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Learning with Laptops: Implementation and Outcomes in an Urban, Under-Privileged School

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Abstract

This study examined the implementation and outcomes of a laptop program initiative in a predominantly low-income, minority school. Both quantitative and qualitative data were collected, analyzed, and compared with students in non-laptop classrooms within the same school. Results of the study revealed that in the hands of well prepared teachers, laptops enabled disadvantaged students to engage in powerful learning experiences. Although quantitative data did not reveal significant differences in student attitudes towards computers and school between laptop and comparison students, qualitative data indicated that laptop integration created enhanced motivation and engagement with schoolwork, influenced classroom interactions, and empowered students. Such behaviors were not evident among comparison students. Furthermore, qualitative data indicated that the laptop program produced academic gains in writing and mathematics within the laptop group. Results of the study have implications for policy makers, researchers, and practitioners, especially those interested in bridging the digital divide in education. (Keywords: laptops, ubiquitous computing, quasi-experiment, urban-elementary students, digital divide.)

INTRODUCTION

Current legislative mandates, such as the No Child Left Behind (NCLB) Act, have increased the demand on school districts to provide every child with access to high-quality education and close the achievement gap. The Enhancing Education through Technology program of the NCLB, in particular, seeks to leverage the power of technology in all areas of K–12 education in ways that impact the quality of teaching and learning (U.S. Department of Education, 2001). Despite this ambitious goal, it has been demonstrated that students who come from low-income minority backgrounds often suffer from poor access and utilization of technology while confronted with inferior quality learning opportunities (Donahue, Finnegan, Lutkus, Allen, & Campbell, 2001; NTIA, 1999). In fact, international assessments reveal that schools in the United States (U.S.) are the most unequal in the industrialized world in terms of spending, curriculum offerings, teaching quality, and outcomes (Darling-Hammond, 2006). As a result, low-income minority students often have limited access to intellectually challenging curriculum material and instruction (Darling-Hammond, 2004).

In response to these inequities, and with assistance from the private sector, several school districts in the U.S. have committed themselves to laptop technology programs as a means to improve access to digital resources, increase opportunities for better quality instruction, and prepare students for the demands

of the modern workplace. Yet, research into the educational uses and student outcomes of laptop programs is still in its infancy. In a recent examination of studies analyzing the implementation and effects of laptop initiatives in multiple countries, Penuel (2006) found only 30 studies that used rigorous research procedures, with the majority of those studies focusing on middle/high school students in affluent schools. Clearly, there is a need for more research on the benefits of laptop programs for teaching and learning and their potential to bridge the digital and *didactic* divide that currently exists (Fulton & Sibley, 2003). Specifically, there is a need to study the new learning environments created by the presence of laptops and determine the conditions under which positive effects on learning outcomes may be achieved (Van Hover, Berson, Bolick, & Swan, 2006).

The purpose of this study is to investigate the implementation and outcomes of a laptop program in a predominantly low-income minority school. Specifically, the study examines the ways in which two primary grade teachers integrated laptops in their instructional practices and the impact of such integration on student educational experiences compared to non-laptop peers in the same school. Three primary questions guided this research:

1. During a one-year period (2002–2003), in what ways did teachers and students utilize laptop computers in their classrooms to achieve instructional goals?
2. How did access to laptops influence student attitudes toward computers and school compared to their non-laptop peers?
3. How did student use of laptop computers support learning processes?[1]

THEORETICAL FRAMEWORK

Digital Divide and Laptop Initiatives

There is urgency in the U.S. to improve the quality of education, close the achievement gap, and equip students with 21st century knowledge and skills (Ladson-Billings, 2006; Partnership for 21st Century Skills, 2003). Generally, 21st century skills are identified as information and communication skills, thinking and problem-solving skills, and interpersonal and self-directional skills (Partnership for 21st Century Skills, 2003). To achieve these goals, students must be given 21st century tools that simulate authentic work environments. They also need to learn academic content through real-world examples. Recent data indicated that great strides have been made to provide schools with 21st century tools (e.g., computers and Internet connections) that can help teachers create more authentic learning environments for students (Wells & Lewis,

[1]This study did not examine differences in student achievement between laptop and comparison classrooms as measured by test scores. Existing research indicates that it is exceedingly difficult to link full time access to laptops to the outcomes of standardized tests currently in use, particularly during the first year of a laptop initiative (Muir, Knezek, & Christensen, 2004; Rockman, 2000, 2003). The main reason behind this difficulty is the mismatch between the content of standardized tests that often include lower-level skills and the type of higher-order skills supported by laptops (Roschelle, Pea, Hoadley, Gordin, & Means, 2000).

2006). In 2005, the ratio of students to instructional computers with Internet access in public schools was 3.8:1 compared to 12.1:1 in 1998. Despite these improvements, schools with lower level of minority enrollment still have fewer students per computer than schools with higher minority enrollment (Wells & Lewis, 2006).

In addition to limited access to technology in school, low-income minority households are also the least likely to be online. It was estimated that approximately 68% of low-income White households did not have access to the Internet, compared to 75% of African American and 74% of Hispanic low-income households (Pew, 2000). This disparity in home access to technology further limits the opportunities of low-income minority students to practice essential learning skills and experience academic success. According to Fulton and Sibley (2003), just as the presence of books and reading material at home can impact the reading readiness of a child, the availability of computers and Internet access at home can also influence a child's technology literacy readiness.

In an effort to bridge the digital divide, several districts have embarked in the implementation of laptop programs. Providing every student with a laptop, which can also be taken home, can have a tremendous impact on students who are currently left out from the world of technology. Access to laptop computers can change both *how* and *what* students learn, *within* as well as *outside* school boundaries (Roschelle et al., 2000). Use of computers can enhance *how* children learn by supporting four fundamental characteristics of learning: (a) active engagement, (b) participation in groups, (c) frequent interaction and feedback, and (d) connections to real-world contexts (Roschelle et al., 2000). Use of computers can also change *what* students learn by providing exposure to ideas and experiences that otherwise would be inaccessible. Such opportunities are particularly useful in developing the higher-order skills of critical thinking, analysis, and inquiry that are necessary for success in the 21st century (Rockman, 2003).

The overarching objective of this study is to investigate the implementation of a laptop program in a predominantly low-income minority school and its potential to *bridge* the digital and didactic divide by providing students with enriched learning experiences both within and outside school borders.

Student Learning and Laptop Initiatives

Cognitive research emphasizes the importance of student *intrinsic* motivation in the learning process (Ryan & Deci, 2000). Students with higher intrinsic motivation have exhibited higher achievement, more favorable perceptions of their academic competence, and lower academic anxiety (Gottfried , 1990; Gottfried & Gottfried, 1996). Many of the tasks that teachers want their students to perform, however, are not inherently interesting or enjoyable (Ryan & Deci, 2000). As a result, a supportive school environment that gives students choices in selecting learning tasks and opportunities for self-directed learning can catalyze greater intrinsic motivation and desire to learn (Ryan & Grolnick, 1986). In contrast, a controlling environment can forestall student motivation and learning desire.

Existing research indicates that use of laptops has the potential to create supportive school environments that can foster student responsibility, competence,

and autonomy in relationship to technology and learning, thereby leading to increased motivation and greater academic aspirations (Light, McDermott, & Honey, 2002; Newhouse & Rennie, 2001; Zucker & McGhee, 2005). Findings from *Project Hiller*, a laptop initiative for urban high-school students, demonstrated that ubiquitous access to technology altered classroom interactions, fostered a sense of autonomy and ownership of learning, and created a student-centered environment that facilitated the development of motivation and academic engagement (Light et al., 2002).

In addition, initial findings from one-to-one initiatives have indicated positive outcomes on student learning. Ubiquitous access to computers has shown to help students acquire increased comfort level with a range of software applications and the ability to apply technology to access, manipulate, and organize information (Lowther, Ross, & Morrison, 2003; Rockman, 2003). It has also shown to improve student writing skills and foster increased confidence and self-efficacy (Penuel, 2006; Russell, Bebell, & Higgins, 2004).

Building upon earlier work, this study further investigates the impact of a laptop initiative on urban elementary student attitudes towards computers and school. It also examines ways in which access and utilization of laptops can benefit student learning processes. Instilling an interest in school and learning has implications for future school success (Gottfried, 1990).

Teacher Professional Development and Laptop Initiatives

Providing laptop computers so that every student can have access to digital resources is important for bridging the digital divide. The biggest challenge, however, is helping teachers develop the expertise required to harness the power of technology. The challenge goes beyond the lack of teachers' technology skills and involves critical issues related to teachers' pedagogy and beliefs towards technology (Garthwait & Weller, 2005; Windschitl & Sahl, 2002).

Designing quality computer-based lessons that address mandated content and standards is very demanding on teachers (Lowther et al., 2003). As a result, teachers often use technology within their existing practice. In low-income minority schools, in particular, teachers are more likely to have students use computers for routine skills practice and are less likely to have students use computers to make presentations, do analytic work, revise and publish text, or engage in exploratory and problem-solving activities (Becker, 2001). To create real improvements, teachers need to use technology to support knowledge-building and discourse rather than reinforce traditional ways of teaching where students act primarily as receivers of information (Donahue et al., 2001). They also need to shift to new pedagogical strategies where they become facilitators of learning.

A growing body of literature indicates that access to laptop computers can change the teaching and learning dynamics in the classroom. Initial findings indicate that access to laptops facilitates the implementation of inquiry-based methods as opposed to memorization and practice, as well as more interdisciplinary approaches that value cooperative learning (Fairman, 2004). Furthermore, ubiquitous computing can act as a catalyst that could facilitate movement towards constructivist practices, where teachers act primarily as coaches (Rock-

man, 2000). Nevertheless, such changes do not happen automatically. Teachers need access to high-quality professional development since use of technology in this scale is neither intuitive nor automatic.

This study investigates the ways in which two primary teachers who participated in a research-based professional development program integrated laptops in their instructional practice at an urban, under-privileged school. It also investigates classroom interactions, such as the interactions between teachers and students, and among students themselves, as a result of laptop integration.

CONTEXT OF THE STUDY

The laptop initiative employed in this study was part of the *Microsoft Anytime, Anywhere, Learning* program. Schools and parents participating in this program lease their notebooks from Toshiba resellers. Hardware and software are discounted, as are service and insurance contracts. The school where the study took place was one of 52 other participating pilot schools located in an urban New York City (NYC) school district. The school was serving 1,277 students in grades K–5. Approximately 94% of the students were Hispanic who qualified for free lunch. The goal of the program was to help bridge the digital divide by providing disadvantaged students with increased access to technology and improved learning experiences.

A total of three classrooms participated in the school's laptop program—one from each grade level in grades three to five. Participating students had leased their notebooks and were required to pay $100 for insurance costs[2]. Unlike other initiatives in which students received state of the art equipment, students in this study received refurbished laptops. Moreover, laptops were not networked or connected to printers because the school lacked the appropriate infrastructure. Students had Internet access and printing capabilities through two desktop computers located in their classrooms. These are important considerations when trying to assess the outcomes of a laptop program because convenient access to the Internet provides incremental advantages compared to computer environments lacking Internet access (Penuel, 2006).

METHODS

Study Design and Participants

This study employed a quasi-experimental design to investigate the benefits of laptops on student academic experiences compared to non-laptop peers in the same school. Classrooms were not randomly assigned. Three laptop classrooms were initially selected by the school's technology coordinator based on the following criteria: (a) the classroom teacher had participated in substantial professional development on the use of technology; (b) the classroom teacher had demonstrated prior evidence of integrating technology (i.e., desktop computers); and (c) the classroom teacher was willing to participate in the program. Control classrooms were selected by the researcher to include *comparable* student populations.

[2]The school contributed this amount for students who could not afford it.

The study included two of the laptop classrooms—the third grade class (22 students) and the fourth grade class (28 students)[3]. For each laptop class, one comparable non-laptop class at the same grade level in the same school was selected[4]. Comparison classes had only two computers available, which was the typical number in the school and were carefully matched to include students who demonstrated achievement levels similar to those of students in laptop classes. The particular school was primarily organized in homogeneous rather than mixed ability classrooms. As a result, some classes included only students who exceeded or met learning standards in language arts (i.e., listening, reading, and writing) and mathematical skills while other classes included only students who partially met learning standards or were struggling to achieve a basic level of proficiency. Furthermore, the school had bilingual classes in which instruction was delivered both in English and in Spanish[5].

To determine student placement, the school relied on results from local diagnostic assessments and other teacher measures of student achievement. Both the third and fourth grade laptop classes were considered advanced classes in the school, whereby all students exceeded or met grade level learning standards in language arts and mathematics. As a result, the matched comparison classes selected were also advanced classes in the school, where all students exhibited grade level proficiency in language arts and mathematics. To determine appropriate matched comparison classes, the researcher sought the input of the school administrators who nominated third and fourth grade advanced classes in the school. All laptop and comparison classes were monolingual classes (i.e., instruction was only provided in English) in which students came from the same socio-economic and ethnic background.

A final measure considered in selecting comparison classrooms was teacher credentials and professional development on the use of technology. All teachers had a bachelors and a master's degree within the education field. Moreover, both laptop (Betsy and Lisa) and comparison (John and Tony) teachers had previously participated in a yearlong, research-based professional development program (2000–2001) on the use of technology offered by a leading university. The purpose of the program was to enhance teachers' technological competence and understanding of technology integration into classroom instruction, particularly within a student-centered framework. Gender was not considered when selecting teacher participants because of the small sample of potential participants. As a result, both laptop teachers were females and both comparison teachers were males. Although there is no evidence that this influenced the findings of the study, it represents a limitation of this work.

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[3]The fifth grade class was not included because it would have required the use of different data collection instruments, thereby making it difficult to compare student results across grades. Specifically, the Young Children's Computer Inventory (YCCI) was used, which is most appropriate for grades K–4.

[4]Each comparison class included 25 students.

[5]The school had eight third-grade classrooms and seven fourth-grade classrooms.

Data Collection

Qualitative and quantitative data from both laptop and non-laptop classrooms were collected throughout the 2002–2003 academic year. Data sources included classroom observations, teacher interviews, student questionnaires, and student focus groups.

Classroom Observations: Each laptop classroom was observed on seven different occasions. Comparison classrooms were observed twice. All observations were conducted by the author. Observations ranged from 90 minutes to three hours and focused on both pedagogy and laptop (or desktop) usage, such as: (a) the type of hardware and software used; (b) the role of the teacher; (c) the role of the students; (d) the types of activities employed (e.g., cooperative learning, direct instruction, etc.); and (e) the interaction among students, and between the teacher and the students. Detailed field notes were kept for every observation and relevant artifacts were collected (e.g., teacher lesson plans, student multimedia presentations, etc.).

Teacher Interviews: Both laptop and comparison teachers were interviewed twice—at the beginning and at the end of the year. All interviews were conducted by the author. Interviews were partially structured and elicited information on: (a) teacher beliefs with regard to the use of technology in teaching and learning (e.g., What do you think is the role of technology in education?); (b) instructional practices (e.g., In what ways do you utilize computers in your classroom?); and (c) impact of technology on student learning (e.g., In what ways do you think implementation of laptop computers influences student learning, motivation to learn, and attitudes towards school?). Each interview was approximately forty minutes long. All interviews were audio-taped and transcribed.

Student Questionnaires: Quantitative data were collected through the Young Children's Computer Inventory (YCCI; Knezek, Christensen, Miyashita, & Ropp, 2000). The YCCI is a 52-item, 3-point scale Likert instrument for measuring elementary school children's attitudes across seven major indices: (a) Computer Importance (perceived value or significance of knowing about computers); (b) Computer Enjoyment (pleasure derived from using computers); (c) Motivation/Persistence (effort and perseverance); (d) Study Habits (ways of pursuing academic exercises); (e) Empathy (caring about others); (f) Creative Tendencies (inclinations toward finding unique solutions to problems); and (g) Attitudes toward School (perceived value of school education)[6]. The YCCI was developed across multiple studies over a 10-year period (1991-2001). In all studies, individual scale internal consistency reliabilities (Cronbach's Alpha) ranged from .66 to .85 for elementary school students (Christensen, Knezek, & Overall, 2005).

A total of 100 students completed the instrument during the months of April and May 2003—50 laptop and 50 comparison students. All data were gathered in a small group setting to ensure the collection of usable surveys. Each student

[6]Although this research was not interested in measuring empathy, students completed all scales of YCCI to avoid influencing the validity and reliability of the instrument.

in the group was given a sheet listing only the response choices. The author and a research assistant read the survey items to the students and provided any necessary explanations. The person not reading monitored students closely to make sure they were marking their answer to each item in the corresponding location. All 100 questionnaires were fully completed and yielded usable data.

Student Focus Groups: Additional qualitative data were collected from a total of 32 students during eight focus groups (four students per group). Two groups of students from each class were selected to participate—one high-achieving group and one lower-achieving group. High-achieving students were defined as those who *clearly met* or *exceeded* (demonstrated *advanced proficiency*) their respective grade level learning standards in language arts and mathematics based on local assessments and other teacher measures of student achievement (e.g., writing samples, quizzes, etc.). Lower-achieving students were defined as those who *minimally met* (demonstrated *proficiency*) their respective grade level learning standards in language arts and mathematics based on the same assessments. All focus group participants were identified by their classroom teachers who had adequate opportunities throughout the year to assess student proficiency of grade level learning standards.

Focus group questions were targeted toward five major topics: (a) computer importance (i.e., Do you think is important to know about computers? Why or why not?); (b) computer enjoyment (i.e., What do you like/dislike about computers?); (c) computer usage at home (i.e., How do you use your computer at home?); (d) student-student and student-teacher interactions (i.e., Do you ever work with other students in your class? If so, in what ways? Have you ever taught something to other students in your class? Have you ever taught the teacher something?); and (e) motivation toward school and learning (i.e., How do you like coming to school?). Each focus group lasted approximately 40 minutes. All focus groups were video-taped. In all focus groups the researcher allowed enough time for each question and encouraged all individuals to voice their ideas. Transcript examination revealed that almost all students responded to all questions and multiple perspectives were generated.

Data Analysis

Data from classroom observations and teacher interviews were first transcribed. Subsequently, the researcher and a graduate assistant repeatedly read the transcripts and identified excerpts that discussed teacher beliefs and practices toward technology. Excerpts on teacher beliefs included statements related to the role of technology in the school curriculum as well as benefits and drawbacks of computers for student learning. Excerpts related to practice included statements on the ways in which students utilized computers for instructional tasks. As analysis of each individual teacher was completed, data were compared with those of the other teachers to identify similarities and differences among laptop and comparison teachers (Miles & Huberman, 1994). Classroom artifacts and excerpts from student focus groups were used to triangulate findings (Maxwell, 1996). Disagreements were only minimal and were all resolved through consensus.

Data from student questionnaires were analyzed using statistical methods and the SPSS software package[7]. Student focus groups were first transcribed and analyzed using a grounded theory approach (Glaser & Strauss, 1967) to look for emergent patterns as well as for commonalities and differences across student responses. Initially, the researcher and three graduate students, who had not been part of conceptualizing the study, repeatedly read and open-coded portions of the transcripts. Based on this analysis an initial coding scheme was developed. This initial coding scheme was subsequently applied to additional data and several revisions were made. The final coding scheme included the following categories: (a) student beliefs about computers, (b) student enjoyment from using computers, (c) student uses of technology at home, (d) motivation and attitudes towards school, (e) benefits from using computers, (f) classroom interactions with teachers and peers, and (g) student empowerment. The researcher and two of the graduate assistants applied the final coding scheme in all eight focus group transcripts. Disagreements were resolved and a consistent inter-rater coding was achieved.

FINDINGS

Findings of the study are presented in this section organized by research question.

In what ways did teachers and students utilize laptops in their classrooms to achieve instructional goals?

Results from observations and interviews indicated that Betsy and Lisa, the laptop teachers, used technology to create meaningful learning activities that engaged students in complex, authentic tasks. Technology was used as part of a model that emphasized project-based learning and construction of knowledge rather than recitation or drill and practice.

Throughout the year, Lisa the third grade teacher was able to implement a variety of sustained projects that integrated laptop computers. In language arts, students used TimeLiner[8] to create interactive timelines that featured the biographies of authors studied in class (e.g., Tomie dePaola). They also used multimedia to create electronic storybooks modeled after fairytales read in class and publish reports that were supplemented with their own illustrations. In mathematics, they worked in cooperative groups using spreadsheets to gather and analyze data collected from conducting classroom polls. These activities were essential for mastering elements of graphing, a required curriculum unit. Finally, in science, they frequently used the Internet to look up information and Inspiration[9] to organize their understanding into concept maps. Concept maps

[7]A full description of the quantitative data analysis is presented later in the "Results from Student Questionnaires."

[8]Timeliner (Tom Snyder Productions) is a software package that allows students to tackle challenging content and concepts by visually organizing information on a time line or number line.

[9]Inspiration (Inspiration, Inc.) is a software package that allows students to create graphic organizers to visually represent concepts and relationships.

Figure 1: Peer sharing in the third grade laptop class.

revealed students' thinking and helped Lisa identify misconceptions and plan appropriate instructional activities.

To accommodate use of technology, Lisa reworked her daily schedule and used blocks of time to work on projects that integrated laptops. As she explained, she also implemented much more cooperative work than in her past practices. In the classroom, she often acted as the *guide-on-the-side*; she provided individual support, facilitated sharing among students (Figure 1), and encouraged exploration through the use of technology.

In Betsy's fourth grade class, learning was also primarily structured around sustained projects that utilized laptops to promote problem solving and knowledge construction within a meaningful context. Students had opportunities to choose topics based on their own interests, collaborate with their peers, and assume different roles. They also had opportunities to raise questions, gather and analyze science data from their local school yard using spreadsheets, and create learning material for their peers in the form of electronic newsletters. In the process, students were forced to explain and defend their ideas thus developing a better conceptual understanding of the issues at hand. The following excerpt describes a technology-integration project related to the topic of the *American Revolutionary War*, which is illustrative of Betsy's practice. Betsy described:

> As part of the project, students worked in groups to prepare a newsletter related to the Revolutionary War using d*esktop publishing* software (Figure 2). Each student in the group conducted research using library

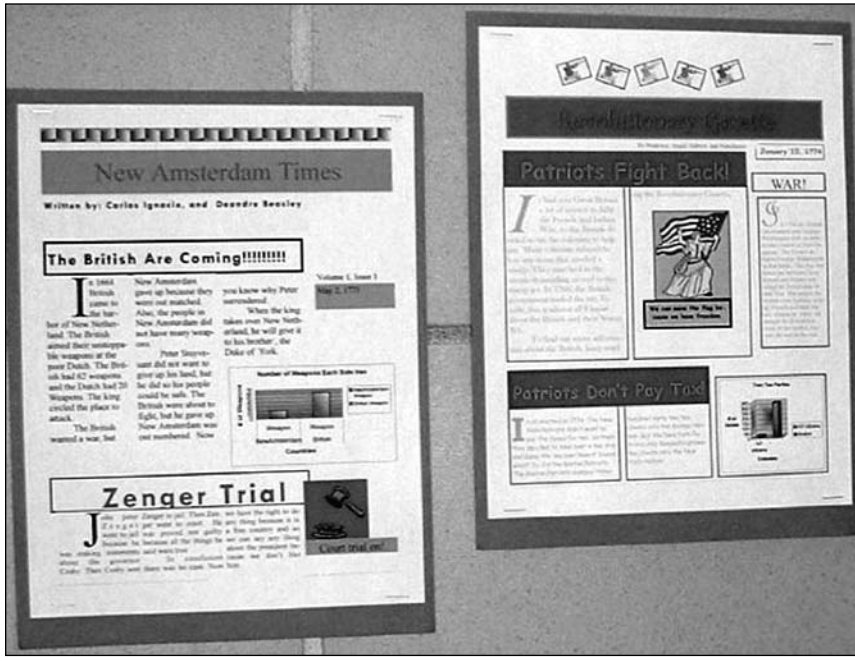

Figure 2: Electronic newsletters on the Revolutionary War created by fourth grade laptop students.

> and Internet resources and prepared a diary entry, a biographical essay, or a report based on a Revolutionary War person or event of their choice (e.g., a biography of an African-American soldier, a report on a major battle such as the Boston Tea Party, etc.). Those students who chose to research particular events used their knowledge of *spreadsheets* to create graphs demonstrating the number of British and American soldiers killed during the battle. We are now working as a class to develop an interactive timeline using *multimedia* that features the major battles of the revolution (Figure 3, p. 458).

Describing the role of laptops in her instructional planning, Betsy explained: "Having the laptops has definitely helped me to think differently. I no longer think of 45 minute lessons; I now plan sustained projects that involve students working collaboratively around an important issue." Furthermore, because access to laptops enabled students to develop artifacts (e.g., multimedia presentations, websites etc.), Betsy often had her students publicly share their work with other peers and adults. In fact, Betsy's students described with pride an event where they demonstrated the school Web site they had created during a parent night.

These findings demonstrated that instead of being restricted by impoverished environments typical in low-income minority schools, Betsy and Lisa used laptops to create rich learning environments that facilitated knowledge construc-

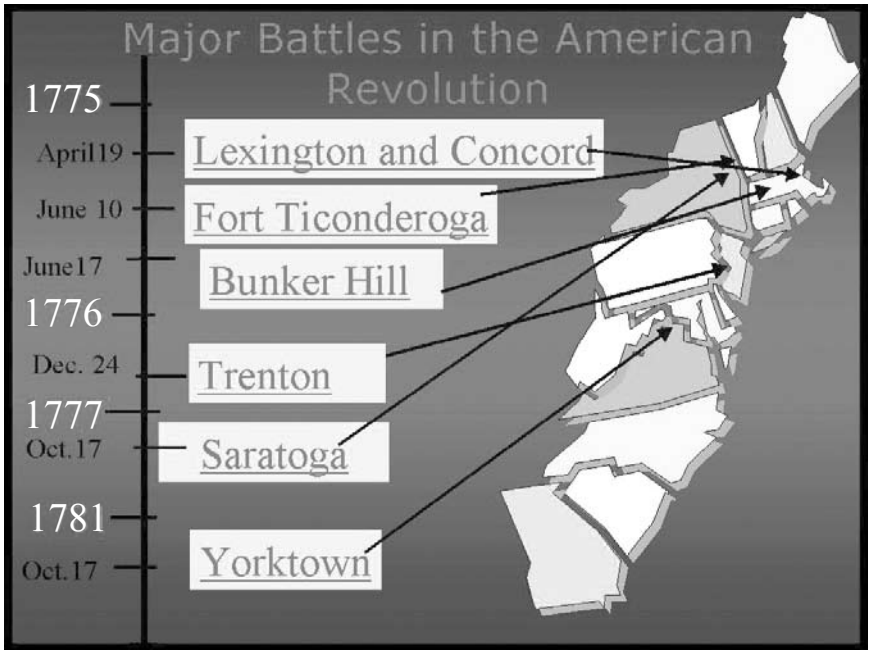

Figure 3: Battles of the American Revolution created by the fourth grade laptop students.

tion. Contrary to laptop teachers, observation and interview data revealed that comparison teachers used technology for mundane instructional tasks, such as word processing and Internet research. Further, computers were sometimes used as a reward for students finishing their work. John, the third grade teacher, indicated: "I have the students rotate on the computer in pairs to word-process documents. However, students who are not behaving do not get a turn." Although such uses of technology helped students automate some tasks (e.g., looking up information), they did not promote new models of instruction. According to John and Tony, the non laptop teachers, limited access to hardware, software, and technical and pedagogical support were all key factors inhibiting extensive use of technology.

How did access to laptops influence student attitudes toward computers and school compared to their non-laptop peers?

Results from Student Questionnaires

The quantitative data were analyzed using the statistical analysis package SPSS. Reliability analyses were first performed to determine whether each of the seven subscales of the YCCI were internally consistent and could be used in a MANOVA. The Cronbach alpha of a scale should be greater than .70 for items to be used together as a scale (Nunnally, 1978). Results of these analyses revealed that only two of the subscales achieved alpha levels exceeding .70 (*Creative Tendencies* alpha = .71 and *Attitudes toward School* alpha = .75). Additional analyses and modifications were performed in attempts to improve the internal

consistency of the other five subscales. Although the internal consistency of the deficient scales improved, none of the improvements led to acceptable alpha levels for the remaining five scales[10]. MANOVAs and separate univariate ANOVAs were subsequently used to determine whether grade level and having laptops in the classroom influenced student attitudes (*Creative Tendencies* and *Attitudes toward School*).

In order to determine how technology in the classroom influenced *Creative Tendencies* and *Attitudes toward School*, a 2 (technology in classroom) x 2 (grade level) MANOVA was performed on the two reliable subscales of the YCCI. *Creative Tendencies* and *Attitudes toward School* subscales were used as dependent variables. All other subscales were excluded from the analysis because of their poor reliability. MANOVA assumes that variances and covariances are homogeneous. Box's Test of Equality tests the null hypothesis that the observed covariance matrices of the dependent variables are equal across groups. Results indicated that the null hypothesis was retained (Box's M= 13.01, p= ns), suggesting that the covariance matrices for the groups were equal to one another.

Results from MANOVA suggested that access to laptops did not influence student *Creative Tendencies* or *Attitudes toward School* (Wilk's λ = .99, F (2, 95) = .37, p = ns). The significant overall multivariate effect for grade level, however, suggested that grade level alone influenced student outcomes (Wilk's λ = .90, F (2, 95) = 5.27, p < .01, Partial η^2 = .100). Separate univariate ANOVAs demonstrated that grade level had a significant influence on *Creative Tendencies* (F (1, 96) = 5.71, p < .05, Partial η^2 = .056, r = 0.24 which represents a small effect size) and *Attitudes toward School* (F (1, 96) = 8.86, p < .01, Partial η^2 = .085, r = 0.29 which represents a small to medium effect size). When a Bonferroni adjustment was made to deter the inflation of Type I error, a more stringent, family-wise alpha level (.025) resulted. The adjusted results showed that third graders (M = 2.65) were significantly more likely than fourth graders (M = 2.51) to report having *Creative Tendencies*. Additionally, the corrected results reflected that third graders (M = 2.19) were significantly more likely to have positive *Attitudes toward School* than fourth graders (M = 1.85).

In order to determine whether the unique combination of technology in the classroom and grade level had an influence on student attitudes, results from the MANOVA were analyzed. Results yielded a marginally significant multivariate effect for the interaction (Wilk's λ = .94, F (2, 95) = 2.88, p = .06, Partial η^2 = .057). Although separate univariate analyses revealed no significant interaction between technology and grade level on *Creative Tendencies* (F (1, 96) = .283, p = ns), they did reveal a significant interaction between grade level and technology in the classroom on *Attitudes toward School*, displayed in Figure 4, p. 460 (F (1, 96) = 3.84, p = .05). After a Bonferroni adjustment was made to deter the inflation of Type I error, a more stringent alpha level (.025) prevented the interaction involving *Attitudes toward School* from being

[10]To the best of our knowledge, no other instruments exist for measuring young children's attitudes toward technology.

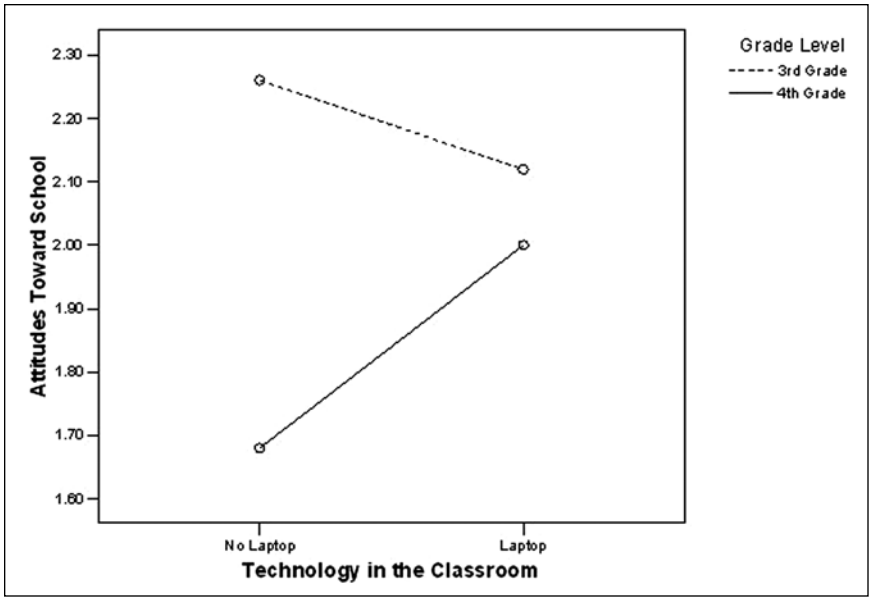

Figure 4: Interaction between Technology and Grade Level on Attitudes toward School.

significant. Despite the lack of statistically significant interaction, the means demonstrated that third graders who had laptops (M = 2.12) did not differ considerably from third graders who did not have laptops (M = 2.26) on *Attitudes toward School*. However, fourth graders who had laptops (M = 2.00) had significantly *more positive* attitudes toward school than fourth graders who did not (M = 1.68)[11].

Results from Student Focus Groups

Findings from focus groups indicated that all students perceived computers to be important tools because they serve as an information resource, they are useful for future employment, and they assist in the learning process. Both laptop and comparison students viewed the computer as a tool that could provide information and help people learn more about the world, particularly through the use of the Internet. All students also commented on the importance of acquiring computer skills for future employment. Diego, a fourth grade laptop student explained: "If you would like to become something in your life, you really need to know how to use computers." Furthermore, most students reported that computers can facilitate learning by helping them find information, develop professional products, and correct spelling and grammar. Finally, they

[11]Considering that the sample size was small and that results from the univariate analyses were marginally significant, we believe it is important to inform readers of the significant difference in the *means* scores. A t-test between fourth graders who had laptops (n=28) and those who did not (n=25) also demonstrated that laptop students were significantly more likely than comparison students to have positive attitudes toward school, t (51) = 2.06, p< .05.

indicated that use of computers fosters creativity and exploration (e.g., users can choose their own fonts and can explore different programs).

One interesting finding was that laptop students emphasized the importance of using computers for exploration and learning while comparison students placed more emphasis on the advantages of using computers as an information resource and for securing future employment. When asked to explain the role of computers in learning, for example, a non-laptop third grade student indicated: "When my teacher asks a question on the test, I can use the computer to find out the answer." Moreover, some comparison students exhibited ambivalence on the importance of computers in learning. Jose, a fourth grade student, noted: "I do not think computers can help you learn. That is what teachers are for; computers are *just for fun.*" Wilfred agreed with the above comment and added: "Computers might tell you something or show you how to do something but they will not help you understand it. Only the teacher will do that."

Results from focus groups also indicated that all students enjoyed working on computers. Students reported being enthusiastic about using computers to play games, visit different Web sites, or listen to music. Furthermore, all students preferred word-processing on a computer rather than hand writing documents. The third grade laptop students, for example, indicated that they preferred typing than handwriting because computers made it easier to identify mistakes, edit or delete text, and prepare neat documents. They also noted that typing was less labor intensive than handwriting. In addition, fourth grade laptop students indicated that they enjoyed choosing different fonts and colors when using word-processing software because it allowed them to be creative and create professional looking reports.

Besides word processing and playing games, laptop students were also enthusiastic about using educational and productivity software, such as Inspiration, Microsoft PowerPoint, and Timeliner. In fact, when asked to indicate their favorite aspect of using computers, the following conversation transpired among the high-achieving fourth grade laptop students:

> **Diego:** My favorite activity on the laptop is using Timeliner.
> **Researcher:** Why is Timeliner your favorite program?
> **Diego:** Because you can create timelines with all things you did in the past and all things you will do in the future. For example, we even did a timeline on ourselves about our past and future[12].
> **Jen:** I like using laptops to create slideshows and multimedia presentations. You can use the Internet to download pictures and insert them in your presentation.
> **Carlos:** And when you present it [slideshow] to someone, they ask you: "How did you do that?" I also like Microsoft Publisher and FrontPage. You can create news articles and websites. We used it to create our school newsletter.

[12]Students conducted this activity in their classroom. Specifically, the teacher asked them to create autobiographical timelines in preparation of creating author biographies.

The above statements demonstrate that students truly enjoyed using their laptops to complete sophisticated school projects. In fact, students preferred using educational and productivity tools for schoolwork instead of playing games on their laptops. In contrast, when asked to describe their favorite activities on the computer, comparison students provided examples of Internet gaming, chatting, and music sites. Results from focus groups also indicated that increased enjoyment from using laptops to complete schoolwork and develop computer skills positively influenced student attitudes towards school. The fourth grade laptop students explained:

> **Luis:** Before we got the laptops I thought school was a little boring.
> **Stephanie:** We learned the same things everyday. Since we got the laptop we learn different things.
> **Luis:** And we learn more about computers each day.
> **Ashley:** I am so excited to have a laptop.

When asked to report their least favorite aspects of using computers, all students indicated that computers are often slow to respond, they freeze, and crash. Interestingly, the third grade laptop students also reported that they were initially very nervous about using laptops because they knew nothing about computers. Manuel, a third grade student noted: "Initially I felt nervous about having a laptop because I did not know how to use it. I did not even know how to turn it on and I was afraid I will damage it." Furthermore, third grade students indicated that they were concerned about the safety of their laptop such as having it stolen. They explained:

> **Mike:** Sometimes I feel that the laptop is holding me back because when I have it with me, I have to guard it. That's why I don't take it home every day.
> **Kiara:** Yes, we have to watch our backpacks. We can't just leave them on the floor. They look different from the other backpacks and someone might just grab them. At school, they told us that if someone outside grabs our laptop we have to let it go so that we won't get hurt[13].
> **Mario:** There is no way I am giving up my laptop! It's very important to me.

The above comments provide important insights related to the concerns of laptop students in high poverty schools. In fact, student safety was a major concern of the district's superintendent when the laptop program was launched. The school was located in a rough NYC neighborhood and administrators often warned students to put their safety above the safety of their laptops. Yet, Mario's comment shows the value and importance that these students attributed to their laptops.

How did student use of laptop computers support learning processes?

Findings indicated that student use of laptops supported learning in four ways: (a) it increased student motivation and persistence in doing schoolwork;

[13]Despite student concerns, no theft or violence incidents were reported throughout the year.

(b) it facilitated increased interactions with peers and teachers; (c) it empowered students by fostering confidence in their academic abilities; and (d) it fostered academic gains in writing and mathematics *within* the laptop group.

Student motivation

An important outcome of using laptops was increased student motivation and persistence in completing schoolwork. Focus group and teacher interview data indicated that laptop students became more motivated to complete schoolwork and often went beyond required assignments, thereby improving the quality of their work. In one instance, fourth grade laptop students studied the work of *William Shakespeare* by reading an age-appropriate adaptation of *Macbeth*. Subsequently, they created electronic newsletters on various events embedded in the story, such as the murder of King Duncan. Betsy explained that the students *really loved* the project and continued working on it on their own:

> The students were so excited about creating electronic newsletters related to *Macbeth*. They completed outstanding work and we put everything on a bulletin board in our school hallway. Some of the students really wanted to continue working on the project. They went to the library and read other books from Shakespeare on their own. They read *Hamlet* and *Romeo and Juliet* and used their laptops to write entries every time a major event happened in the story. Some students wrote and illustrated poems on their laptops that supposedly Hamlet wrote to his loved ones. So they were doing all these higher-order tasks on their own. There is something about publishing their work on the computer that really excites them and motivates them to keep going further and further. I taught Shakespeare in previous years but this time students really developed a better appreciation of Shakespeare because of their *increased engagement* with his work.

Furthermore, students took the initiative to come up with their own classroom projects that made use of technology. A group of fourth grade laptop students initiated a project where they used the Internet every morning to record the temperature and prepare reports on temperature highs and lows. At the same time, they polled students and created graphs on various topics, such as how many students had a sweater on during a cold day or how many students had a bottle of water with them during a hot day. In another initiative, students conducted their own school polls and generated reports with their findings after reading articles from an online magazine called *TIME for Kids*[14]. Arlene, with much pride, explained this project:

> First we started the project by researching topics of interest such as sports, famous people etc., on the Internet and presenting our findings by acting as reporters. But one day we thought … why should we

[14]TIME For Kids (TFK) is a weekly classroom news magazine packed with stories about world and national events, scientific discoveries, sports, entertainment, kids in the news and more. More than 4 million students read TFK every week.

always be reporting about other people? We should be reporting on things that have to do with *us*. So we conducted surveys with fourth and fifth grade students about improvements they wanted to see at our school. Most of the fifth graders said they wanted pizza on Fridays and ice-cream in the summer. Other kids said they wanted air-conditioning for the summer and soda machines.

The above examples clearly illustrate how use of laptops enabled low-income minority students to go beyond required schoolwork, direct their own learning, and engage in higher-order activities. Many of these activities were refined during after-school hours as students carried their laptops at home. During focus groups, laptop students reported using their laptops frequently at home to improve their homework, practice typing, learn new computers skills, and figure out shortcuts that helped them improve the efficiency in which they performed tasks on the computer. In contrast, comparison students reported using home computers when available primarily for games or to chat online. They indicated a variety of games they liked to play online such as those available through the Cartoon Network, chess, and trading cards.

Classroom Interactions and Empowerment

Findings of the study also demonstrated increased interaction among students and teachers in laptop classrooms. Specifically, laptop students frequently traded skills with other students, shared technology related tips, and served as peer tutors for both technology and non-technology related topics. Lisa emphasized how peer sharing and collaboration was key to the implementation of laptops in her classroom. She noted how students who finished their work would volunteer to help their peers by providing technical or academic support. Betsy also acknowledged the powerful role of laptops in promoting collaboration and sharing. She noted:

> Students are interacting in a much nicer manner when they use their laptops than when they just work on a regular group activity or independently. When we do independent work, it is more difficult to keep them on task. But when they work in groups using their laptops, they behave in a very civilized way, they help each other, and accept that their peers can help them too. Even those students who might not have been looked upon to provide help in areas such as math, they are now asked to participate and provide help with other related skills on the computer.

In addition to trading skills with their peers, laptop students often shared their competencies with their teacher. In fact, both laptop teachers attended training sessions on the use of Web design software along with their students so that they can support each other back in the classroom. In their interviews, teachers acknowledged that over time, they learned to rely on their students for technical support since they were frequently very much quicker in picking up technology skills. In essence, computers helped expose some of the teachers'

own limitations with technology, empowering the students to use their coaching and teaching skills. Joshua, a fourth grade laptop student explained:

> We often *teach the teacher* various technical skills. If she doesn't know something she asks: "How did you do that?" Like the other time, I highlighted and deleted a lot of items at once and she did not know how to do that and I taught her. I was surprised because I really thought she knew how to do it.

Other teachers also began acknowledging student expertise and asking for technical support.

On the contrary, comparison students offered far more limited incidents of helping their peers or the teacher (e.g., correcting something that the teacher wrote on the blackboard). In fact, when asked if they ever taught the teacher anything, a third grade student reported: "I have never taught my teacher anything. When we try to tell him something, he does not really pay attention—he thinks he is smart and does not need our help."

In addition to assisting their peers and other teachers, laptop students were frequently looked upon by family members and friends to provide help with technology. As students explained, they often taught their friends how to use the laptop at home. Acquiring increased technological competence and trading skills with the teacher, as well as their peers, provided laptop students with a sense of pride and empowerment. The fourth grade teacher noted:

> There are some students who are quiet and might not be particularly noticed by other students or teachers. But when they get to their laptop, they showcase a special talent and they get a confidence boost. Consequently, when they get praised and realize that they can help other students, they try even harder.

Will, a lower-achieving fourth grade student, corroborated Betsy's observations when he said: "I feel proud when I teach the teacher something. The teacher is always teaching us, so now I feel like *it is my turn to teach you*." When further asked about how it feels to be a laptop student, Luis, another fourth grader, explained: "I feel really smart because I think laptop classes are for smart kids." Third graders also expressed more confidence in their academic abilities and felt that they would be better off as they progress in fourth grade because of their technology skills and all the things they had learned through the use of their laptops.

Academic Gains within the Laptop Group

Use of laptop computers did not only improve student motivation and altered classroom interactions but it also produced academic gains in writing and mathematics *within* the laptop group. Use of word processing and concept mapping software enhanced writing by: (a) providing assistance with spelling and grammar, (b) helping students communicate ideas more clearly, (c) redirecting attention to the content rather than the mechanics of writing, and (d) enabling the production of longer and more sophisticated writing pieces. Betsy described:

> Student writing improved dramatically over the year. Use of word-processing software keeps students aware of what is going on when they write. It upsets them seeing the green lines highlighting grammatical errors so they go back and try to fix them. Moreover, because use of word-processing software makes it easier to edit, students are more willing to rework their writing. This year, I started providing comments electronically and saving them on student documents. This way, the students could see my comments and rework their writing by adding more details, explaining things better, etc. As we kept going over this technique throughout the year, their writing became better and better.

Lisa, the third grade teacher, also explained that use of word-processing and concept mapping software enabled students to write more detailed and sophisticated pieces. It also motivated students to read their peers' writing because of the legible print. As she noted, there was definitely an increase in both the *quality* and *quantity* of student writing throughout the year.

Students also indicated that use of laptops improved their writing by providing assistance with spelling, grammar, and the mechanics of writing. Fourth grade laptop students reported:

> **Carlos:** Computers help you learn how to spell. If you do not know how to spell a word, you can figure it out very quickly.
> **Diego:** You can just type it the way you know and then look it up using spell-checker. Also, if you spell something wrong, the computer puts a red line underneath and you can right click on it to help you find the correct word.
> **Arlene:** And when you use a pencil, sometimes it is sloppy. On the computer you can edit your work without messing it up.

Besides writing, use of laptops fostered improvements in mathematics. Both Betsy and Lisa explained how extensive use of spreadsheets reinforced student understanding of mathematical concepts, fostered an appreciation for mathematics, and improved their graphing capabilities (e.g., ability to construct and interpret different types of graphs). Lisa explained that graphing became a second nature for her students who became accustomed to constructing graphs using age-appropriate software. Further, Betsy explained that use of spreadsheets in mathematics helped students enhance their understanding of data manipulation and analysis. She indicated that students became very good at comparing different sets of data and formulating questions based on those data.

Focus group data corroborated teacher responses. When asked on the importance of laptops for learning, the fourth grade students explained:

> **Carlos:** Laptops helped us in mathematics. We learned how to use spreadsheets to do graphs—we made a double graph for the science fair that compared findings from the science experiments we conducted this year with findings from last year's fourth grade students.

Researcher: How does making graphs on the computer help you learn more? Can't you use paper and pencil?
Carlos: No it's different. When you make the bars in Microsoft Excel it is easier and more accurate. If you do them on paper, they come out crooked or misleading. They come out perfectly on the computer.
Jen: You can also pick different kinds of graphs like bar graphs or pie charts and can add color to compare data. And when you finish, you can copy and paste the graphs in another program like Word, and then come up with questions and answers related to the graphs.

These findings are significant because low-income minority students rarely have extended opportunities to work on computers for long periods of time to improve their writing and develop higher-order mathematical skills involved in data manipulation.

Given the limited use of computers in non-laptop classrooms, neither the teachers nor the students discussed ways in which technology facilitated academic improvements. Use of computers for word-processing and Internet research did not alter instructional practices or the nature of the classroom environment and teachers were unable to witness clear benefits for their students. Comparison teachers, however, did indicate that word-processing software helped those students who continued to struggle with fine motor skills and often increased their motivation for completing their writing assignments.

DISCUSSION

This study investigated the implementation and outcomes of a laptop program in an urban, under-privileged school. The study focused on a limited number of classrooms in order to provide rich data related to low-income minority student experiences in ubiquitous computing environments. Specifically, the study looked at the ways in which laptops can serve as vehicles for bridging the digital divide and providing low-income minority students with enriched learning experiences. Laptop and non-laptop classrooms were purposely selected to represent a comparable student population that would reveal instructive data. Although, to a great extent, quantitative data did not reveal significant differences in attitudes toward computers and school between laptop and comparison students, they provided crucial insights that can guide future research.

One important insight from quantitative data involved the influence of grade level on student responses. Findings revealed that third graders exhibited higher creative tendencies than fourth graders and more positive attitudes toward school. This finding might be attributed to differences in third and fourth grade curricula and school context. As students progress to higher grades, curricula become more complex and teachers' expectations become higher. Furthermore, fourth graders are under pressure because of high-stakes testing requirements. During the year that the study was conducted, school administrators conducted several extensive test preparation sessions with all fourth graders in the school, often resulting in both teachers and students becoming frustrated. These events limited the amount of time that students could spend on solving problems in

different ways using technology and might have also influenced their overall attitude toward school due to frustration and anxiety. Studies on academic intrinsic motivation which includes school enjoyment and creative tendencies, such as persistence and the learning of challenging tasks, have demonstrated that a controlling school environment and academic anxiety are inversely related to intrinsic motivation (Gottfried, Fleming, & Gottfried, 2001).

Quantitative data also suggested that fourth grade laptop students had more positive attitudes toward school than non-laptop students. This finding was also clearly evident in fourth grade laptop students' qualitative responses. Students appeared enthusiastic about having laptops and reported enjoying school more, since computers allowed them to learn things in different ways and direct their own learning. As a result, they became more motivated, exhibited greater academic engagement, and often went beyond required assignments. This finding has important implications for student learning. While research has demonstrated that motivation declines as students progress to higher grades (Gottfried et al., 2001), it appears that meaningful use of technology can help teachers sustain or increase student motivation. Developing such motivation is important for students' effective participation in school functions and can predict academic achievement as measured by report card grades and teachers' ratings (Gottfried, 1990).

Quantitative data, however, demonstrated that third grade laptop students did not enjoy school more than third grade non-laptop students. It is possible that the anxiety over learning new computer skills and the fear of damaging or having the equipment stolen influenced student responses. This finding suggests that future laptop initiatives with young urban students may need to devote time for technical training to familiarize students with computer equipment. They may also need to articulate security measures to help students feel protected.

Results from qualitative data revealed that in the hands of well prepared teachers who valued the use of technology, laptops enabled students to engage in powerful learning experiences. Laptop students used computers for sophisticated activities that included written expression, preparation of multimedia presentations for an audience, and data analysis and interpretation. These activities not only created enhanced motivation and engagement with schoolwork, but also influenced classroom interactions and created a sense of pride and empowerment among laptop students. Such behaviors were not evident among comparison students. Qualitative data also showed that laptops produced academic gains in areas such as writing and mathematics within the laptop group.

It is worth noting that data for the study were collected during the 2002–2003 year when laptop initiatives were still in their infancy. In fact, Microsoft's Anytime, Anywhere Learning program was the first large-scale laptop initiative in the U.S. Since then, major advances in technology, including pervasive Internet connectivity, provide additional teaching advantages such as increased access to information and resources. Access to information, however, does not automatically result in improved learning opportunities. Specifically, Darling-Hammond (2007) found that while historically underserved groups are getting improved access to information, such access does not translate into more

challenging curricula and activities that emphasize problem-solving and critical thinking. The current study demonstrated *how* access to laptop computers and productivity software can assist well-prepared teachers design activities that allow students to think, write, create, and develop meaningful projects. Such activities have the potential to bridge disparities in educational access present in today's schools.

LIMITATIONS

As with other empirical investigations, this study reflects some limitations. First, the study was conducted in a single school. Students in the school were predominantly minority students from low-income households who had very limited access to technology at home. Therefore, the results of the study may not reflect a larger population with different demographic characteristics and greater exposure to technology at home. Second, neither teachers nor students were randomly selected; laptop teachers had already demonstrated a commitment to integrating desktop technology in their classroom and were enthusiastic about the opportunity to teach in a laptop environment. Thus, results may look different in laptop initiatives where teachers are not given the choice of participation. Third, the lack of pre-test data limits the study from establishing a stronger causal relationship between access to laptops and differentiated outcomes in student attitudes towards computers and school. Finally, the study specifically examines the implementation and outcomes of the laptop initiative during its early stages. Longer-term effects on teaching and learning need to be evaluated in future studies.

CONCLUSION

Laptop programs represent an important class of initiatives in the field of educational technology because of their increased popularity and their potential to bridge the digital and didactic divide that currently exists in schools. As a result, a better understanding of *how, when,* and *to what degree* they work to support student learning, particularly with student populations that have not received much attention to date is needed. Research studies, like the one undertaken here, that link laptop implementation strategies to specific student attitudes and outcomes can enhance the effectiveness of laptop programs and their potential to provide low-income minority students with enriched, authentic learning experiences and skills needed to live and work in the 21st century. As this work demonstrated, ubiquitous access to technology and access to well-prepared teachers who value the experiences that technology offers can help ensure equality of digital opportunities among less advantaged students.

Future studies will need to include a larger population of teachers and students involved in the implementation of laptop programs in urban schools to further investigate the conditions under which such programs can help bridge the digital divide in education. Such studies should also focus on developing more reliable data collection instruments that measure young children's attitudes toward technology as well as reliable assessments that can better capture cognitive gains among students in laptop classrooms.

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