A Review of the Research Literature on the Infusion of Technology into the School Curriculum

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American educators, legislators, and others have demonstrated a long-time interest in the use of technology in the classroom. The pioneer one-room schoolhouses depended primarily on one-to-one instruction and the slate that was the technology of the day. Over 100 years ago, Thomas A. Edison claimed that books would become obsolete in the schools as a result of the silent film (Saettler, 1968). A year after Russia launched the first space satellite, Sputnik, in 1957, the U.S. Congress passed the National Defense Education Act that included funds to place overhead projectors in many K-12 classrooms. We soon learned that poor instruction "amplified" on an overhead projector was still poor instruction. For over thirty years, we have seen school initiatives aiming to improve student achievement through the introduction of desktop and laptop computers, tablets, and smartphones. A few years after personal computers were introduced into the classroom, Bork (1987) claimed the personal computer would revolutionize the way students learn. It appears that, in many schools nationwide, students are still learning in ways similar to the students of the 1950s and 1960s. Yet, computers have proliferated with and spurred the globalization of social and business communications and economic transactions. Can computers likewise transform education and enhance student achievement?

For many years, researchers attempted to prove that the use of technology would improve student achievement (Morrison, 1994). Many of these assertions prompted researchers to "test" the effectiveness of these various technologies by comparing a technology such as television or computers to a teacher teaching. While a number of researchers cautioned against such studies as being meaningless and poorly designed (Knowlton, 1964; Salomon & Clark, 1977), Clark's

(1983) well-organized review and evidence for abandoning these so called media comparison studies had the greatest impact on reconceptualizing technology's role in education. Clark and Knowlton both maintained that it was *not* the technology that would affect student achievement, but rather the instructional strategy that was used with the technology. Thus, just using a computer would not lead to increased student achievement. Rather, it was how the software was designed or how the teacher had the students use a computer that would impact student performance. According to Clark, many of the media comparison studies were actually comparing apples to oranges. That is, frequently the lesson content when using the technology differed from the content taught by the teacher, whereas the achievement test often focused on the content taught with the technology!

Just as buying a professional-looking chef mixer will not make you a better cook, technology alone will not make student learning better. If the teacher, though, introduces new methods of teaching requiring different uses of a computer rather than to simply present information, then we are likely to see an improvement in learning. Just as a driver of a horse and buggy had to learn new methods for driving a gasoline powered buggy, teachers must use new methods for teaching with technology if they are going to be successful.

This review will examine the results from a number of studies investigating the effectiveness of computer use in the classroom. These studies go beyond the media comparison studies that Knowlton (1964) and Clark (1983) have criticized. Not only are they better designed, they answer different questions to provide meaningful information. The first section summarizes a variety of evaluation studies. These studies examine focuses ranging from student engagement to achievement using observations, surveys, and achievement tests. The second section summarizes the results from several meta-analyses. A meta-analysis is a complex statistical

methodology that allows a researcher to analyze the results of 10 or even a 1,000 research studies to determine the overall effect. Thus, a meta-analysis provides a rigorous scientific synthesis of the results of many individual studies to quantify the impacts of the instructional technique or technology employed in the various related studies.

Evaluation Studies of Technology Initiatives in the Classroom

These evaluation studies vary in their focus from a single school district to multiple districts in a state. Four of the studies focused on state-wide initiatives and will be summarized first followed by a study of a county-wide initiative. Generally, these evaluations were not experimental studies designed to compare those who had computers with those who did not. In real-world contexts and larger scale initiatives, conducting randomized controlled trials (RCTs) is highly challenging due to the awkwardness and logistic difficulties of withholding technology infusion for some schools and fragmenting school-by-school instructional orientations and professional development for teachers. These evaluation studies, in contrast, take a much broader view and collect a wide range of data to give the reader a more complete picture of the implementation and varied educational outcomes.

Maine Learning Technology Initiative

Maine was one of the first states to implement a computer technology program to transform teaching and learning in middle-school classrooms. This project is one of the largest one-to-one initiatives in the country where each middle school student and teacher was given a laptop. The initial phase of the project started in 2002 with 17,000 seventh grade students in 243 schools and was extended to include both the seventh and eighth grades the next school year. The initiative continues to this day and includes elementary schools.

An initial evaluation was conducted by Silvernail and Lane (2004) between 2002 and 2004. Seventh and eighth grade students in over 240 schools were included. The researchers used surveys, site visits, observations, and document analysis to collect data. Achievement test data were included in three separate studies.

The evaluators noted that the majority of teachers reported an increase in engaged student learning and work quality. Teacher responses also indicated that student access to laptops facilitated the individualization of instruction to meet Maine's statewide learning standards. Usage of laptops by teachers was higher for those who had advanced technology skills and those who participated in professional development. In general, teachers reported a positive impact on attendance, behavior, and achievement. Anecdotally, students revealed that they completed more work with a laptop. Further, students completed more work when they were permitted to take laptops home. Most frequent laptop activities included finding information, organizing information, and taking class notes.

Another study by Silvernail and Gritter (2007) examined eighth grade writing scores for the first five years with data from the Maine Educational Assessment (MEA). In addition, the researchers administered a student survey with a series of questions soliciting perceptions about their classrooms and learning. One of the items asked students to indicate how the laptop was used for the writing process (e.g., for drafts and the final copy, final copy only, drafts only, or not at all). The writing scores for students in the laptop program were significantly higher than scores the year prior to the start of the laptop project (an effect size[1] of +0.32). For the most frequent users of a laptop (i.e., used for both drafts and the final copy), the increase in gain was

[1] An effect size indicates the number of standard deviations by which the treatment group mean differs from the control group mean on the outcome measure of interest.

double (effect size +0.64). Researchers consider an effect size of +0.20 or greater as an important improvement.

A second analysis of achievement data for the Maine Learning Technology Initiative was reported by Muir, Knezek, and Christensen (2004). They analyzed three years of MEA test data for eighth grade students in nine different schools. Their analysis found that students in the laptop program scored significantly higher in science, math, and social studies when compared to students in other middle schools who did not participate in the laptop initiative.

A third study, conducted in 2011 (Silvernail, Pinkham, Wintle, Walker, & Bartlett, 2011), analyzed student test data for mathematics and writing. Findings showed significantly higher scores in mathematics and in writing for the students in the laptop program. While one might argue that laptops simply produced better writing with technology, the writing assessment indicated there was no difference in scores regardless if the laptop students used a computer or paper and pencil to write their answers. The study also found that students participating in the laptop program exhibited superior skills in locating and evaluating information.

Texas Technology Immersion Project (TIP)

The Texas project involved 23 school districts participating in a one-to-one laptop program with over 7,000 sixth – eighth grade students for three years. This project was directed at high-need students. Similar to other one-to-one laptop initiatives, this project also provided professional development for teachers, as well as other curricular support resources.

The Texas Center for Educational Research (2008) conducted a limited study to analyze the data for *just* the final year of the project. Data included 42 sixth, seventh, and eighth grade

classrooms (21 laptop classrooms and 21 control classrooms[2]) and 591 laptop teachers and 662 control teachers. The researchers used classroom observations, student and teacher surveys, disciplinary data, and achievement test performance for Year 3 of the project.

Findings indicated that technology immersion as a result of each student having a laptop produced three important changes:

1. Students' technology proficiency (e.g., computing and Internet skills) was increased and the proficiency gap between economically advantaged and disadvantaged students was reduced for students in the technology immersion program.
2. Technology immersion increased the frequency of use of the laptops, as measured by the survey, and it increased the interactions with their peers in small-group activities.
3. Analysis of data also revealed that the immersion schools experienced fewer disciplinary actions. Surprisingly, they also found a significantly lower school attendance rate for the immersion students when compared to the control students; however, the low attendance rate did not result in lower academic achievement.

Differences in achievement between the students using laptops and those who did not use laptops were related to the frequency of laptop use as identified through surveys. Those students who used laptops for learning, especially outside of school, had significantly higher reading and mathematics achievement scores on the state tests. Similarly, the benefits of technology immersion became stronger in the third year as students and teachers became accomplished users of the technology. In the third year, laptop students in all three grades scored significantly higher on the mathematics test than the non-laptop students. These results suggest a strong relationship

[2] Control classrooms are those that did not have laptops for each student. This group provides a basis for comparison with the laptop classrooms where each student has a laptop. The laptop classroom is also described as the treatment group in the studies.

between how frequently students used a laptop for learning both during and outside of school and improvement in mathematics scores. Effects on science, social studies, and writing achievement were inconclusive because the tests were not administered every year.

Michigan's Freedom to Learn One-to-One Initiative

Michigan's Freedom to Learn One-to-One initiative evaluation (Lowther, Inan, Ross, & Strahl, 2012) involved 195 middle and secondary schools. The demonstration phase was implemented in 2002-2003 in 15 middle and high schools involving 7,256 students. In 2004, the second phase funded 200 schools that designed their own program; 30,000 students and 1,500 teachers were involved. Unfortunately, no achievement data were collected. Results suggested that students were more interested in learning as a result of the program. Teachers also reported an increase in student-centered practices that resulted in improvements in both instruction and learning.

A precursor to the Michigan Freedom to Learn program was the Technology as a Tool program implemented by the Walled Lake School District in Michigan. Laptop classrooms employed a different instructional framework based on students working on inquiry-based lessons in small groups that focused on solving real-world problems (Morrison & Lowther, 2005). The pilot implementation involved 26 laptop classrooms. Results showed that teaching was noticeably changed, with more inquiry-oriented and student-centered instruction in the laptop classroom when compared to traditional classrooms. Students in the laptop program outperformed students in the traditional classrooms on district-wide writing tests, with effect sizes ranging from +0.61 to +0.78. Both students and teachers viewed the laptops as increasing interest in learning and stimulating meaningful classroom discussions, a finding confirmed by observation data (Lowther, Ross, & Morrison, 2003).

A second study was conducted to compare the laptop classrooms with classrooms equipped with 5-6 desktop computers (Lowther et al., 2003). Teachers in the two types of classrooms used the same inquiry approach. This study involved 12 laptop classrooms and 9 desktop middle-school classrooms. A total of 257 laptop students and 134 desktop students participated in the study. Sixth- and seventh-grade students completed a writing test and sixth-grade students completed a problem-solving achievement test. Results included the following:

1. Sixth-grade laptop students scored significantly higher than the desktop students on the idea and content, organization, and style components of the writing test. The effect sizes ranged from +0.53 to +1.47.
2. Seventh-grade laptop students scored significantly higher than the desktop students on the idea and content, organization, conventions, and style components of the writing test. The effect sizes ranged from +0.59 to +0.94.
3. The laptop students scored significantly higher than the desktop students on the seven problem solving components.

As one might expect, the researchers found that the laptop students did make more use of their laptops than the desktop students. Results from the writing and problem-solving tests suggested a positive of ubiquitous laptop usage on student achievement.

Henrico County Public Schools

This last study involved a single county's three-year implementation of a laptop initiative. The implementation included 10 curricular areas with achievement data from Virginia's Standards of Learning (SOL) achievement test that is administered state wide. Students also completed a survey addressing how often they used their laptops.

Positive improvements were seen in SOL scores ranging from 11 to 35 points on a 300-600 point scale. There were significant improvements each year in biology, world history, chemistry, US history, reading, earth science, and world history II (only one score) for laptop students. Test scores showed a positive increase for writing in the first year, but declines in years two and three for laptop students. The researchers attributed the negative relationship to potential limited use of laptops for writing due to mode of test (paper-pencil). Similarly, there were decreases in algebra I and II test scores for laptop students in all three years.

As teachers gained experience with the laptops, they reported an increase in coaching students and a reduction in direct instruction (i.e., presenting information) resulting in more active learning by the students. In addition, the use of laptops made small-group projects and small-group instruction more feasible. Teachers' positive perceptions of the effects of laptops remained stable throughout the project. Students indicated that they felt they learned more because of the laptops with survey results indicating a significant agreement that they were receiving better grades, turning in more assignments on time, taking more interest in class, taking more responsibility for work, behaving better, and cooperating more with their peers. Last, students felt that they were "more likely to do well after I graduate because of the laptops."

Summary

Results of these evaluation studies indicate that the one-to-one laptop projects lead to increased engagement of students in learning. A culminating effect was higher writing scores of laptop students compared to traditional classroom or desktop students. An exception occurred in the Henrico County study, however, where a likely disadvantage for laptop students was taking the writing test using paper and pencil rather than on a computer. Other than the lower algebra scores obtained in the Henrico County research, the studies also reported increases in

mathematics, reading, and problem-solving performance. Another important finding was reduced disciplinary actions in the laptop groups, seemingly a function of their increased engagement in learning. The next section will review meta-analysis studies of one-to-one computing.

Meta-Analysis Studies

Meta-analysis is a rigorous statistical analysis technique used to combine quantitative data (e.g., achievement test scores) from multiple studies to develop a single conclusion that has greater statistical power. For example, there are over 1,000 published studies on distance education and more than 1,000 on tutoring. Trying to summarize these studies in a review of the literature on either topic would be daunting and if attempted, likely would result in confusing and possibly biased conclusions. A meta-analysis, however, can combine the results from these studies using statistical analysis to derive a quantitative measure of the magnitude of the effect (i.e., the effect size) for different types of applications.

Meta-analysis is very time consuming as the researchers must apply exacting criteria to select each of the studies. Studies that are flawed in some way or do not match the criteria are rejected. The end result might be selection of only a small proportion of the full population of studies conducted in the particular domain. However, the final sample will be high-quality studies that meet rigorous criteria and thereby increase confidence in yielding a valid overall conclusion.

A meta-analysis study produces one or more effect sizes for each treatment, such as a teaching method (lecturing versus self-study) or environmental condition (quiet versus noisy classroom). The effect size indicates the number of standard deviations by which the treatment group's mean differs from the control group's mean on the outcome measure of interest.

Generally, an effect size of +0.20 is considered moderate to strong in magnitude and educationally meaningful (Cheung & Slavin, 2015). The following is a summary of related meta-analyses.

Effectiveness of Computer-Based Instruction

One of the earliest meta-analysis studies of computers in elementary schools was conducted by Kulik, Kulik, and Bangert-Drowns (1985) soon after the introduction of the Apple II into the classroom. The researchers identified 32 comparative studies that met their criteria. The studies were classified as either computer-managed instruction (CMI) or computer-assisted instruction (CAI). CMI evaluates the student's progress and then directs the student to appropriate resources (e.g., books, worksheets, manipulatives, etc.). The student does not interact with or study on the computer other than possibly taking a test or receiving directions on what to do next. CAI, in contrast, actually "teaches" the student. For example, the student might be involved in a drill-and-practice exercise similar to flash cards or tutorial that provides instruction and then typically asks questions the student must answer. CMI manages the student's work where CAI presents instruction on the computer.

The effect size for CAI studies was +0.47, which is considered above average indicating a meaningful instructional method. The average effect size for the CMI studies was +0.07. However, there were only four studies in the CMI analysis. Given the focus of CMI on *management* of learning rather than instructional design or delivery, we might not expect to find as strong a difference in student achievement as in learning efficiency. The results from the CAI study were typically due to each student working four days a week for 15 minutes a day interacting with computerized instruction for 26 weeks.

Effectiveness of Technology on Enhancing Math Achievement

This meta-analysis conducted in 2011 focused on the effects of technology on math achievement in K-12 schools (Cheung & Slavin, 2011). The researchers identified 75 studies that met their criteria for the analysis. Over 56,000 students were involved, with data obtained from 45 elementary schools and 30 high schools. The overall effect size was +0.15 and considered small by the authors. Similar to the Kulik et al. (1985) study, this review also found CAI to be the most effective method with an effect size of +0.18. Computer managed instruction (CMI) had an effect size of +0.08.

Effectiveness of Technology on Enhancing Reading Achievement

In a parallel study, Cheung and Slavin (2012) conducted a meta-analysis on how technology affects reading achievement. They identified 84 studies, involving over 60,000 K-12 students, which met the specified inclusion criteria. The effect size found for reading achievement was +0.16, a moderate positive effect. The researchers then examined how the technology was used in each of the studies. For a comprehensive approach that integrates the computer instruction with traditional classroom instruction, the effect size was largest -- a moderately strong +0.28. Unlike other studies the effect size for CAI was only +0.11. Cheung and Slavin concluded, “What matters is how technology integrates with non-technology components of reading instruction” (p. 22). Immersion or integration of technology focuses on the degree to which the technology is used with other components of the instruction. For example, if a teacher requires students to search the Internet for information, incorporate the information into an assignment written and edited on a laptop, then we would consider this approach as a higher level of immersion. In contrast, requiring students to type the paper from a draft they wrote with pencil and paper, print the typewritten version, edit the paper print out, and

then make changes with a computer would be considered a low level immersion. The more the students use the technology as a tool to do research, analysis, and writing the higher the level of immersion and the greater the effect on achievement.

Learning in One-to-One Environments

Zheng, Warschauer, Lin, and Chang (2016) recently published a literature review and a meta-analysis of one-to-one laptop programs. They found 96 studies that met their criteria for the literature review and 10 of those studies met the more rigorous criteria for the meta-analysis. All studies involved students in grades four through eight. Results of the meta-analysis indicated a moderate effect size of +0.16 for the one-to-one laptop initiatives on overall academic achievement. Next, they examined the effect of the laptop programs on achievement in six different content areas. The largest effect sizes were found for science (+0.25) and writing (+0.20). The effects sizes for English, math, and reading were +0.15, +0.17, and +0.12, respectively. These effect sizes, while small to moderate in size, suggest clear potential for one-to-one laptop programs to support learning, while producing the additional benefits.

Zheng et al.'s (2016) review of the 96 studies also indicated:

- *Increased student technology use.* The most common uses of technology were writing and editing, in addition to gathering information from the Internet. Laptops enabled a wide range of technology-enhanced learning activities across content areas and for all grade levels (kindergarten through high school).
- *Increased student-centered approaches to learning.* Laptop use led to more student-centered or individualized learning in several studies. Further, some studies revealed that associated resources or Internet connections allowed students to have more control over

their learning paths. Due to the affordances of devices, some studies revealed that laptops provided increased opportunities for project-based learning.

- *Increased writing.* Student writing activities increased due to the availability of individual devices. In addition, laptops were found to be used in all stages of the writing process (e.g., gathering information, planning, drafts, editing, receiving feedback, and publishing). Importantly, students in classrooms where laptops were available received more feedback, revised papers more often, and drew on a wider range of resources during the writing process.
- *Improved relationships.* Teachers in several studies reported that laptop programs improved teacher-student and home-school relationships.
- *Positive student and teacher perceptions.* In addition to having very positive attitudes towards the effects of laptops on their learning, students often indicated they preferred learning with laptops and felt their work became more interesting. Studies that examined teacher attitudes longitudinally revealed that teachers had very positive attitudes toward the laptop program after at least a year of use.

A second meta-analysis was recently completed on one-to-one computing by Bethel and Bernard (2016). The researchers identified over 1,300 K-12 one-to-one laptop studies. Eighty-eight of those studies were selected for the meta-analysis after a rigorous review. There were four key findings:

- One-to-one programs had a small, positive effect on student engagement (+.15) and a larger positive effect on student satisfaction (+0.29).
- One-to-one laptop projects with *younger* students yielded better learning achievement results than those with older students.

- Fully-integrated laptop programs had an effect size of +0.37 on student achievement as compared to minimally-integrated programs (+0.06). Thus, the greater the buy-in and thoughtful use of the laptops, the stronger the effect. Even partial integration resulted in an effect size of +0.26.
- The laptop program also had significant effects on student achievement in a variety of content areas. The following effect sizes were reported: writing (+0.33), cognitive skills (+0.29), reading (+0.23), English/language arts (+0.21), and mathematics (+0.17). Overall, these effect sizes for achievement in different areas are moderate to strong in size suggesting that the one-to-one laptop programs are effective at influencing student achievement.

Forty Years of Technology Research

Tamin, Bernard, Borokhovski, Abrami, and Schmid (2011) conducted a second-order meta-analysis on the impact of technology on learning. A second-order meta-analysis uses data from prior meta-analyses rather than individual studies. Like the meta-analyses discussed, it is also a way to determine an overall effect size for multiple studies. Tamin et al. found 185 meta-analysis studies on the impact of technology published since 1985 and selected 37 that met their criteria for quality studies. The results from this study found an effect size of +0.30 that is well above average according to Cheung and Slavin (2015). According to Tamin et al.,

> *The average student in a classroom where technology is used will perform 12 percentile points higher than the average student in the traditional setting that does not use technology to enhance the learning process (p. 17).*

A more important finding in this study was that the effect sizes for programs that use technology to support cognition are significantly higher than when the technology is used to present content. That is, a student using a spreadsheet to solve a problem (supporting cognition) will score higher than a student receiving the same information through a recorded PowerPoint presentation. Thus, we would expect to see more benefit from one-to-one laptop projects and other computer projects where the computer technology is used as a tool to achieve rather than as a passive device like television to present content to a learner.

Overall, these meta-analyses found an above average effect size for using technology in the classroom. Similarly, several studies demonstrated the importance of integrating computer technology into the lesson design.

Conclusions

We have presented a variety of studies in this literature review that revealed six important benefits of integrating computer technology into the classroom:

1. Multiple studies reported *higher engagement* of students with their course work when involved in one-to-one laptop programs that produced two key findings. First is the development of a deeper level of understanding. Second is an increase in student achievement.
2. Several studies reported *increased interactions with peers*. One study found that students interacted twice as much when they were using a computer than doing other activities, with the conversations focused primarily on problem-solving (Svensson, 2000).
3. A common finding in many of the studies was *increased technology proficiency*. Mastering computer skills beyond clicking a few buttons is essential in today's world.

Students need to know how to use tools such as spreadsheets and word processors if they are going to be successful in school from kindergarten to university work. These skills are also essential for the work place. The one-to-one laptop projects help develop these skills.

4. A few studies found that there were *fewer discipline problems* with students participating in the laptop projects. A reduction in disciplinary problems means a greater focus and time devoted to instruction for both the students and the teachers.
5. Many studies found an *increase in student-centered instruction*. Teachers had additional tools and time they could devote to individualized instruction to meet the needs of specific learners. Thus, rather than a one size fits all approach, teachers could customize the instruction to address the specific needs of individual students.
6. Research on computer technology has shown that when the technology is highly integrated into the instruction, then it has a *positive impact on student learning*.

Zheng et al. (2016) stated, "Contrary to Cuban's (2003) argument that computers are "oversold and underused" in schools, laptop environments are reshaping many aspects of education in K-12 schools" (p. 24). They noted significant improved in student achievement and improved teacher-student and home-school relationships.

Tamin et al. (2011) found that if the computer technology is simply used to present instruction such as having students watch a PowerPoint presentation the teacher or other instructor has recorded, then computer technology will have very little if any effect on student achievement. However, if the technology is used to support learning such as using a spreadsheet to analyze data or solve a problem, then the technology will have a significant effect. Bethel and Bernard (2016) concluded from their meta-analysis that, "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" (p. 29). According to Tamin et al. (2011), research has established the benefits of integrating computer technology into the classroom. Now, it is time to shift the focus on finding the most effective ways to use the technology to enhance achievement.

Today, computer technology is ubiquitous in our society whether it is a smart phone, a smart refrigerator, a home alarm system, automobile, treadmill, or a tablet. Technology is used in almost all aspects of the workplace to solve problems, make work more efficient, and to improve productivity. The research on technology and specifically one-to-one computing in K-12 schools supports the wide-spread implementation in K-12 schools. Studies from the past 30 years have shown that well-integrated computer technology programs can affect student achievement in a positive manner. In addition, researchers have found that such programs result in higher student engagement, increased student-to-student interactions, more student-centered instruction, improved home and school relations, and fewer disciplinary problems. As we move forward, we can expect improved strategies that are likely to have an even greater impact on student achievement.

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