., & Roberts, H. (2003). Evidence, hierarchies, and typologies: Horses for courses. *Journal of Epidemiology and Community Health*, *57*(7), 527-529. doi:10.1136/jech.57.7.527

Ploskonka, Y. (2009, April 29). The use and misuse of computers in education. OLPC//News. Retrieved April 14, 2010, from http://www.olpcnews.com/implementation/evaluations/use_misuse_computers_in_edu.html

Pope, C., Mays, N., & Popay, J. (2007). *Synthesising qualitative and quantitative health evidence: A guide to methods*. Maidenhead, England: McGraw-Hill International.

Prensky, M. (2001). Digital natives, digital immigrants part 1. *On the horizon*,*9*(5), 1-6. Retrieved from http://www.marcprensky.com/writing/Prensky%20-%20Digital%20Natives,%20Digital%20Immigrants%20-%20Part1.pdf

Raudenbush, S. W. (2009). Analyzing effect sizes: Random-effects models. In H. Cooper, L. V. Hedges and J. C. Valentine (Eds.), *The handbook of research synthesis and meta-analysis* (2nd ed.) 295-315. New York, NY: Russell Sage Foundation.

Rees, R., Kavanagh, J., Harden, A., Shepherd, J., Brunton, G., Oliver, S., & Oakley, A. (2006). Young people and physical activity: a systematic review matching their views to effective interventions. *Health education research*,*21*(6), 806-825. doi: 10.1093/her/cyl120 Retrieved from http://her.oxfordjournals.org/content/21/6/806.full

Rice, J. K. (1997). Cost analysis in education: Paradox and possibility. *Educational Evaluation and Policy Analysis*, 309-317. doi: 10.2307/1164445

Rockman, S. (2004). Getting results with laptops. *Technology & Learning*,*25*(3), 1-12. Retrieved from http://www.sca2006.tic-educa.org/archivos/modulo_2/sesion_3/getting_results_with_laptops.pdf

Rogers, E. M. (2010). *Diffusion of innovations*. New York, NY: Simon and Schuster.

Rogers, P. J., & Weiss, C. H. (2007). Theory-based evaluation: Reflections ten years on: Theory-based evaluation: Past, present, and future. *New directions for evaluation*, *2007*(114), 63-81. doi:10.1002/ev.225

Rosenthal, R. (1979). The "file drawer problem" and tolerance for null results. *Psychological Bulletin*, 86, 638-641. http://dx.doi.org/10.1037/0033-2909.86.3.638

Ross, S. M., Gil, L., & Cross, C. T. (2004). The past and future of comprehensive school reform: Perspectives from a researcher and practitioner. In *Putting the pieces together: Lessons from comprehensive school reform research,* 151-174. Washington, DC: The National Clearinghouse for Comprehensive School Reform. Retrieved from http://www.centerforcsri.org/PDF/PTPTLessonsfromCSRResearch.pdf

Rothstein, H. R., Sutton, A. J., & Borenstein, M. (2005). *Publication bias in meta-analysis prevention, assessment and adjustments*. Chichester, UK: John Wiley & Sons.

Rowan, B., & Miller, R. J. (2007). Organizational strategies for promoting instructional change: Implementation dynamics in schools working with comprehensive school reform providers. *American Educational Research Journal*, *44*(2), 252-297. doi: 10.3102/0002831207302498

Rowell, L. (2007). Can the "$100 laptop" change the world? *netWorker*, *11*(1), 18-25. doi:10.1145/1231827.1231828

Russell, M., Bebell, D., & Higgins, J. (2004). Laptop learning: A comparison of teaching and learning in upper elementary classrooms equipped with shared carts of laptops and permanent 1:1 laptops. *Journal of Educational Computing Research*, *30*(4), 313-330. doi: 10.2190/6E7K-F57M-6UY6-QAJJ

Russell, M., Bebell, D., Cowan, J., & Corbelli, M. (2002). *An AlphaSmart for each student: Does teaching and learning change with full access to word processors?* Chestnut Hill, MA: Technology and Assessment Study Collaborative, Boston College. Retrieved from http://www.bc.edu/research/intasc/PDF/AlphaSmartEachStudent.pdf

Russell, M., & Higgins, J. (2003). *Assessing effects of technology on learning: Limitations of today's standardized tests*. Chestnut Hill, MA: Technology and Assessment Study Collaborative, Boston College. Retrieved from http://www.bc.edu/research/intasc/PDF/EffectTechOnLearn.pdf

Sandelowski, M. (2004). Using qualitative research. *Qualitative Health Research*, *14*(10), 1366-1386. doi:10.1177/1049732304269672

Sandelowski, M., Barroso, J., & Voils, C. I. (2007). Using qualitative metasummary to synthesize qualitative and quantitative descriptive findings. *Research in nursing & health*, *30*(1), 99-111. doi:10.1002/nur.20176 Retrieved from http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2329806/

Sandelowski, M., Docherty, S., & Emden, C. (1997). Focus on qualitative methods Qualitative metasynthesis: issues and techniques. *Research in nursing and health*, *20*, 365-372. doi: 10.1002/(sici)1098-240x(199708)20:4<365::aid-nur9>3.0.co;2-e

Savage, R., & Abrami, P. C. (2007). ABRACADABRA: Progress in the development, implementation and effectiveness of a web-based literacy resource. In T. Bastiaens & S. Carliner (Eds.), *World Conference on E-Learning in Corporate, Government, Healthcare, and Higher Education 2007,* 6530-6536. Quebec City, Canada: AACE.

Savage, R., Abrami, P. C., Piquette-Tomei, N., Wood, E., & Deleveaux, G. (2008). *ABRACADABRA: A study in the development, implementation and effectiveness of a web-based literacy resource*. Ottawa, ON: Canadian Council on Learning.

Scardamalia, M. & Bereiter, C. (1996). Computer support for knowledge-building communities. In Koschmann, T. D. (Ed.), *CSCL: Theory and practice of an emerging paradigm*, 249-268. Mahwah, NJ: Erlbaum.

Schacter, J. (1999). *The impact of education technology on student achievement: What the most current research has to say*. Santa Monica, CA. Milken Exchange on Education Technology. Retrieved from http://files.eric.ed.gov/fulltext/ED430537.pdf

Scheirer, M. A., & Rezmovic, E. L. (1983). Measuring the degree of program implementation: A methodological review. *Evaluation Review*, *7*(5), 599-633. doi:10.1177/0193841x8300700502

Schmid, R. F., Bernard, R. M., Borokhovski, E., Tamim, R. M., Abrami, P. C., Surkes, M. A., Wade, C. A., & Woods, J. (2014). The effects of technology use in postsecondary education: A meta-analysis of classroom applications. *Computers & Education, 72*, 271-291. http://dx.doi.org/10.1016/j.compedu.2013.11.002

Schmid, R. F., Miodrag, N., & Di Francesco, N. (2008). A human-computer partnership: The tutor/child/computer triangle promoting the acquisition of early literacy skills. *Journal of Research on Technology in Education*, *41*(1), 22. doi:abs/10.1080/15391523.2008.10782523

Schmidt, H. G., Loyens, S. M. M., Van Gog, T., & Paas, F. (2007). Problem-based learning is compatible with human cognitive architecture: Commentary on Kirschner, Sweller, and Clark (2006). *Educational Psychologist*, *42*(2), 91-97. doi:10.1080/00461520701263350

Sell, G. R., Cornelius-White, J. H. D., Chang, C., Mclean, A., & Roworth, R. (2012). *A meta-synthesis of research on 1: 1 technology initiatives in K-12 education*. Springfield, MO: Ozarks Educational Research Initiative. Institute for School Improvement, Missouri State University. Retrieved from http://education.missouristate.edu/assets/clse/Final_Report_of_One-to-One_Meta-Synthesis__April_2012_.pdf

Selwyn, N. (2004). Reconsidering political and popular understandings of the digital divide. *New Media & Society*, *6*(3), 341-362. doi: 10.1177/1461444804042519

Severin, E., & Capota, C. (2011). *One-to-one laptop programs in Latin America and the Caribbean: Panorama and perspectives*. Washington, DC: Inter-American Development Bank. Retrieved from http://publications.iadb.org/bitstream/handle/11319/4919/One-to-One%20Laptop%20Programs%20in%20Latin%20America%20and%20the%20Caribbean%20%20%20%20%20%20%20%20%20%20.pdf?sequence=1

Shadish, W. R., & Haddock, C. K. (2009). Combining estimates of effect size. In H. Cooper, L. V. Hedges and J. C. Valentine (Eds.), *The handbook of research synthesis and meta-analysis* (2nd ed.), 257-277. New York, NY: Russell Sage Foundation.

Shadish, W., & Myers, D. (2004). *Campbell Collaboration research design policy brief,* No. 4684. Retrieved from http://www.campbellcollaboration.org/artman2/uploads/1/C2_Research_Design_Policy_Brief-2.pdf

Shakeshaft, C., Mann, D., & Tinsley, K. (2009). The relationship of ubiquitous computer use, teacher behavior, and students achievement: A longitudinal study of Henrico County

Virginia public school's laptop computing initiative: 2005-06 to 2007-08. Presented at the *2009 AERA Annual meeting "Disciplined inquiry: Education research in the circle of knowledge"*, San Diego: CA. Retrieved from http://www.aera.net/Default.aspx?id=5348

Shapley, K.S., Sheehan, D., Maloney, C., & Caranikas-Walker, F. (2010). Evaluating the implementation fidelity of technology immersion and its relationship with student achievement. *Journal of Technology, Learning, and Assessment, 9*(4). Retrieved from https://ejournals.bc.edu/ojs/index.php/jtla/article/viewFile/1609/1460

Shapley, K., Sheehan, D., Sturges, K., Caranikas-Walker, F., Huntsberger, B., & Maloney, C. (2006a). *Evaluation of the Texas Technology Immersion Pilot: First year results*. Austin, TX: Texas Center for Educational Research. Retrieved from http://www.txtip.info/images/06.05.06_eTxTIP_Year_1_Report.pdf

Shapley, K., Sheehan, D., Sturges, K., Caranikas-Walker, F., Huntsberger, B., & Maloney, C. (2006b). *Evaluation of the Texas Technology Immersion Pilot: An analysis of the baseline conditions and first-year implementation of technology immersion in middle school*. Austin, TX: Texas Center for Educational Research. Retrieved from http://www.tcer.org/research/etxtip/documents/01_final_qualitative.pdf

Shapley, K., Sheehan, D., Maloney, C., Caranikas-Walker, F., Huntsberger, B., & Sturges, K. (2007). Evaluation of the Texas Technology Immersion Pilot: Findings from the second year. Austin, TX: Texas Center for Educational Research. Retrieved from http://files.eric.ed.gov/fulltext/ED536295.pdf

Shapley, K., Sheehan, D., Maloney, C., & Caranikas-Walker, F. (2008). Evaluation of the Texas Technology Immersion Pilot: Outcomes for the third year (2006-07). Austin, TX: Texas

Center for Educational Research. Retrieved from http://files.eric.ed.gov/fulltext/ED536294.pdf

Shapley, K., Sheehan, D., Maloney, C., & Caranikas-Walker, F. (2009). Evaluation of the Texas Technology Immersion Pilot: Final outcomes for a four-year study (2004-05 to 2007-08). Austin, TX: Texas Center for Educational Research. Retrieved from http://files.eric.ed.gov/fulltext/ED536296.pdf

Sharpe, D. (1997). Of apples and oranges, file drawers and garbage: Why validity issues in meta-analysis will not go away. *Clinical psychology review*,*17*(8), 881-901. doi:10.1016/S0272-7358(97)00056-1

Shuell, T. J., & Farber, S. L. (2001). Students' perceptions of technology use in college courses. *Journal of Educational Computing Research*, *24*(2), 119-138. doi:10.2190/ywpn-h3dp-15lq-qnk8

Siemens, G. (2005). Connectivism: A learning theory for the digital age. *International Journal of Instructional Technology and Distance Learning*, *2*(1), 521–528. http://er.dut.ac.za/handle/123456789/69

Silvernail, D. L., & Gritter, A. K. (2007). *Maine's middle school laptop program: Creating better writers*. Portland, ME: Maine Education Policy Research Institute, University of Southern Maine. Retrieved from http://maine.gov/mlti/resources/Impact_on_Student_Writing_Brief.pdf

Silvernail, D. L., & Lane, D. M. M. (2004). The impact of Maine's one-to-one laptop program on middle school teachers and students. Portland, ME: Maine Education Policy Research

Institute, University of Southern Maine. Retrieved from https://maine.gov/mlti/articles/research/MLTIPhaseOneEvaluationReport2004.pdf

Sivin-Kachala, J., & Bialo, E. (2002). *2000 Report on the effectiveness of technology in schools* (7th ed.). Washington, DC: Software & Information Industry Assoc. Retrieved from http://www.sunysuffolk.edu/Web/Central/InstTech/projects/iteffrpt.pdf

Slavin, R. E. (2008). Perspectives on evidence-based research in education—What works? Issues in synthesizing educational program evaluations. *Educational Researcher*, *37*(1), 5-14. doi:10.3102/0013189X08314117

Slavin, R. E., & Lake, C. (2008). Effective programs in elementary mathematics: A best-evidence synthesis. *Review of Educational Research*, *78*(3), 427–515. doi:10.3102/0034654308317473

Spires, H. A., Oliver, K., & Corn, J. (2011). The new learning ecology of one-to-one computing environments: Preparing teachers for shifting dynamics and relationships. *Journal of Digital Learning in Teacher Education*, *28*(2), 63-72. doi: 10.1080/21532974.2011.10784682 Retrieved from http://files.eric.ed.gov/fulltext/EJ960152.pdf

Stevenson, K. R. (1999). *Evaluation report-year 3: Middle school laptop program, Beaufort County School District.* Beaufort, SC: Beaufort County School District. Retrieved from http://www.beaufort.k12.sc.us/district/evalreport3.htm

Steyn, H. S. (2012). Manual for the determination of effect size indices and practical significance. Retrieved from http://www.nwu.ac.za/content/statcs-effect-size

Strobel, J., & van Barneveld, A. (2009). When is PBL more effective? A meta-synthesis of meta-analyses comparing PBL to conventional classrooms. *Interdisciplinary Journal of Problem-based Learning*, *3*(1), 4. doi:10.7771/1541-5015.1046

Swan, K. (2002). Building learning communities in online courses: The importance of interaction. *Education, Communication & Information*, *2*(1), 23-49. doi:10.1080/1463631022000005016

Sweller, J., Kirschner, P. A., & Clark, R. E. (2007). Why minimally guided teaching techniques do not work: A reply to commentaries. *Educational Psychologist*, *42*(2), 115-121. doi:10.1080/00461520701263426

Tamim, R. M., Bernard, R. M., Borokhovski, E., Abrami, P. C., & Schmid, R. F. (2011). What forty years of research says about the impact of technology on learning: A second-order meta-analysis and validation study. *Review of Educational Research*, *81*(1), 4-28. doi: 10.3102/0034654310393361

Thomas, J., Harden, A., Oakley, A., Oliver, S., Sutcliffe, K., Rees, R., Brunton, G. & Kavanagh, J. (2004). Integrating qualitative research with trials in systematic reviews. *BMJ: British Medical Journal*, *328*(7446), 1010-1012. doi:10.1136/bmj.328.7446.1010 Retrieved from http://www.ncbi.nlm.nih.gov/pmc/articles/PMC404509/

Tobias, S., & Duffy, T. M. (2009). *Constructivist instruction: Success or failure?* New York, NY: Taylor & Francis.

Trimmel, M., & Bachmann, J. (2004). Cognitive, social, motivational and health aspects of students in laptop classrooms. *Journal of Computer Assisted Learning*, *20*(2), 151-158. doi:10.1111/j.1365-2729.2004.00076.x

Ungerleider, C., & Burns, T. C. (2002). Information and communication technologies in elementary and secondary education: A state of the art review. In *Actes du Colloque 2002 du Programme pancanadien de recherche en éducation (PPRE): La technologie de l'information et l'apprentissage*. Retrieved from http://www.ic.unicamp.br/~wainer/cursos/2s2004/impactos2004/ICTInSchoolsReview.pdf

United States. Web-based Education Commission, Kerrey, R., & Isakson, J. (2000). *The power of the Internet for learning: Moving from promise to practice: report of the Web-based Education Commission*. Retrieved from http://www.ed.gov/offices/AC/WBEC/FinalReport/WBECReport.pdf

Valiente, O. (2010). 1-1 in education: Current practice, international comparative research evidence and policy implications. *OECD Education Working Papers*, No. 44. Paris: OECD Publishing. http://dx.doi.org/10.1787/5kmjzwfl9vr2-en

Vernez, G., Karam, R., Mariano, L. T., & DeMartini, C. (2006). *Evaluating comprehensive school reform models at scale: Focus on implementation*. Santa Monica, CA: RAND Corporation. Retrieved from http://www.rand.org/pubs/monographs/2006/RAND_MG546.pdf

Viechtbauer, W. (2010). Conducting meta-analyses in R with the metaphor package. *Journal of Statistical Software,* 36(3), 1-48. Retrieved from http://www.jstatsoft.org/v36/i03/.

Viechtbauer, W. (2014). The metafor package: A meta-analysis package for R. (Version 1.9-5) [software] Available from http://cran.r-project.org/web/packages/metafor/index.html

Vigdor, J. L., Ladd, H. F. & Martinez, E. (2014). Scaling the digital divide: Home computer technology and student achievement. *Economic Inquiry, 52*:3, 1103–1119. doi: 10.1111/ecin.12089

Wambach, C. (2006). From revolutionary to evolutionary: 10 years of 1-to-1 computing: laptop initiatives are now a decade old. Once a point of controversy, they have become the cornerstone of every district's technology hopes. *THE Journal (Technological Horizons In Education)*, *33*(14), 58. Retrieved from http://thejournal.com/Articles/2006/09/01/Smart-Classroom--From-Revolutionary-to-Evolutionary-10-Years-of-1to1-Computing.aspx?sc_lang=en&Page=2

Warschauer, M. (2002). Reconceptualizing the digital divide. *First Monday*, *7*(7). Retrieved from http://firstmonday.org/htbin/cgiwrap/bin/ojs/index.php/fm/article/viewArticle/967/888

Warschauer, M. (2004). *Technology and social inclusion: Rethinking the digital divide*. Cambridge, MA: MIT Press.

Warschauer, M. (2006). *Laptops and literacy: Learning in the wireless classroom*. New York, NY: Teachers College Press.

Warschauer, M. (2007). Information Literacy in the Laptop Classroom. *Teachers College Record*, *109*(11), 2511-2540.

Warschauer, M. (2009). OLPC: How not to run a laptop program. *Educational technology debate: Exploring ICT and learning in developing countries*. [Web log]. Retrieved from http://edutechdebate.org/one-laptop-per-child-impact/olpc-how-not-to-run-a-laptop-program/#IDComment64902922

Warschauer, M., & Ames, M. (2010). Can One Laptop per Child save the world's poor? *Journal of International Affairs*, *64*(1).

Warschauer, M., Grant, D., Real, G. D., & Rousseau, M. (2004). Promoting academic literacy with technology: Successful laptop programs in K-12 schools. *System*, *32*(4), 525-537. doi:10.1016/j.system.2004.09.010

Warschauer, M., & Matuchniak, T. (2010). New technology and digital worlds: Analyzing evidence of equity in access, use, and outcomes. *Review of Research in Education*, *34*(1), 179-225. doi: 10.3102/0091732X09349791

Waxman, H., Lin, M., & Michko, G. (2003). *A meta-analysis of the effectiveness of teaching and learning with technology on student outcomes*. Naperville, IL: Learning Point Associates. Retrieved from http://treeves.coe.uga.edu/edit6900/metaanalysisNCREL.pdf

Weiss, C. H. (1997). How can theory-based evaluation make greater headway? *Evaluation Review*, *21*(4), 501-524. doi:10.1177/0193841X9702100405

Wertheimer, A. I., Santella, T. M., Finestone, A. J., & Levy, R. A. (2005). Drug delivery systems improve pharmaceutical profile and facilitate medication adherence. *Advances in Therapy*, *22*(6), 559-577. doi:10.1007/BF02849950

Weston, M. E., & Bain, A. (2010). The end of techno-critique: The naked truth about 1:1 laptop initiatives and educational change. *The Journal of Technology, Learning and Assessment*, *9*(6). Retrieved from http://ejournals.bc.edu/ojs/index.php/jtla/issue/view/150

Wilson, D. B. (n.d.). Practical meta-analysis effect size calculator. [Web-based software]. Available from: http://www.campbellcollaboration.org/escalc/html/EffectSizeCalculator-Home.php

Woodbridge, S. (2000). *Norwood School laptop and technology program evaluation final report.* Bethesda, MD: Norwood School. Retrieved from http://www.norwood.pvt.k12.md.us/uploads/Laptop_Evaluation_Full.pdf

Wozney, L., Venkatesh, V., & Abrami, P. (2006). Implementing computer technologies: Teachers' perceptions and practices. *Journal of Technology and teacher education*, *14*(1), 173-207

Yang, Y., Hu, X., Qu, Q., Lai, F., Shi, Y., Boswell, M., & Rozelle, S. (2013). Roots of tomorrow's digital divide: documenting computer use and internet access in china's elementary schools today. *China & World Economy*, *21*(3), 61-79. doi:10.1111/j.1749-124X.2013.12022.x

Yazon, J. M. O., Mayer-Smith, J. A., & Redfield, R. J. (2002). Does the medium change the message? The impact of a web-based genetics course on university students' perspectives on learning and teaching. *Computers & Education*, *38*(1-3), 267-285. doi:10.1016/S0360-1315(01)00081-1

Zucker, A. (2004). Developing a research agenda for ubiquitous computing in schools. *Journal of Educational Computing Research*, *30*(4), 371-386. doi: 10.2190/byr8-cgfc-wvhv-t0tl

APPENDIX A

Codebook

1. General Research Question

How, to what extent, and under what circumstances does one-to-one computing in K-12 settings impact educational goals including but not limited to student achievement, technology use, technology proficiency, engagement, attendance, and attitudes toward technology?

a) Case Survey Questions

Which variables moderate program effectiveness? Can we develop a profile or profiles of one-to-one programs by aggregating a variety of variables? Can we develop theoretical frameworks for one-to-one program effectiveness from the profiles created?

b) Meta-Analysis Questions

1. Is there a general laptop effect on the variables of student achievement, technology use, technology proficiency, engagement, attendance, and attitudes toward technology?
2. Are those general effects moderated by study quality?
3. Are the general effects moderated by contextual variables, as predicted in the literature, namely: technology use, technology integration/program implementation, duration, program theory, year, age, program size, or gender?

2. Terms and Definitions

One-to-one computing. One-to-one computing refers to educational settings in which each student has a unique laptop computer to use for educational purposes in every class, every day for no less than 6 weeks (Penuel, 2006). In some one-to-one programs students have full time access to the computers: that is they are allowed to take them home; in others, students can only use the computers at school. Though these two types of programs exhibit unique characteristics, for the purpose of this study they were both be classified as one-to-one programs and included in the study. This difference was noted in the case survey.

Student Achievement. Student achievement refers to the assessed performance on a standardized assessment, particular assignment, a group of assignments, or the composite or average score over a series of assignments. Achievement scores must be reported in both the laptop and comparison condition and be similar enough to be compared one to the other (Bernard et al., 2009). Both subjective and objective measures were included and coded in the case study.

Technology Use. Technology use refers to the frequency that and purpose(s) for which the laptops (and other related technologies) were used. Technology use as an outcome variable refers to frequency of use only. Technology use as a moderating variable or study feature refers to both frequency and purpose.

Technology Proficiency. Technology proficiency refers to the ability of students to use the available technology, particularly laptops, including but not limited to productivity software, communication tools, search and retrieval tools, and cognitive tools (Schmid et al., 2014).

Technology Integration. Technology integration refers to the degree to which technology is incorporated into the teaching and learning process. Technology integration consists of four components: (a) access, (b) technological and pedagogical support, (c) professional development, and (d) teacher and student technology use (Shapley et al., 2006).

Engagement. Engagement describes the degree to which the intervention has impacted the willingness of students to apply themselves to their studies. This category also includes the concepts of motivation, self-discipline, time on task, attention and interest (Shapley et al., 2006).

Attendance. Attendance refers to the degree to which the intervention has impacted the regularity with which students go to school.

Technology Attitudes. Technology attitudes refer to how and to what extent the intervention has impacted attitudes toward technology. By definition, this measure is self-reported.

Whether these variables were self-reported or measured was coded as a study feature.

3. Search Strategy

The following keywords and descriptors were used for document searches: one-to-one, ubiquitous computing, laptop initiative, laptop computing, K-12, school, education, laptop, notebook, netbook, pda, handheld, mobile, portable, technology integration, personal digital assistant, computers, evaluation, technology uses in education, computer uses in education, handheld computer, lab, access to computers, computer assisted instruction, computer attitudes, computer centers, computer literacy, computer managed instruction, and integrated learning systems.

The following databases were searched using a variety of combinations of the search terms: ERIC, ProQuest full text, ProQuest dissertations, ProQuest CBCA Canadian, Educational Technology Abstracts, and Academic Search Premier. In addition, using the same search terms, Internet searches were conducted using the Google and Google Scholar search engines. Additional web resources were accessed using several online one-to-one clearinghouses: One-to-One Information Resource (http://www.k12one2one.org/), Ubiquitous Computing Consortium – Literature Review and Resources (http://ubiqcomputing.org/lit_review.html), One-to-One Institute (http://sparty.crt.net/121/research.cfm), BC Ministry Education – Laptop Initiative (http://www.bced.gov.bc.ca/onetoone/resources.htm), Govt of Western Australia, Dept of Education and Training, Notebooks for students 1:1 (http://www.det.wa.edu.au/education/cmis/eval/curriculum/ict/notebooks/).

When dead links were encountered, attempts were made to locate the documents using the Internet Archive's WayBackMachine (http://www.archive.org). Additional documents were located by two methods of pearling: first, additional documents would be identified from reference lists of documents already retrieved, and second, retrieved documents would be scanned for any mention of other school, district, or state laptop programs. The name of the school or district would then be used as search terms to attempt to locate documents relating to the referenced laptop initiative. Searches were first conducted in March 2007 and updated according to the following schedule: ERIC – March 2007, January 2008, March 2008, March 2009, April 2010, Jan 2014; other databases – March 2007, March 2008, April 2010, Jan 2014, hand searches (internet and paper based) – March 2007, March 2008, March 2009, April 2010, Jan 2014.

Finally, when there was evidence of the existence of a K-12 one-to-one program with no publicly available reports or evaluations, schools, school boards, school district offices, or other relevant governing bodies were contacted directly to request access to reports of any evaluation studies.

Specific database search strategies are listed below:

ERIC

- (DTC=143) and (((("technology uses in education" or "computer uses in education") in DEM,DER,IDM,IDR) or ((technology integration) in DEM,DER,IDM,IDR)) and (((personal digital assistant*) or (handheld* near3 computer*)) or (handheld* near3 computer*) or (#1 or (cell* adj telephone*)) or (portable adj lab*) or ((laptop* or portable* or mobile) adj computer*)))
- ((portable) or (mobile) or (one-to-one) or (ubiquitous) or (Laptop)) and ((PY>=1997) and (DTC=143)) and (("Access-to-Computers" in DEM,DER) or ("Computer-Assisted-Instruction" in DEM,DER) or ("Computer-Attitudes" in

DEM,DER) or ("Computer-Centers" in DEM,DER) or ("Computer-Literacy" in DEM,DER) or ("Computer-Managed-Instruction" in DEM,DER) or ("Computer-Uses-in-Education" in DEM,DER) or ("Integrated-Learning-Systems" in DEM,DER))

PRO QUEST full text

(mobile) OR (portable) AND (technology uses in education) AND PDN(>12/31/1989)

PRO QUEST full text

(mobile) OR (portable) AND (technology uses in education) AND PDN(>12/31/1989)

PRO QUEST CBCA Canadian

(ubiquitous) OR (laptops) OR ("one to one") OR (mobile) OR (portable) AND (education) AND PDN(>12/31/1989)

Database: CBCA Education
Limit results to: scholarly
Look for terms in: Citation and abstract
Publication type: Scholarly journals
Set Up Alert

(LSU({EDUCATION}) AND LSU({TECHNOLOGY}) AND LSU({COMPUTER USES IN EDUCATION})) AND PDN(>12/31/1996)

Database: CBCA Education
Limit results to: scholarly
Look for terms in: Citation and abstract
Publication type: Scholarly journals
Set Up Alert

Education Technology Abstracts

Name: laptop, one-to-one, ubiquitous

Search Expression: laptop (all) OR ubiquitous (all) OR one-to-one (all) published after 1/1/1997 Educational Technology Abstracts (era sub-databases) within Educational Research Abstracts Online, limited to subscriptions

Academic Search Premier

Query: (one-to-one OR ubiquitous) and (laptop OR computers) and (school or education)

Limiters: Scholarly (Peer Reviewed) Journals; Published Date: 199701-200703

Run via: **Interface** – EBSCOhost; **Search Screen** – Advanced Search; **Database** – Academic Search Premier

4. Selection of Studies: Inclusion and Exclusion Criteria

For the Case Survey, studies were excluded only for the following reasons:

- N121 (Not a One-to-One study): Conditions do not fit the One-to-One definition.
- DUR (Duration): The analysis does not consider studies in which the duration of one-to-one computing exposure lasted for less than six weeks.
- NSB (Not school based): One-to-one initiative not in K-12 school environment.
- OA (Opinion article): An article that reflects personal opinion.
- RA (Review article): An article that includes a general review of findings or studies in the field will be excluded from the case study and meta-analysis steps.
- MA (Meta-analysis): Meta-analyses addressing one-to-one initiatives will be excluded from the case study and meta-analysis.

For the meta-analysis, more stringent criteria were used. Studies must compare one-to-one computing in K-12 with a control condition (one to many, computer lab time, no technology, a pre-treatment condition). One-to-one initiatives must be school based and evaluate at least six weeks of the treatment. Outcomes must include one or more of the following: Achievement, Technology use, Technology proficiency, Attendance, Engagement, or Attitudes toward technology. Measures must be reported in a way that enables effect size extraction or estimation, including information on total and group sample sizes (quantitative data sufficiency criterion). Other reasons for exclusion are noted below. Studies that satisfy inclusion criteria were retrieved for full text review, regardless of the type of study design: experimental (randomly assigned group comparison), quasi-experimental (comparison of pre-existing groups) or pre-experimental (one group pre-test and post-test). Study design was coded in the Case Study. Studies were excluded from the quantitative analysis for the following reasons:

- DOA (Description or opinion article): An article that reflects personal opinion or a description of a specific implementation that does not report outcomes.

- QLR (Qualitative research): A qualitative study will be excluded from the quantitative analysis but may be included in the narrative summary if the study reports one or more outcomes identified for this review.

- ISD (Insufficient Statistical Data): Articles that do not fit the quantitative data sufficiency criterion will not be included for quantitative analysis, but may be included in the narrative summary.

Studies not matching the criteria of the particular review step were excluded from that section. Studies were coded according to the level of confidence about the decision made using a 5 point scale: (1) almost definitely unsuitable; (2) probably unsuitable; (3) doubtful, but possibly suitable; (4) most likely suitable; and (5) almost definitely suitable. Abstracts rated (3) or higher were retrieved.

5. **Case Survey Analysis**

Case items were as follows:

Study Variables. These include items that describe the study itself, such as study design, publication information, and study orientation (what relationship the study authors have to the program).

- Type of study;

- Research design;

- Sample size;

- Treatment duration;

- Comparison group.

Demographic Variables. These include items that describe the program context, for example, size of implementation, ages of students, and location.

- Level of Program;

- Type of educational institution (public/private);

- Age of participants / Educational level;

- Gender;

- Location of program (urban, suburban, rural).

Implementation Variables. These include items that describe program implementation such as delivery of machines, policy creation, professional development, and establishment of technical support.

- Laptops deployed and working;
- Educational design;
- Curriculum development;
- Professional Development;
- Wireless infrastructure;
- Tech support& maintenance;
- Relevant peripherals;
- Stakeholder buy in;
- Student laptop ownership;
- Staged implementation;
- Pilot studies;
- Planned evaluation;
- Professional development/in-service training on using computer technology in the classroom;
- Timing of Professional development exercises (Inan & Lowther, 2010a; Shapley, et al., 2010; and Warschauer, 2009).

Each implementation variable was scored and the implementation scores were combined into a single technology integration score from 1 to 4 as follows: 1 = minimal integration, 2 = partial integration, 3 = substantial integration, and 4 = full integration. This overall "technology integration score" was intended to reflect as closely as possible the various factors impacting technology integration discussed above. The score was used as a proxy for program implementation fidelity. Typically, programs with minimal integration (technology integration score = 1) could be best described as technology only programs, involving little more than hardware deployment. In these programs, teachers receive very little professional development, very little technology and administrative support, little to no classroom guidance on how to integrate the laptops into teaching activities, and no guidance on how to adapt the curriculum to take advantage of a technology-rich environment. Classroom practices are not changed to take advantage of the technology affordances, in particular, technology is seldom used to support core learning.

In programs with full integration (technology integration score = 4) on the other hand, technology integration to support student learning is a consistent theme, receiving support from school leaders, teachers, students and parents alike. Teachers are supported through comprehensive and consistent professional development activities that strengthen their abilities and build their confidence in using technology to transform their teaching and their students' learning. Teachers are encouraged and shown how to use technology to support day-to-day classroom practices, in particular, those uses that promote higher-order learning goals such as critical thinking, goal setting, self-monitoring, and developing critical research and inquiry skills. Technology is frequently used to communicate more closely with students and parents.

Where there was insufficient information to rate one or more of the factors, the aggregate included only the coded scores. In this way as many studies as possible were given integration scores.

Program Variables. These include items that describe the degree to which (if at all) technologies were integrated in the ways described. These were used to infer or confirm program theory, which is how the computers are expected to impact student learning, such as intended and actual uses of technology, and policy statements of intended technology impact.

- Teacher centered instruction (PowerPoint presentations, electronically posted notes, online lectures);
- Student centered learning (problem/project-based learning, individualized learning programs, electronic enrichment activities);
- Expansive (simulations, modeling, virtual experiments);
- Expressive (electronic writing – word processor, blog, etc);
- Organizational/Administrative (electronic grade book/plan book, record keeping);
- Communicative (emails, websites, bulletin boards, web forums, discussion boards);
- Evaluative (electronic assessment, electronic portfolios);

- Informative (electronic research);
- Creative (art, music, design, creative writing);
- Specific general literacy applications;
- Specific technology literacy applications.

Program Variables. These include items that describe outcomes that can be or have been attributed to the intervention, such as attendance, achievement, and discipline. These variables are evaluated in terms of whether they are stated as goals (1 = yes, 0 = no) and whether they were attained (+1 = improvement, 0 = no change, – 1 = no change). Items were drawn from the literature, and supplemented with items drawn from iterative sample coding of a random sample of documents.

- Achievement;
- Problem-solving skills;
- Attendance;
- Motivation;
- Discipline;
- Retention;
- Graduation;
- College-bound graduates;
- Collaboration;
- Student-centered learning;
- Technology deployment;
- Technology use;
- Technology literacy;
- Information literacy;
- Just-in-time professional development;

- Community outreach;
- Media literacy;
- Closing the digital divide;
- 21^{st} Century skills.

Outcome measures. These include items that describe how outcomes were measured. Both qualitative and quantitative measures were included. Items are scored as 1 = yes or 0 = no.

- Observation;
- Interview;
- Focus groups;
- Document analysis;
- Survey;
- Course grades;
- GPA;
- Teacher-made measure;
- Researcher-made measure;

Standardized measure.

6. Mixed Effects Meta-analysis

The questions that are being investigated derive from the broader research question:

- Do students with continual access to laptop computers (the one-to-one condition) outperform students with more limited access on measures of achievement, technology use, and technology proficiency?
- Do students with continual access to laptop computers (the one-to-one condition) behave differently than students with more limited access in terms of attendance and engagement?

- Do students with continual access to laptop computers (the one-to-one condition) have more positive attitudes towards technology than students with more limited access?

  The “limited access” of comparison groups coded as a study feature.

  Effect Size Coding:

  Retrieved studies were read for final inclusion decisions and for effect size coding. In effect size coding, statistical data from which effect sizes could be extracted according to outcome type was identified and coded (standardized measure, researcher-produced test, teacher-produced test) and type of statistics that allow for effect size extraction. The unit of analysis is independent effect size rather than study, so it was possible that one study could yield more than one effect size. By the same token, because several included studies are annual evaluation reports of the same program, care was taken to ensure that effect sizes from each of these studies are in fact independent in the sense that they did not include the same participants’ scores. In some cases, effect sizes from multiple year studies were excluded when independence could not be confirmed. An argument could be made that scores from different samples of the same program cannot be considered to be completely independent and should be counted only once (either by aggregation or exclusion). While independent scores from the same program were often aggregated, in some cases independent scores were retained if they differed from one another sufficiently on one or more of the study feature variables, for example by age or duration.

  The moderators used for the meta-analysis are described below.

  Moderators (categorical). The categorical moderators used for the mixed-effects meta-analysis are described below.

  - Gender. Programs were coded as F = all-female school or program, M = all male school or program, CE = co-educational school or program or gender not specified).

  - Program size. Programs were coded as follows: 1 = Class(es) w/in single school, 2 = Grade(s) w/in single school, 3 = School-wide program, 4 = Selected Schools w/in Board, 5 = Board-wide program, 6 = Selected Schools w/in District, 7 = District-wide, and 8 = State/Province-wide. Although this moderator is ranked numerically in ascending order, the categories overlapped considerably. For example there may have been more schools in a particular board participating (category 4) in one program than schools in a district (category 6). Similarly, in certain large jurisdictions a district wide program may be larger than a state or province-wide program in a smaller jurisdiction. As a result the moderator was treated as categorical and findings were interpreted carefully.

- Program theory. Program theory was open-coded in the Case Survey. From this process, three broad program theory themes were developed: technology-enhanced learning environment (TLE), technology-enhanced instruction (TEI), and use of computers as mind tools or learning tools (CMT). These three program theory categories were used to recode the studies for the meta-analysis.

- Type of outcome. The complete set of effect sizes contained six different types of outcomes. The categorical moderator Type of Outcome therefore had six levels: Technology Use, Technology Proficiency, Student Achievement, Attendance, Student Engagement, and Student Satisfaction. For this moderator the dataset was partitioned into six subsets which were then meta-analyzed separately.

- Subject area. The achievement subset was further subdivided to reflect the academic subject or area of study from which the effect sizes were extracted. The following subject codes were used: reading, writing, mathematics, English/language arts, cognitive skills, and other academic subjects.

Moderators (categorical/quasi-continuous). Several of the categorical moderators were numerically ranked. As such they were also treated as quasi-continuous moderators and analyzed using meta-regression.

- Age. Participant age was coded using the following ranked categorical scale: 1 = elementary school (K-6), 2 = middle school (5-8), 3 = all-ages (K-12), 4 = secondary (7-12), 5 = high school (9-12). Ranks were determined by the median grade level for each category.

- Duration. Program duration codes reflected the elapsed time between the commencement of the program and the program evaluation. Duration codes were as follows: 1 = < 1 academic year, 2 = 1-2 academic years, 3 = 3-4 academic years, 4 = > 4 academic years.

- Study quality. Study quality was coded using a quality index. The quality index was created by adding together two quality variables: design quality (1=one group pre-experiment, 2=intact groups quasi experiment, and 3=randomized true experiment), and effect size quality (1=low: estimated from p or dichotomous data, 2=medium: estimated from beta weights, adjusted means, and 3=high: direct calculations). Quality index scores ranged from 2 to 6.

- Student/teacher centered learning. Studies were coded on the frequency of teacher-centered instruction and student-centered learning. Each variable (teacher-centered, student-centered) was coded separately on a scale of 1 – 4 as follows: 1 = never, 2 = sometimes, 3 = often, and 4 = almost always.

- Technology integration/program implementation. Programs were rated on a scale of 1 (minimal integration) to 4 (full integration) by combining scores on individual integration items as described in the methodology section.

- Technology use. Although technology use was an outcome (dependent) variable, it was also treated as a moderator variable to determine the impact of technology use on achievement, technology proficiency and other variables. Technology use was coded according to the following scale: 1 = low (less than once a week), 2 = medium (greater than once a week, but not daily), and 3 = high (daily or more frequently). For those studies with technology use effect sizes, Cohen's groupings were used to rank effect sizes: small effects (~0.2) mapped onto the low category, medium effects (~0.5) mapped onto the medium category, and large effects (~0.8) mapped onto the high category. For those studies without numerical data, codes were extracted from program descriptions.

- Year. Studies were coded for year according to the year that the study was released. The year code categories were as follows: 1 = before 2000; 2 = 2000 - 2004 (5 years); 3 = 2005 - 2009 (5 years); 4 = 2010 - present (5 years).

APPENDIX B

Documents included in the case survey

ID	TYPE	AUTHOR	YEAR	TITLE
4	Conference Proceedings	Abrams, R.	2000	Laptop computers in an all-girls school: hearing the student voice in an evaluation of technology use
1374	Conference Proceedings	Cavanaugh, Cathy, Dawson, Kara and Ritzhaupt, Albert.	2008	Conditions, Processes and Consequences of 1:1 Computing in K-12 Classrooms: The Impact on Teaching Practices and Student Achievement
50	Conference Proceedings	Fisher, D., Stolarchuk, E.	1998	WAIER Forum 1998: Fisher and Stolarchuk - laptop computers and classroom environment in science
955	Conference Proceedings	Fox, Michael, Greenlaw, Jim and MacPherson, Murdock.	2007	Student Views on the Role of Dedicated Notebook Computers in Transforming the Teaching and Learning Environment
1362	Conference Proceedings	Fox, Michael, Greenlaw, Jim.	2008	Teachers and Principals Share Their Views on a Government-Initiated Dedicated Notebook Computer Project
637	Conference Proceedings	Hargis, Jace, Schofield, Kathleen.	2006	Effects of Laptop Computers on Elementary Student Achievement and Attitude
636	Conference Proceedings	Johnson, Michael.	2003	Digital Scholars: The Effects of One-on-One Laptop Wireless Computing on At-Risk Middle School Students
1302	Conference Proceedings	Kessell, Stephen R.	2002	A Formal Evaluation of the Personal Laptop Program at Penrhos College, Western Australia
644	Conference Proceedings	Lee, Insook, Seo, Jeong H., Kim, Aram and Kim, Seung S.	2007	How are Mac Mobile Laptop Computers Working within a Regular Classroom
1396	Conference Proceedings	Lee, Insook.	2007	What Can We Learn From 'S' Elementary School?: Wireless Laptop Computers in Regular Classroom Activities
94	Conference Proceedings	Lei, Jing, Zhao, Yong.	2006	What Does One-To-One Computing Bring To Schools?
107	Conference Proceedings	Lowther, Deborah L., Ross, Steven M. and Morrison, Gary R.	2001	Evaluation of a laptop program: Successes and recommendations
124	Conference Proceedings	Mouza, Chrystalla.	2006	Learning with laptops: the impact of one-to-one computing on student attitudes and classroom perceptions
1364	Conference Proceedings	Oliver, Kevin, Holcomb, Lori.	2008	Changes in Student Technology Use and Skill in the First Year of a 1-to-1 Computing Program

ID	TYPE	AUTHOR	YEAR	TITLE
639	Conference Proceedings	Rutledge, David, Durán, James.	2006	New Mexico Laptop Learning Initiative: The Second-year Impact on One School District
160	Conference Proceedings	Schaumburg, H.	2001	The impact of mobile computers in the classroom. Results from an ongoing video study
249	Conference Proceedings	Schaumburg, Heike.	2001	Fostering Girls' Computer Literacy through Laptop Learning: Can Mobile Computers Help To Level Out the Gender Difference?
1328	Conference Proceedings	Shakeshaft, Carol, Mann, Dale and Tinsley, Kristy.	2009	The Relationship of Ubiquitous Computer Use, Teacher Behavior, and Students Achievement: A Longitudinal Study of Henrico County Virginia Public Schools Laptop Computing Initiative: 2005-06 to 2007-08
1442	Conference Proceedings	Wolfgramm, Jannifer, Christie, Alice and Keefer, Beverly.		1-to-1 Laptops-to-Students or Mobile Carts: 21st-Century Learning
1701	Dissertation	Smith, L.A.	2012	Leveling the Playing Field: Using a One-to-One Laptop Initiative to Close the Achievement Gap
1650	Dissertation/Thesis	Brogdon, S.	2008	Relationships between perceptions of personal ownership of laptop computers and attitudes toward school
1652	Dissertation/Thesis	Jamison, M.	2008	The effects of the ubiquitous computing environment on student achievement and teacher perceptions
811	Dissertation/Thesis	Mara, Jack.	2006	Computers as ubiquitous tools for teachers and learners: a case study of the Maine laptop initiative
1654	Dissertation/Thesis	Meyer, R.	2007	A case study of one-to-one computing: The effects on teaching and learning
129	Dissertation/Thesis	Niles, R.	2006	A study of the application of emerging technology: teacher and student perceptions of the impact of one-to-one laptop computer access
840HI	Dissertation/Thesis	Rousseau, Michele L.	2007	Ubiquitous computing, equity, and k-12 schools: can one-to-one laptop programs level the playing field?
840MHS	Dissertation/Thesis	Rousseau, Michele L.	2007	Ubiquitous computing, equity, and k-12 schools: can one-to-one laptop programs level the playing field?
840CMS	Dissertation/Thesis	Rousseau, Michele L.	2007	Ubiquitous computing, equity, and k-12 schools: can one-to-one laptop programs level the playing field?
1339	Dissertation/Thesis	Soorma, Jyoti.	2008	Teacher Concerns and Attitudes During the Adoption Phase of One-to-One Computing in Early College High Schools

ID	TYPE	AUTHOR	YEAR	TITLE
716	Generic	Mcteer, Douglas E. J.	2004	An evaluation of the South Carolina laptop program to improve SAT scores
440	Journal Article	Abrami, Philip C., Sclater, Jennifer, Sicoly, Fiore and Wade, C. A.	2006	Ubiquitous Technology Integration in Canadian Public Schools: Year One Study
734	Journal Article	Breese, Chris, Jackson, Anita and Prince, Terry.	1995	Promise in impermanence: Children writing with unlimited access to word processors
1470UT	Journal Article	Drayton, B., Falk, J.,K., Stroud, R., Hobbs, K. and Hammerman, J.	2010	After Installation: Ubiquitous Computing and High School Science in Three Experienced, High-Technology Schools
1470RH	Journal Article	Drayton, B., Falk, J.,K., Stroud, R., Hobbs, K. and Hammerman, J.	2010	After Installation: Ubiquitous Computing and High School Science in Three Experienced, High-Technology Schools
1470PA	Journal Article	Drayton, B., Falk, J.,K., Stroud, R., Hobbs, K. and Hammerman, J.	2010	After Installation: Ubiquitous Computing and High School Science in Three Experienced, High-Technology Schools
46	Journal Article	Dunleavy, M., Dexter, S. and Heinecke, W. F.	2007	What added value does a 1: 1 student to laptop ratio bring to technology-supported teaching and learning?
653	Journal Article	Dunleavy, M., Heinecke, W. F.	2007	The Impact of 1:1 Laptop Use on Middle School Math and Science Standardized Test Scores
333	Journal Article	Gardner, J.	1993	The Impact of High Access to Computers on Learning
326	Journal Article	Gardner, John.	1994	Learning with Portable Computers
993	Journal Article	Grimes, Douglas, Warschauer, Mark.	2008	Learning with Laptops: A Multi-Method Case Study
64	Journal Article	Gulek, James C., Demirtas, Hakan.	2004	Learning With Technology: The Impact of Laptop Use on Student Achievement
1636	Journal Article	Gulek, James C., Demirtas, Hakan.	2005	Learning with Technology: The Impact of Laptop Use on Student Achievement
225	Journal Article	Lowther, Deborah L., Ross, Steven M. and Morrison, Gary R.	2003	When Each One Has One: The Influences on Teaching Strategies and Student Achievement of Using Laptops in the Classroom
108	Journal Article	Mabry, L., Snow, J. Z.	2006	Laptops for High-Risk Students: Empowerment and Personalization in a Standards-Based Learning Environment
1465	Journal Article	McMahon, G.	2009	Critical thinking and ICT integration in a Western Australian secondary school
329	Journal Article	Morrison, H.	1993	The Impact of Portable Computers on Pupils' Attitudes to Study
1495	Journal Article	Mouza, Chrystalla.	2008	Learning with Laptops: Implementation and Outcomes in an Urban, Under-Privileged School

ID	TYPE	AUTHOR	YEAR	TITLE
1027	Journal Article	Murphy, Diane M., King, Frederick B. and Brown, Scott W.	2007	Laptop Initiative Impact: Assessed Using Student, Parent and Teacher Data
260	Journal Article	Newhouse, C. P.	2001	A Follow-Up Study of Students Using Portable Computers at a Secondary School
128	Journal Article	Newhouse, P., Rennie, L.	2001	A longitudinal study of the use of student-owned portable computers in a secondary school
1322	Journal Article	Oliver, Kevin,M., Corn, Jeni,O.	2008	Student-reported differences in technology use and skills after the implementation of one-to-one computing
136	Journal Article	Owston, R. D., Wideman, H. H.	2001	Computer access and student achievement in the early school years
1691	Journal Article	Rosen, Yigal & Beck-Hill, Dawne	2009	Intertwining Digital Content and a One-To-One Laptop Environment in Teaching and Learning: Lessons from the Time To Know Program
638	Journal Article	Rutledge, David, Duran, James and CarrollMiranda, Joseph.	2007	Three Years of the New Mexico Laptop Learning Initiative (NMLLI): Stumbling Toward Innovation
1464	Journal Article	Shapley, K.,S., Sheehan, D., Maloney, C. and Caranikas-Walker, F.	2010	Evaluating the Implementation Fidelity of Technology Immersion and its Relationship with Student Achievement
1340	Journal Article	Stolarchuk, Ed.	2001	First years of laptops in science classrooms result in more learning about computers than science
259	Journal Article	Stolarchuk, Fisher, Darrell.	2001	An Investigation of Teacher-Student Interpersonal Behavior in Science Classrooms Using Laptop Computers
1463	Journal Article	Suhr, K.,A., Hernandez, D.,A., Grimes, D. and Warschauer, M.	2010	Laptops and Fourth Grade Literacy: Assisting the Jump over the Fourth-Grade Slump
788	Journal Article	Trimmel, Michael, Bachmann, Julia.	2004	Cognitive, Social, Motivational and Health Aspects of Students in Laptop Classrooms
189	Journal Article	Warschauer, M.	2007	Information Literacy in the Laptop Classroom
190	Journal Article	Warschauer, M., Grant, D., Real, G. D. and Rousseau, M.	2004	Promoting academic literacy with technology: successful laptop programs in K-12 schools
1474	Report	Banks, Karen E.	2007	Evaluation of the Kent Technology Academy 2005-2007
10	Report	Bebell, D.	2005	Technology promoting student excellence: An investigation of the first year of 1: 1 computing in New Hampshire middle schools

ID	TYPE	AUTHOR	YEAR	TITLE
13	Report	Bebell, D., Russell, M.	2005	Berkshire Wireless Learning Initiative Phase 1 Final Evaluation Plan
12	Report	Bebell, D., Russell, M.	2006	Berkshire Wireless Learning Quarterly Evaluation Report
1434	Report	Bebell, Damian, Kay, Rachel E.	2009	Berkshire Wireless Learning Initiative: Final evaluation report
1263	Report	Bebell, Damian, Kay, Rachel.	2008	Lilla G. Frederick Pilot Middle School Wireless Learning Initiative Year 2 Results: Student and Teacher Survey Results
1261	Report	Bebell, Damian.	2007	Berkshire Wireless Learning Initiative Quarterly Evaluation Report
1262	Report	Bebell, Damian.	2008	Berkshire Wireless Learning Initiative Year 2 Evaluation Report
1678	Report	Bell & Thompson	2011	Wireless Writing Program: Peace River North Summary Report on 2009-2011 Cohort Group
17	Report	Bernard, Robert M., Bethel, Edward C., Abrami, Philip C. and Wade, Anne C.	2007	DMI-ELS ETSB Laptop Research Project: Report on the Grade Three Students
1265	Report	Berry, Alexis M., Wintle, Sarah E.	2009	Using Laptops to Facilitate Middle School Science Learning: The Results of Hard Fun
21	Report	Bolstad, Rachel.	2005	Digital opportunities pilot project (2001-2003): Evaluation of Notebook Valley
31	Report	Cates, Ward M.	2005	Bethlehem Area School District One-to-One Laptop Initiative: Final Report
32	Report	Center for Technology in Education, Johns Hopkins University,.	2006	Talbot County Public Schools One-to-One Laptop Initiative External Evaluation
36	Report	Chessler, M., Rockman, S. and Walker, L.	1998	Powerful tools for schooling: Second year study of the laptop program
1274	Report	Christensen, Rhonda, Knezek, Gerald.	2005	Student Findings from the Spring 2005 Irving Laptop Survey
1277	Report	Christensen, Rhonda, Knezek, Gerald.	2006	Young Children's Computer Inventory: Irving ISD 2006 TIP Treatment vs. Comparison School Report
1278	Report	Christensen, Rhonda, Knezek, Gerald.	2007	Student Findings from the Spring 2006 Irving Laptop Survey
1279	Report	Corn, J. O., Osborne, J. W., Halstead, E. O., et al.	2008	Executive Summary: Evaluation Study of the Progress of the North Carolina 1:1 Learning Initiative (Year 1)
1280	Report	Corn, J. O., Osborne, J. W., Halstead, E., et al.	2009	Mid-Year Evaluation Report on the Progress of the North Carolina 1:1 Learning Technology Initiative (Fall Semester, Year 2)

ID	TYPE	AUTHOR	YEAR	TITLE
39	Report	CRF & Associates.	2003	The Impact of Plato Learning, Inc. Technology in East Rock Magnet School
41	Report	Davies, Anne.	2004	Finding proof of learning in a one-to-one computing classroom
42	Report	Davis, D., Garas, N., Hopstock, P., Kellum, A. and Stephenson, T.	2005	Henrico County Public Schools IBook Survey Report
120	Report	Dawson, Monte E., D'Alois, Lydia A., Rockoff, David, Reid, Brian and Alston, Rose.	2006	Formative Evaluation of the Technology Integration in 2004-05
1282	Report	Diepenhorst, B., Kamps, K. and Vos, D.	2007	Integrating a One-to-One Laptop Program at the Middle School Level
44	Report	Donovan, Loretta, Grimes, Douglas.	2006	Laptops for Learning Year 2: 2005-2006
232	Report	Dyson, Michael, Cairns, Len, Hesse, Alice and Reeves, Mark.	2002	An Alternative to the Traditional Educational Program for Year Nine Students: A New Issue to Research in an Unchanging System
48	Report	Fairman, J.	2004	Trading Roles: Teachers and Students Learning with Technology
49	Report	Faulk, H. R.	2003	Quaker Valley School District: An Evaluation Report of the Digital School District Project
295	Report	Fouts, Jeffrey T., Stuen, Carol.	1997	Copernicus Project: Learning with Laptops: Year 1 Evaluation Report
957	Report	Freiman, V., Lirette-Pitre, N., Manuel, D., et al.	2007	Impact of individual laptop use on middle school mathematics teaching and learning: implementation of problem based learning scenarios
53	Report	Fryer, W.	2004	Assessing the Impact of One to One Technology Immersion on Student Attendance: Chasing Shadows or Panacea for Educational Reform
56	Report	Gardner, J., Morrison, H., Jarman, R., Reilly, C. and McNally, H.	1992	Pupils' Learning and Access to Information Technology-an Evaluation
960	Report	Hill, J. R., Reeves, T. C., Grant, M., Wang, S. K. and Han, S.	2003	The Impact Of Portable Technologies On Teaching And Learning: Year Three Report
959	Report	Hill, J. R., Reeves, T. C., Heidemeier, H., Grant, M. and Wang, S. K.	2001	The Impact Of Portable Technologies On Teaching And Learning: Year One Report
71	Report	Hill, Janette R., Reeves, Thomas C.	2004	Change Takes Time: The Promise of Ubiquitous Computing in Schools: A report of a four year evaluation of the Laptop Initiative at Athens Academy

ID	TYPE	AUTHOR	YEAR	TITLE
72	Report	Hill, Janette R., Reeves, Thomas C., Grant, Michael and Wang, Shiang-Kwei.	2002	The impact of portable technologies on teaching and learning: Year two report
73	Report	Hill, Janette R., Reeves, Thomas C., Wang, Shiang-Kwei, Han, Seungyeon and Mobley, Mary.	2004	The impact of portable technologies on teaching and learning: Year four
1293	Report	Ingram, Debra, Willcutt, Jennifer and Jordan, Kelly.	2008	Stillwater Area Public Schools Laptop Initiative Evaluation Report
1294	Report	Institute for the Integration of Technology into Teaching,and Learning.	2006	ExecSummary6.pdf (application/pdf Object)
79	Report	Jeroski, S.	2003	Wireless writing project: Research report phase II. Vancouver, BC
78	Report	Jeroski, S.	2004	Implementation of the Wireless Writing Program: Phase 3. 2003-2004
77	Report	Jeroski, S.	2005	Research Report: The Wireless Writing Program 2004-2005
1674	Report	Jeroski, Sharon	2006	Research Report: The Wireless Writing Program 2004-2006
1675	Report	Jeroski, Sharon	2007	Research Report: The Wireless Writing Program 2004-2007
1676	Report	Jeroski, Sharon	2008	Wireless Writing Program (WWP): Peace River North Summary Report on Grade 6 Achievement: 2008
1677	Report	Jeroski, Sharon	2009	Wireless Writing Program: Peace River North Summary Report on Grade 7 Achievement: 2009
1670	Report	Julián P. Cristia Pablo Ibarrarán Santiago Cueto Ana Santiago Eugenio Severín	2010	Technology and Child Development: Evidence from the One Laptop per Child Program
1672	Report	Kelly Shapley, Daniel Sheehan, Catherine Maloney & Fanny Caranikas-Walker	2011	Effects of Technology Immersion on Middle School Students' Learning Opportunities and Achievement
83	Report	Kerr, K. A., Pane, J. F. and Barney, H.	2003	Quaker Valley School District Early Effects and Plans for Future Evaluation
1700	Report	Kessell, Stephen R.	2011	Evaluation of the Personal Laptop Program at Penrhos College [1998-2000]
90	Report	Lane, D.	2003	Early evidence from the field: The Maine Learning Technology Initiative: Impact on students and learning

ID	TYPE	AUTHOR	YEAR	TITLE
92	Report	Lavoie, M., Bernard, B., Abrami, P. C. and Wade, C. A.	2006	DMI-ELS: ETSB/SWLSB Research Project: Year 2 Final Report
101	Report	Light, D., McDermott, M. and Honey, M.		Project Hiller: The impact of ubiquitous portable technology on an urban school
1501	Report	Lowes, Susan, Luhr, Cyrus.	2008	Evaluation of the Teaching Matters One Laptop per Child (XO) pilot at Kappa IV
105	Report	Lowther, Deborah L., Ross, Steven M., Strahl, J. D., Inan, Fethi A. and Pollard, Demetra.	2005	Freedom to Learn Program Michigan 2004-2005 Evaluation Report
1591	Report	Lowther, Deborah L., Strahl, J. D., Ross, Steven M. and Huang, Ying.	2007	Florida's Enhancing Education through Technology (Florida EETT). Leveraging Laptops: Effective Models for Enhancing Student Achievement. 2006-2007 Evaluation Report: Classroom Practices
1467	Report	Masaryk, Radomir, Sokolova, Lenka.	2009	Assessing educational impact of the "Notebook for Every Pupil" project
115	Report	Metis Associates, .	1999	Program Evaluation: The New York City Board of Education Community School District Six Laptop Project
117	Report	MGT of America.	2000	Florida Learning Alliance... The Rural Connection: Evaluation Report Year One
116	Report	MGT of America.	2001	Florida Learning Alliance... The Rural Connection: Evaluation Report Year Two
1441	Report	Milton, Penny.	2008	A review of New Brunswick's Dedicated Notebook Research Project: One-to-one computing - a compelling school-change intervention
118	Report	Mitchell Institute.	2004	One-to-One Laptops in a High School Environment: Piscataquis Community High School Study Final Report
125	Report	Muir, M., Knezek, G. and Christensen, R.	2004	The Maine learning technology initiative: An exploratory study of the impact of ubiquitous technology on student achievement
1436	Report	Pinkham, Caroline, Wintle, Sarah E. and Silvernail, David L.	2008	21st Century teaching and learning: An assessment of student website evaluation skills
147	Report	Ross, Steven M., Lowther, Deborah L. and Morrison, Gary R.	2001	Anytime, anywhere learning: Final evaluation report of the laptop program: Year 2
149	Report	Ross, Steven M., Lowther, Deborah L., Wilson-Relyea, Barbara, Wang, Weiping and Morrison, Gary R.	2003	Anytime, Anywhere Learning: Final Evaluation Report of the laptop program: Year 3

ID	TYPE	AUTHOR	YEAR	TITLE
150	Report	Ross, Steven M., Morrison, G. R., Lowther, D. L. and Plants, R.	2000	Anytime, Anywhere Learning: Final Evaluation Report of the Laptop Program
720	Report	Russell, Michael, Bebell, Damian and Higgins, Jennifer.	2004	Laptop learning: A comparison of teaching and learning in upper elementary classrooms equipped with shared carts of laptops and permanent 1:1 laptops
1432	Report	Russell, Michael, Bebell, Damian, Cowan, Jennifer and Corbelli, Mary.	2002	An AlphaSmart for each student: Does teaching and learning change with full access to word processors?
161	Report	Sclater, J., Sicoly, F., Grenier, A., Abrami, P. C. and Wade, C. A.	2005	ETSB-CSLP Laptop Research Partnership SchoolNet Report: Preliminary Study
163	Report	Shapley, K., Sheehan, D., Sturges, K., Caranikas-Walker, F., Huntsberger, B. and Maloney, C.	2006	Evaluation of the Texas Technology Immersion Pilot: First Year Results
1335HI	Report	Shapley, Kelly, Maloney, Catherine, Caranikas-Walker, Fanny and Sheehan, Daniel.	2008	Evaluation of the Texas Technology Immersion Pilot: Third-Year (2006-07) Traits of Higher Technology Immersion Schools and Teachers
1335LO	Report	Shapley, Kelly, Maloney, Catherine, Caranikas-Walker, Fanny and Sheehan, Daniel.	2008	Evaluation of the Texas Technology Immersion Pilot: Third-Year (2006-07) Traits of Higher Technology Immersion Schools and Teachers
1334	Report	Shapley, Kelly, Sheehan, Daniel, Maloney, Catherine and Caranikas-Walker, Fanny.	2008	Evaluation of the Texas Technology Immersion Pilot: Outcomes for the Third Year (2006-07)
1336	Report	Shapley, Kelly, Sheehan, Daniel, Maloney, Catherine and Caranikas-Walker, Fanny.	2009	Evaluation of the Texas Technology Immersion Pilot: Final Outcomes for a Four-Year Study (2004-05 to 2007-08)
1333	Report	Shapley, Kelly, Sheehan, Daniel, Maloney, Catherine, Caranikas-Walker, Fanny and Huntsberger, Briana.	2007	Evaluation of the Texas Technology Immersion Pilot: An Analysis of Second-Year (2005-06) Implementation

ID	TYPE	AUTHOR	YEAR	TITLE
1332	Report	Shapley, Kelly, Sheehan, Daniel, Maloney, Catherine, Caranikas-Walker, Fanny, Huntsberger, Briana and Sturges, Keith.	2007	Evaluation of the Texas Technology Immersion PIlop: Findings from the Second Year
1331	Report	Shapley, Kelly, Sheehan, Daniel, Sturges, Keith, Caranikas-Walker, Fanny, Huntsberger, Briana and Maloney, Catherine.	2006	Evaluation of the Texas Technology Immersion Pilot: An Analysis of the Baseline Conditions and First-Year Implementation of Technology Immersion in Middle School
167	Report	Silvernail, D. L., Gritter, A. K.	2007	Maine's Middle School Laptop Program: Creating Better Writers
168	Report	Silvernail, D. L., Harris, W. J.	2003	The Maine Learning Technology Initiative: Teacher, Student, and School Perspectives Mid-Year Evaluation Report
1338	Report	Silvernail, David L., Buffington, Pamela J.	2009	Improving Mathematics Performance Using Laptop Technology: The Importance of Professional Development for Success
169	Report	Silvernail, David L., Lane, Dawn M.	2004	The Impact of Maine's One-to-one Laptop Program on Middle School Teachers and Students: Phase One Summary Evidence
1437	Report	Silvernail, David L., Small, Dorothy, Walker, Leanne, Wilson, Richard L. and Wintle, Sarah E.	2008	Using technology in helping students achieve 21st Century skills: A pilot study
1435	Report	Silvernail, David.	2005	Does Maine's middle school laptop program improve learning? A review of evidence to date
1399SC	Report	Simpson, Mary, Payne, Fran.	2004	Evaluation of Personal Laptop Provision in Schools - Final Evaluation Report
1399PR	Report	Simpson, Mary, Payne, Fran.	2004	Evaluation of Personal Laptop Provision in Schools - Final Evaluation Report
174	Report	Stevenson, K. R.	1999	Evaluation report-Year 3: Middle School Laptop Program, Beaufort County School District
173	Report	Stevenson, K. R.	2001	Evaluation report: High school laptop computer program (School year 2000/2001)
172	Report	Stevenson, K. R.	2002	Evaluation report-Year 2: High school laptop computer program (Final Report, for school year 2001/2002)
171	Report	Stevenson, K. R.	2004	Evaluation report-Year 3: High school laptop computer program (Final Report, for school year 2002/2003)

ID	TYPE	AUTHOR	YEAR	TITLE
175	Report	Stevenson, K. R.		Evaluation Report?Year 2: Schoolbook Laptop Project, Beaufort County School District, South Carolina
1394	Report	The Eastern Townships School Board.	2008	Report on The Eastern Townships School Board Dennis McCullough Initiative-Enhanced Learning Strategy survey
1341	Report	The Metiri Group and the University of Calgary for Stakeholder,Technology Branch.	2009	Emerge One-to-One Laptop Learning Initiative: Year One Report
143	Report	Walker, L., Rockman, S.	1997	Report of a Laptop Program Pilot: A Project for Anytime Anywhere Learning by Microsoft Corporation, Notebooks for Schools by Toshiba America Information Systems
187	Report	Walker, L., Rockman, S. and Chessler, M.	2000	A More Complex Picture: Laptop Use and Impact in the Context of Changing Home and School Access (Third in a Series of Research Studies on Microsoft's Anytime Anywhere Learning Program)
191	Report	Warschauer, M., Grimes, D.	2005	First Year Evaluation Report: Fullerton School district Laptop Program
197	Report	Woodbridge, S.	2000	Norwood School Laptop and Technology Program Evaluation: Final Report
203	Report	Zucker, 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
1020	Report	Zucker, Andrew A., Hug, Sarah T.	2007	A Study of the 1:1 Laptop Program at the Denver School of Science & Technology

APPENDIX C

Studies and Effect Sizes Used in the Mixed Effects Meta-analysis

Study ID	Author	Title	Year	Type of Outcome	ES ID	ES Estimate (*g*+)	SE Estimate
4	Abrams, R.	Laptop computers in an all-girls school: hearing the student voice in an evaluation of technology use	2000	Computer Use	1	0.1358	0.2369
12	Bebell, D., Russell, M.	Berkshire Wireless Learning Quarterly Evalaution Report	2006	Computer proficiency	2	0.7365	0.3071
17	Bernard, R. et al.	DMI-ELS ETSB Laptop Research Project: Report on the Grade Three Students	2008	reading	3	0.5574	0.0802
				math	4	0.6789	0.0810
				language	5	0.7346	0.0813
21	Bolstad, R.	Digital opportunities pilot project (2001-2003): Evaluation of Notebook Valley	2005	Computer Use	6	-0.3000	0.1749
31	Cates, W. M.	Bethlehem Area School District One-to-One Laptop Initiative: Final Report	2005	Computer proficiency	7	0.3067	0.2915
				Computer Use	8	0.5150	0.2946
39	CRF & Associates.	The Impact of Plato Learning, Inc. Technology in East Rock Magnet School	2003	Reading (Grade 5)	9	0.3124	0.1631
				Reading (Grade 3)	10	0.3361	0.1185
44	Donovan, L. & Grimes, D.	Laptops for Learning Year 2: 2005-2006	2006	Language	11	0.0419	0.0401
				Math	12	0.2395	0.0402
				Discipline (suspensions)	13	0.5193	0.0881
50	Fisher, D., Stolarchuk, E.	Laptops for Learning Year 2: 2005-2009	1998	Perceptions of Laptop Classroom	14	0.0583	0.0680
56	Gardner, J., et al.	Pupils' Learning and Access to Information Technology-an Evaluation	1992	Secondary # of words	15	-0.2936	0.1375
				Composite Secondary English	16	-0.1196	0.1369
				Composite Mathematics	17	-0.1191	0.1226
				Composite Primary English	18	0.3047	0.2856
				Composite Science	19	0.3957	0.1237
				Primary English # of words	20	0.8464	0.2964

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64	Gulek, J. C. & Demirtas, H.	Learning With Technology: The Impact of Laptop Use on Student Achievement	2004	Math GPA cohort 2	21	0.2900	0.1229
				Language achievement cohort 1	22	0.3082	0.1412
				Math achievement cohort 1	23	0.3694	0.1422
				Overall GPA cohort 2	24	0.3761	0.1232
				Math achievement cohort 2	25	0.3990	0.1291
				Language achievement cohort 2	26	0.4010	0.1297
				Math GPA cohort 1	27	0.4077	0.1367
				Overall GPA cohort 1	28	0.5046	0.1372
77	Jeroski, S.	Research Report: The Wireless Writing Program 2004-2005	2005	Writing	29	0.4145	0.1285
78	Jeroski, S.	Implementation of the Wireless Writing Program: Phase 3. 2003-2004	2004	validated writing score	30	0.3752	0.1443
92	Lavoie, M. et al.	DMI-ELS: ETSB/SWLSB Research Project: Year 2 Final Report	2006	CAT3 Mathematics	31	-0.4675	0.1079
				CAT3 Language	32	-0.2649	0.1088
				CAT3 reading	33	-0.1183	0.1085
94	Lei, J. & Zhao, Y.	What Does One-To-One Computing Bring To Schools?	2006	Computer proficiency	34	0.1694	0.1063
107	Lowther, D. L., Ross, S. M. & Morrison, G. R.	Evaluation of a laptop program: Successes and recommendations	2001	Classroom Time – Composite	35	0.2965	0.2915
				Writing	36	0.5043	0.2509
108	Mabry, L., Snow, J. Z.	Laptops for High-Risk Students: Empowerment and Personalization in a Standards-Based Learning Environment	2006	Math scores	37	0.0442	0.1420
				Writing scores	38	0.1746	0.1437
				Reading scores	39	0.2389	0.1435
				Attitude composite	40	0.6879	0.1483
				Use composite	41	1.1934	0.1563

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115	Metis Associates	Program Evaluation: The New York City Board of Education Community School District Six Laptop Project	1999	Pilot reading	42	-0.1922	0.2635
				Pilot math (cat)	43	-0.1401	0.0621
				Pilot math	44	-0.0212	0.2643
				Pilot attendance	45	0.0000	0.0555
				Smart Schools math (ctn)	46	0.0400	0.2358
				Smart Schools reading	47	0.0607	0.1454
				Smart Schools language	48	0.1605	0.1273
				Smart Schools attendance	49	0.3085	0.2623
120	Dawson, M. E. et al.	Formative Evaluation of the Technology Integration in 2004-05	2006	Student Computer Use (Teacher Survey)	50	0.0840	0.1116
				Computer proficiency	51	0.2000	0.1118
				Student Computer Use Student Survey	52	0.3227	0.1123
124	Mouza, C.	Learning with laptops: the impact of one-to-one computing on student attitudes and classroom perceptions	2006	Attitudes toward learning	53	0.0000	0.1985
125	Muir, M., Knezek, G. & Christensen, R.	The Maine learning technology initiative: An exploratory study of the impact of ubiquitous technology on student achievement	2004	Social Studies	54	0.1215	0.3392
				VP Arts	55	0.1576	0.3393
				Science	56	0.1695	0.3393
				Math	57	0.1835	0.3393
128	Newhouse, P. & Rennie, L.	A longitudinal study of the use of student-owned portable computers in a secondary school	2001	Computer Proficiency Cohort C	58	-0.1648	0.1394
				Computer Proficiency cohort B	59	0.2837	0.1408
136	Owston, R. D. & Wideman, H. H.	Computer access and student achievement in the early school years	2001	Behavior	60	0.0000	0.1377
				Writing scores	61	0.4427	0.1047
143	Walker, L. & Rockman, S.	Report of a Laptop Program Pilot: A Project for Anytime Anywhere Learning by Microsoft Corporation, Notebooks for Schools by Toshiba America Information Systems	1997	Computer Use	62	0.0293	0.1382

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147	Ross, S. M., Lowther, D. L. & Morrison, G. R.	Anytime, anywhere learning: Final evaluation report of the laptop program: Year 2	2001	Composite Problem Solving	63	0.5479	0.1924
				Computer proficiency	64	0.8986	0.2840
				Composite Writing	65	0.9287	0.1933
				Computer Use	66	1.5300	0.3078
160	Schaumburg, H.	The impact of mobile computers in the classroom?Results from an ongoing video study	2001	Computer Use	67	0.0000	0.3099
161	Sclater, J. et al.	ETSB-CSLP Laptop Research Partnership SchoolNet Report: Preliminary Study	2005	Satisfaction	68	-0.2963	0.0824
				Computer Use	69	0.4477	0.0830
163	Shapley, K. et al	Evaluation of the Texas Technology Immersion Pilot: First Year Results	2006	Discipline	70	-0.2697	0.0307
				Reading/ELA	71	-0.2003	0.0306
				Mathematics	72	-0.1912	0.0306
				Attendance	75	0.0046	0.0276
163 (cont'd)	Shapley, K. et al	Evaluation of the Texas Technology Immersion Pilot: First Year Results	2006	Satisfaction	76	0.1300	0.0306
				Technology Use	77	0.4700	0.0309
				Technology Proficiency	78	0.9600	0.0322
164	Shapley, K. et al	Effects of Technology Immersion on Teaching and Learning: Evidence from Observations of Sixth-Grade Classrooms	2006	Student Engagement	79	0.2413	0.1292
				Intellectual Challenge	80	0.4113	0.1335
				Technology Use	81	1.0551	0.1374
167	Silvernail, D. L. & Gritter, A. K.	Maine's Middle School Laptop Program: Creating Better Writers	2007	Writing	82	0.3467	0.0111
169	Silvernail, D. L. & Lane, D. M.	The Impact of Maine's One-to-one Laptop Program on Middle School Teachers and Students: Phase One Summary Evidence	2004	Computer Use (composite)	83	0.1427	0.0174
187	Walker, L., Rockman, S. & Chessler, M.	A More Complex Picture: Laptop Use and Impact in the Context of Changing Home and School Access (Third in a Series of Research Studies on Microsoft's Anytime Anywhere Learning Program)	2000	Basic Computer Access (home)	84	0.1172	0.1021
				Basic Computer Access (School)	85	0.3377	0.1026
				Computer Use	86	1.1637	0.1089

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232	Dyson, M. et al.	An Alternative to the Traditional Educational Program for Year Nine Students: A New Issue to Research in an Unchanging System	2002	Satisfaction composite	87	0.4300	0.2138
				Self Efficacy	88	0.5548	0.2314
				Computer Use	89	0.7438	0.2185
637	Hargis, J. & Schofield, K.	Effects of Laptop Computers on Elementary Student Achievement and Attitude	2006	Primary Mathematics	90	0.0000	0.2402
				Intermediate Mathematics	91	0.0000	0.1248
				Intermediate Science	92	0.0000	0.1423
				Intermediate Reading	93	0.2178	0.1283
				Technology Satisfaction Middle	94	0.3022	0.1242
				Technology Satisfaction Primary	95	0.4697	0.1622
				Primary Reading	96	0.4765	0.2436
638	Rutledge, D., Duran, J. & Carroll-Miranda, J.	Three Years of the New Mexico Laptop Learning Initiative (NMLLI): Stumbling Toward Innovation	2007	Composite Computer Use	97	0.4665	0.0570
644	Lee, I. et al.	How are Mac Mobile Laptop Computers Working within a Regular Classroom	2007	Language-Korean composite	98	1.5410	0.1240
653	Dunleavy, M. & Heinecke, W. F.	The Impact of 1:1 Laptop Use on Middle School Math and Science Standardized Test Scores	2007	Science Achievement	99	0.2238	0.1677
720	Russell, M., Bebell, D. & Higgins, Jennifer.	Laptop learning: A comparison of teaching and learning in upper elementary classrooms equipped with shared carts of laptops and permanent 1:1 laptops	2004	Student Engagement	100	0.5895	0.1272
788	Trimmel, M. & Bachmann, J.	Cognitive, Social, Motivational and Health Aspects of Students in Laptop Classrooms	2004	Discomfort	101	-0.4649	0.3141
				Social Intelligence	102	0.0710	0.3177
				Computer proficiency	103	0.6928	0.3191
				Spatial ability	104	0.6947	0.3403
				Academic Motivation	105	0.8344	0.3312
				Computer Use	106	2.3470	0.4028
811	Mara, J.	Computers as ubiquitous tools for teachers and learners: a case study of the maine laptop initiative	2006	Composite Computer Use	107	1.1351	0.1183
993	Grimes, D. & Warschauer, M.	Learning with Laptops: A Multi-Method Case Study	2008	Language	108	0.0139	0.0595
				Mathematics	109	0.3634	0.0600

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1,020	Zucker, A. A. & Hug, S. T.	A Study of the 1:1 Laptop Program at the Denver School of Science & Technology	2007	Composite Proficiency	110	0.4010	0.0809
1,262	Bebell, D.	Berkshire Wireless Learning Initiative Year 2 Evaluation Report	2008	ela scores (G8)	111	0.0600	0.0704
				Mathematics (G8)	112	0.0600	0.0704
				ela scores (G7)	113	0.1001	0.0741
				Mathematics (G7)	114	0.1403	0.0741
				Science (G8)	115	0.3242	0.0708
				Technology Proficiency	116	0.6315	0.1952
				Computer Use	117	1.2425	0.0412
1,263	Bebell, D.	Lilla G. Frederick Pilot Middle School Wireless Learning Initiative Year 2 Results: Student and Teacher Survey Results	2008	Discipline (On-task)	118	-0.0532	0.2163
				Motivation (Engagement)	119	0.0000	0.2162
				Technology Use	120	0.6225	0.1930
1,277	Christensen, R. & Knezek, G.	Young Children's Computer Inventory: Irving ISD 2006 TIP Treatment vs. Comparison School Report	2006	Motivation	121	0.0901	0.0989
				Attitude to School	122	0.1175	0.0985
				Attitudes to technology	123	0.4014	0.0990
				Attitudes to technology (composite)	124	-0.2823	0.0555
				Technology Proficiency	125	-0.0589	0.0552
				Attitudes to school	126	0.1394	0.0553
				Computer use (home)	127	0.5187	0.0561
				Computer use (school)	128	1.0187	0.0587

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1,280	Corn, J. O. et al.	Mid-Year Evaluation Report on the Progress of the North Carolina 1:1 Learning Technology Initiative (Fall Semester, Year 2)	2009	Technology Proficiency Composite (Trad)	129	-0.1025	0.0649
				Attendance Trad	130	-0.0918	0.0571
				Technology Proficiency Composite (ECHS)	131	-0.0364	0.0552
				21st C Skills Composite	132	0.0296	0.0552
				Attendance ECHS Composite	133	0.0358	0.0622
				Engagement (ECHS) Composite	134	0.1646	0.2132
				Composite Computer Use (Trad)	135	0.5225	0.0580
				Composite Computer Use (ECHS)	136	0.8049	0.0646
1,282	Diepenhorst, B., Kamps, K. & Vos, D.	Integrating a One-to-One Laptop Program at the Middle School Level	2007	Attitudes to computers (composite)	137	0.1036	0.0463
				Computer Use	138	0.4100	0.0467
				Computer Proficiency	139	0.4287	0.0468
				Reading (Composite)	140	0.4861	0.0468
				Mathematics (Composite)	141	0.6353	0.0473
				Language Usage (Composite)	142	0.6537	0.0475
1,293	Ingram, D., Willcutt, J. & Jordan, K.	Stillwater Area Public Schools Laptop Initiative Evaluation Report	2008	Attitude composite	143	-0.3080	0.0790
				Technology Satisfaction	144	-0.2728	0.0789
				Engagement Composite	145	-0.1929	0.0788
				Cohort 3 Reading	146	-0.1487	0.0765
				Cohort 1 Reading	147	-0.0807	0.0796
				Cohort 2 Reading	148	-0.0195	0.0749
1,293	Ingram, D., Willcutt, J. & Jordan, K.	Stillwater Area Public Schools Laptop Initiative Evaluation Report	2008	Cohort 1 Math	149	-0.0061	0.0822
				Cohort 2 Math	150	0.0020	0.0747
				Cohort 3 Math	151	0.0312	0.0761

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1,322	Oliver, K. M. & Corn J.	Student-reported differences in technology use and skills after the implementation of one-to-one computing	2008	Composite Tech supported activities	152	0.4841	0.1072
				Composite attitude to technology	153	0.5358	0.1075
				Composite Tech proficiency	154	0.8894	0.1107
				Composite Tech use	155	1.5248	0.1199
1,336	Shapley, K. et al.	Evaluation of the Texas Technology Immersion Pilot: Final Outcomes for a Four-Year Study (2004-05 to 2007-08)	2009	Cohort 3 Attendance	156	-0.0358	0.0273
				Cohort 2 Attendance	157	-0.0205	0.0272
				School Satisfaction - Cohort 2	158	-0.0188	0.0272
				School Satisfaction - Cohort 3	159	0.0251	0.0273
				Tech Use - Cohort 2	160	0.0963	0.0272
				Tech Proficiency - Cohort 2	161	0.0984	0.0272
				Reading - Cohort 3	162	0.1228	0.0273
				Tech Proficiency - Cohort 3	163	0.1918	0.0273
				Tech Use - Cohort 3	164	0.2477	0.0274
				Reading - Cohort 2	165	0.3316	0.0273
				Mathematics - Cohort 1	166	0.3417	0.0279
				Reading - Cohort 1	167	0.4138	0.0280
				Mathematics - Cohort 2	168	0.5523	0.0277
				Mathematics - Cohort 3	169	0.5768	0.0278
1,338	Silvernail, D. L. & Buffington, P. J.	Improving Mathematics Performance Using Laptop Technology: The Importance of Professional Development for Success	2009	Mathematics	170	0.0181	0.0707
1,340	Stolarchuk, E. & Fisher, D.	First years of laptops in science classrooms result in more learning about computers than science	2001	Science Achievement	171	0.6979	0.0990
				Science Attitude	172	1.9033	0.1159

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1,364	Oliver, K. & Holcomb, L.	Changes in Student Technology Use and Skill in the First Year of a 1-to-1 Computing Program	2008	Computer proficiency	173	0.1931	0.1059
				Computer Use	174	1.3919	0.1176
1,374	Cavanaugh, C., Dawson, K. & Ritzhaupt, A.	Conditions, Processes and Consequences of 1:1 Computing in K-12 Classrooms: The Impact on Teaching Practices and Student Achievement	2008	Computer Use	175	0.6253	0.0699
1,396	Lee, I.	What Can We Learn From 'S' Elementary School?: Wireless Laptop Computers in Regular Classroom Activities	2007	Achievement Korean & Soc St	176	0.4281	0.1612
1,398	Owston, R. D. et al.	The Differential Effects of Computer Access Level on Student Achievement in the Early School Years	1999	Usage Mathematics	177	-0.3606	0.1342
				Usage Other Subjects	178	-0.2447	0.1339
				Discipline (On-task)	179	0.0000	0.1336
				Usage Language Arts	180	0.7068	0.1360
1,434	Bebell, D., & Kay, R. E.	Berkshire Wireless Learning Initiative: Final evaluation report	2009	Math scores	181	0.0000	0.0351
				Technology Use	182	0.1336	0.0384
				ELA scores	183	0.2492	0.0352
1,436	Pinkham, C., Wintle, S. E. & Silvernail, D. L.	21st Century teaching and learning: An assessment of student website evaluation skills	2008	Information Literacy	184	0.5419	0.0804
1,437	Silvernail, D. L. et al	Using technology in helping students achieve 21st Century skills: A pilot study	2008	Information Literacy	185	0.5855	0.1792
1,463	Suhr, K.,A. et al.	Laptops and Fourth Grade Literacy: Assisting the Jump over the Fourth-Grade Slump	2010	ELA scores	186	0.3251	0.1923
1,465	McMahon, G.	Critical thinking and ICT integration in a Western Australian secondary school	2009	Technology Proficiency	187	0.1396	0.0572
1,474	Banks, K. E.	Evaluation of the Kent Technology Academy 2005-2007	2007	Mathematics - Cohort 2	188	0.1030	0.1511
				Mathematics – Cohort 1	189	0.1640	0.1734
				Writing, Cohort 2	190	0.2883	0.1517
				Reading - Cohort 2	191	0.3044	0.1518
				Reading – Cohort 1	192	0.3784	0.1746
1,474	Banks, K. E.	Evaluation of the Kent Technology Academy 2005-2007	2007	Science, Cohort 1	193	0.4757	0.1755

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1,591	Lowther, D.	Florida's Enhancing Education through Technology (Florida EETT). Leveraging Laptops: Effective Models for Enhancing Student Achievement. 2006-2007 Evaluation Report: Classroom Practices	2007	Computer Enjoyment	194	0.6610	0.2207
				Composite Computer Use	195	0.8000	0.2232
				Focused Class time	196	1.0054	0.2277
1,650	Brogdon, S.	Relationships between perceptions of personal ownership of laptop computers and attitudes toward school	2008	Attitudes to school (G7)	197	0.2193	0.1119
				Attitudes to school (G8)	198	0.5541	0.2827
				Attitudes to technology	199	0.9720	0.2794
1,652	Jamison, M.	The effects of the ubiquitous computing environment on student achievement and teacher perceptions	2008	Math	200	-0.7558	0.1156
				Language	201	0.0701	0.1118
1,670	Cristia, J. P. et al.	Technology and Child Development: Evidence from the One Laptop per Child Program	2010	Language	202	-0.0390	0.0570
				Motivation	203	-0.0090	0.0060
				Avg Academic	204	0.0030	0.0550
				Attendance	205	0.0240	0.0190
				Math	206	0.0460	0.0610
				Coding	207	0.0860	0.0970
				Avg Cognitive	208	0.1100	0.0600
				Raven's	209	0.1120	0.0570
				Verbal Fluency	210	0.1340	0.0900
1,672	Shapley, K. et al.	Effects of Technology Immersion on Middle School Students’ Learning Opportunities and Achievement	2011	Discipline Cohort 1 (suspensions)	211	0.1073	0.0271
				Discipline Cohort 2 (suspensions)	212	0.1569	0.0270
1,674	Jeroski, S.	Research Report: The Wireless Writing Program 2004-2006	2006	Writing Scores	213	-0.2768	0.2056
1,675	Jeroski, S.	Research Report: The Wireless Writing Program 2004-2007	2007	Writing Scores	214	-0.0200	0.1681
1,676	Jeroski, S.	Wireless Writing Program (WWP): Peace River North Summary Report on Grade 6 Achievement: 2008	2008	Writing Scores	215	0.8571	0.0874
1,677	Jeroski, S.	Wireless Writing Program: Peace River North Summary Report on Grade 7 Achievement: 2009	2009	Writing Scores	216	0.1330	0.0918
1,678	Bell, J. & Thompson, T.	Wireless Writing Program: Peace River North Summary Report on 2009-2011 Cohort Group	2011	Writing Scores	217	0.2936	0.0820

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1,691	Rosen, Y. & Beck-Hill, D.	Intertwining Digital Content and a One-To-One Laptop Environment in Teaching and Learning: Lessons from the Time To Know Program	2012	Math Motivation G5	218	0.1130	0.1410
				Math G5	219	0.2298	0.1369
				Reading G5	220	0.2825	0.1289
				Math G4	221	0.3516	0.1523
				Reading G4	222	0.4001	0.1516
				Reading Motivation G5	223	0.4065	0.1422
				Math Motivation G4	224	0.4541	0.1574
				Attitudes to Tech G5	225	0.5452	0.1433
				Reading Motivation G4	226	0.7261	0.1603
				Attitudes to Tech G4	227	1.4277	0.1732
1,700	Kessel, S. R.	Evaluation of the Personal Laptop Program at Penrhos College [1998-2000]	2001	Composite Tech Proficiency	228	0.1624	0.0760
				Composite Improves Learning	229	0.2825	0.0762
				Composite Tech Satisfaction	230	0.4664	0.0768
				Composite More enjoyable	231	0.5642	0.0773
1,701	Smith, L. A.	Leveling the Playing Field: Using a One-to-One Laptop Initiative to Close the Achievement Gap	2012	Algebra	232	-0.0414	0.0795
				English	233	0.1664	0.0699