inTASC

Technology and Assessment Study Collaborative

**Laptop Learning:
A Comparison of Teaching and Learning
in Upper Elementary Classrooms
Equipped With Shared Carts of Laptops
and Permanent 1:1 Laptops**

Michael Russell, Damian Bebell, and Jennifer Higgins
Technology and Assessment Study Collaborative
Boston College
332 Campion Hall
Chestnut Hill, MA 02467

www.intasc.org

Laptop Learning: A Comparison of Teaching and Learning in Upper Elementary Classrooms Equipped With Shared Carts of Laptops and Permanent 1:1 Laptops

Michael Russell, Damian Bebell & Jennifer Higgins
Technology and Assessment Study Collaborative
Boston College

Introduction

Over the past decade, the student to computer ratio has become the accepted proxy measure of students' access to computers in school. Believing that increased access to computers in schools will lead to increased use of computers, educational leaders have gradually reduced target student to computer ratios. In turn, the ratio of students to computers has dropped dramatically from 125:1 in 1983 to 9:1 in 1995, 6:1 in 1998, and 4:1 in 2002 (Market Data Retrieval, 1999; Education Week, 2003).

While use of computers in schools has increased over this same time period, students currently report using computers in schools for a small amount of time each day (Cuban, 2001; Russell, O'Brien, Bebell, & O'Dwyer, 2003). Two explanations are often provided for why use of computers has increased at a relatively slow rate despite the dramatic decrease in student:computer ratios. The first explanation focuses on the need to prepare teachers to integrate technology with their instructional practices (Milken Exchange on Education Technology, 1999). In response to this need, the U.S. Department of Education has launched several efforts to prepare pre-service and in-service teachers to use computers for instructional purposes. As two examples, the Preparing Tomorrow's Teachers for Technology (PT3) program was launched in 1999 and has provided more than 400 grants to institutions that work with pre-service teachers. To assist in-service teachers, the most recent round of technology funding provided by the federal government to state agencies requires that a minimum of 25% be invested in professional development for teachers (Bailey, 2003).

The second explanation for the slow increase in computer usefocuses on challenges presented by the ways in which computers are distributed within a school set-

ting. Despite relatively low student:computer ratios, in many middle and high schools computers are removed from the classroom setting and are instead located in labs and the library, which make access during class time difficult. In contrast, elementary schools often place computers directly in the classroom, but at a ratio that requires teachers to rotate students on and off computers in order to provide all students with access. Despite the many ways in which computers can be distributed within schools, some observers theorize that the disjuncture between the dramatic increase in the presence of computers in schools and relatively stagnant student use results, in part, because student:computer ratios have not yet reached a stage at which the technology is pervasive or ubiquitous (Bull, Bull, Garofolo, & Harris, 2002; Papert, 1996; Rockman, 1998). To make access to large numbers of computers more pervasive, some schools place large numbers of portable computers on a cart which can be brought into classrooms to create a 1:1 environment on a temporary basis. Still other schools have fully committed to ubiquitous computing by providing each student with full-time access to a laptop.

Experiments to provide computers to students at a 1:1 ratio began in 1989 when the Methodist Ladies College in Melbourne Australia required all incoming students in grades 5 through 12 to purchase a school-approved Toshiba laptop. Similar programs were adopted by other Australian schools and by the late 1990's over 50,000 Australian children were reported to have their own laptop computer (Stager, 1998).

Within the United States, several schools experimented with laptop programs during the 1990's. Typically, these programs were funded through special fund raisers (Stevenson, 1999), local foundations and grants (Cromwell, 1999), and increases in tuition at private schools (Thompson, 2001). More recently, Henrico County School District (VA) has experimented with 1:1 laptops at a variety of grade levels while the state of Maine has launched a state-wide laptop program in which all students in grades 7 and 8 have been equipped with an Apple iBook.

Although much of the research on laptop programs is still on-going, anecdotal evidence and findings from program evaluations report several positive outcomes. These outcomes range from increased student engagement (Cromwell, 1999; Rockman, 1998; MEPRI, 2003), decreased disciplinary problems (Baldwin, 1999, MEPRI, 2003), increased use of computers for writing, analysis and research (Cromwell, 1999; Baldwin, 1999; Guignon, 1998), a movement towards student-centered classrooms (Rockman, 1998), and an increase in standardized test scores (Stevenson, 1999). Baldwin (1999) also documented that the outcomes also affect student behaviors at home such that students reported spending less time watching television and more time on homework after they were provided with laptops.

Despite these positive outcomes, most of these early findings are based on anecdotal evidence rather than systematic research. In the remainder of this paper, we present findings from an intensive study that focused on two types of classrooms located in South Elementary School. The first set of classrooms shared a cart of laptops that was brought into a classroom for a one-week period once every five weeks to create a temporary 1:1 environment. The second set of classrooms provided each student with his/her own laptop on a permanent basis. Thus, this study compared teaching and learning in settings that create a 1:1 laptop environment on either a temporary or permanent basis. This paper provides a brief background to the study, an overview of

the research methodology, and then summarizes and discusses the primary findings. A more detailed report is available at www.intasc.org.

Study Background

South Elementary School is located in Andover, Massachusetts, an affluent suburb located 20 miles north of Boston. During the 2000-01 school year, the district provided the school with a cart of 30 laptop computers which was shared among all fourth and fifth grade classrooms. To increase the time teachers were able to use the laptops, the cart was brought into each classroom for a one-week period. In addition, all teachers met once a week with a technology resource leader to learn how to use the laptops, troubleshoot problems, and integrate technology into their curriculum. That year, the principal conducted an experiment in which one classroom was allowed to keep the laptops for a longer period of time. During this time period, a notable increase in technology use was observed. In an effort to provide each student with his/her own laptop while remaining within a tight budget, the principal developed a voluntary parent purchase program. For those parents who could not afford a laptop, a fund was established which allowed any family that wished to participate to receive a free laptop computer.[1] Since this program was voluntary, not all parents opted to have their children participate. Nonetheless, a sufficient number of families participated so that two fourth grade classrooms were provided with a permanent 1:1 laptop environment during the 2001-02 year. At the start of the 2002-03 school year, those fourth graders who had participated in the laptop program brought their laptops to fifth grade and all incoming fourth graders were offered to participate in the program. Since the program was optional, two fourth and two fifth grade classrooms had 1:1 laptops during the 2002-03 year, while the five remaining classrooms continued to share a cart of laptops on a weekly basis.

Every classroom was equipped with a printer, while the shared laptop classrooms had three stationary desktop computers. In addition to the hardware, the school also formed a network of participating parents, which offers technical support to students at home via phone, email, and home visits. The district provides computer support and offers professional development programs for all of the teachers, including bi-weekly technology reflections at faculty meetings. The principal was curious whether teaching and learning differentiated between the two settings. Therefore, she invited the authors' research team at the start of the 2002–2003 school year to conduct an independent study of the two strategies for providing students with access to laptops.

Methodology

Since the laptops were already in the hands of the students, it was not possible to examine the effects of the technology utilizing a pre-post research design. Instead, the study focused on comparing differences in instructional practices and learning activities experienced by students in classrooms that were permanently equipped with laptops and those that shared a cart of laptops. In total, 209 students located in 9 classrooms participated in the study. Four of the classrooms participated in the parent purchase program and five shared a cart of laptops.

Data Collection

To document instructional practices and learning activities in the two settings, four types of data were collected. Between March and April of 2003, fifty-six classroom observations were conducted.[2] During the observations, students' engagement level, the number of students working with technology, the number of students working independently, in pairs, in small groups, or in large groups and the role of the teacher was recorded every ten minutes via an observational checklist. In addition, observers recorded narrative accounts of the activities occurring throughout the one hour observation period, with a specific emphasis on teacher-student interactions, student-student interactions, uses of technology, and student engagement. At the end of each observation, a detailed summary of the observation was also produced.

In addition to the classroom observations, teachers were interviewed using a semi-structured interview protocol that focused on several issues related to the use of technology in his/her classroom. All two hundred and nine students also completed a survey that focused on students' specific uses of technology in school and at home, their teacher's use of technology in the classroom, as well as demographic information. Finally, to provide further insight into students' writing processes, students responded to the following drawing prompt: "Think about the work you do in your classroom. In the space below, draw a picture of yourself writing in school."

Analyses

Classroom observations were analyzed using three techniques. First, three readers who were blind to the focus of the research read the observation studies and were asked to identify patterns or trends within each of the classrooms as well as across the classrooms. In addition, the "blind" readers were asked to describe how the classrooms were similar and/or different in terms to teaching and learning activities.

To objectively quantify and summarize the observation notes and teacher interviews, content analyses of all observations and interviews were performed independently. Specifically, an emergent analytic coding procedure was used to identify key events and behaviors described in the observation notes. After creating formal definitions for each content code and establishing that the 102 specific codes could be applied with an adequate level of reliability, all observation notes were coded.

Finally, the data collected via the fixed interval observation checklists were analyzed to examine differences in the way in which students were grouped, the roles teacher played in the classroom, the level of student engagement, and the number of students working with technology. For each category of data collected via the ten-minute checklist, means were calculated across all observations within each classroom and classroom setting.

Student survey responses were summarized at the group level (i.e., 1:1 laptop and shared cart) and independent sample t-tests were employed to examine differences at the item level between the two groups. In the presentation of findings, all reported differences were statistically significant at the .05 level.

The student drawings were coded using an emergent analytic coding framework that had been used in previous research (Russell, Bebell, Cowan, & Corbelli, 2003).

The specific features that were coded fall into four broad categories: 1) Student Characteristics (what the students were doing); 2) Technology Present (type of technologies depicted); 3) Student Demeanor (whether the student was depicted positively, negatively, or neutral), and; 4) Other Features, which included the presence of the teacher, other students, or classroom decorations.

Findings

Below, we present five primary findings that resulted from the investigation of differences in teaching and learning between two classroom types: one classroom type shared a cart of laptops which allowed teachers to provide laptops for every student one in every five weeks, while the other classroom type had 1:1 full access to laptop. For ease of reference, classrooms that shared a cart of laptops will be referred to as "shared classrooms". Classrooms that were equipped with one laptop per student on a permanent basis will be referred to as "1:1 classrooms".

Technology Used More Frequently in 1:1 Classrooms

The classroom observations, teacher interviews, and student surveys all indicated that technology use by students and their teachers was significantly higher in the 1:1 classrooms as compared to the shared classrooms. Although increasing access to technology to the point where each student has his or her own laptop in school would expectedly lead to increased technology use, the magnitude of the difference in technology use was dramatic. Whereas students in the shared classrooms reported using computers during class time for between "15 minutes or less" and "15 to 60 minutes" a day, students in the 1:1 classrooms reported using technology between "1-2 hours per day" and "2+ hours per day."

This difference in the amount of use during class time was also evident in the classroom observation data. Checklist data and content analysis of the observation narratives corroborate that technology use in the 1:1 classroom was far greater than the use in the shared laptop classrooms. Table 1 summarizes the mean number of times that a code related to technology was applied to the classroom observations within the 1:1 and the shared classrooms. For example, a value of 3.2 indicates that, on average, the observation narrative referenced that specific phenomenon 3.2 times per hour long observation.

In general, Table 1 indicates that students in the 1:1 classroom were much more likely to be observed using their laptops than students in the shared classrooms. On average, observers recorded an event that involved technology 33 times per observation when in the 1:1 classrooms. In contrast, events involving technology were recorded fewer than five times per observation, on average, in the shared classrooms.

Table 1   Comparison of Mean Application of Technology Code Per Observation

	1:1 Laptop Classrooms	Shared Laptop Classrooms
Teacher Technology Codes		
Directions related to technology	4.11	0.46
Technical assistance	1.78	0.38
Other involving technology	1.67	0.69
Conferencing with ind. students w/technology	1.56	0.31
Assigning work related to technology	1.39	0.15
Discussing technology with whole class	0.22	-
Aide working individually w/student w/technology	0.17	0.08
Conferencing with groups of students w/technology	0.11	-
Aide providing technical assistance	0.06	-
Other involving technology at home	0.06	-
Individual Student Technology Codes		
Other laptop	6.61	0.88
Working on the web	4.22	0.46
Composing text on a laptop	3.39	0.08
Using laptop at their desk	1.00	-
Printing work	0.94	0.12
Saving work to the server	0.72	0.15
Other involving technology	0.44	0.08
Presenting to class w/technology	0.44	-
Editing text on laptop	0.17	-
Taking laptop out of the room	0.17	-
Printing CD ROM/Web resources	0.11	-
Testing/quizzing using technology	0.11	-
Using laptop in other part of room	0.11	-
Composing text on a desktop computer	0.06	0.12
Transcribing text from paper to laptop	0.06	0.04
Other desktop	-	0.15
Transcribing text from paper to desktop	-	0.23
Student-to-Student Technology Codes		
Peer conference/work with work displayed on laptop	1.89	0.15
Other laptop	1.22	0.04
Working in groups on project assignment-no writing- w/ technology	0.33	0.04
Providing technical assistance	0.28	0.08
Sharing web/CD ROM sources	0.22	-
Other involving technology	0.06	0.12
Peer conference/work w/work printed from desktop	-	0.04
Technology Index (Sum across codes)	33.67	4.85

In addition to the number of times technology-related events occurred in the classrooms, the observation notes also document the variety of ways in which teachers and students in the 1:1 laptop classrooms used computers. As a few examples, the observation notes documented laptops being used for a variety of purposes across the curriculum:

"The teacher then tells the class that their next assignment, for the next 20 minutes, is to draw their own picture of the solar system on Appleworks. Students use the internet and books as references to their drawing."

"Students are reading a news story on the Internet about the war in Iraq. The teacher instructs the students to go to another site about British Prime Minister Tony Blair and protests over the war in England."

"The teacher tells students to copy and paste the questions in Microsoft Word. She gives the students a minute to do this. Students quickly and easily copy and paste the website in Word. The majority of students are having a very easy and comfortable experience on the Internet, Word, copy and paste, and answering questions directly on the laptop."

Student surveys also provide evidence of more frequent technology use in the 1:1 classrooms as compared to the shared classrooms. As depicted in Figure 1, students in the 1:1 classrooms reported significantly higher levels of technology use across all subject areas. For example, students in the shared laptop classrooms reported using computer during science about "once a month" compared to somewhere between "once a week" and "every day" for the 1:1 students – a difference that represents between 4 and 12 times more frequent use.

Figure 1   **Mean student school computer use by subject area.**
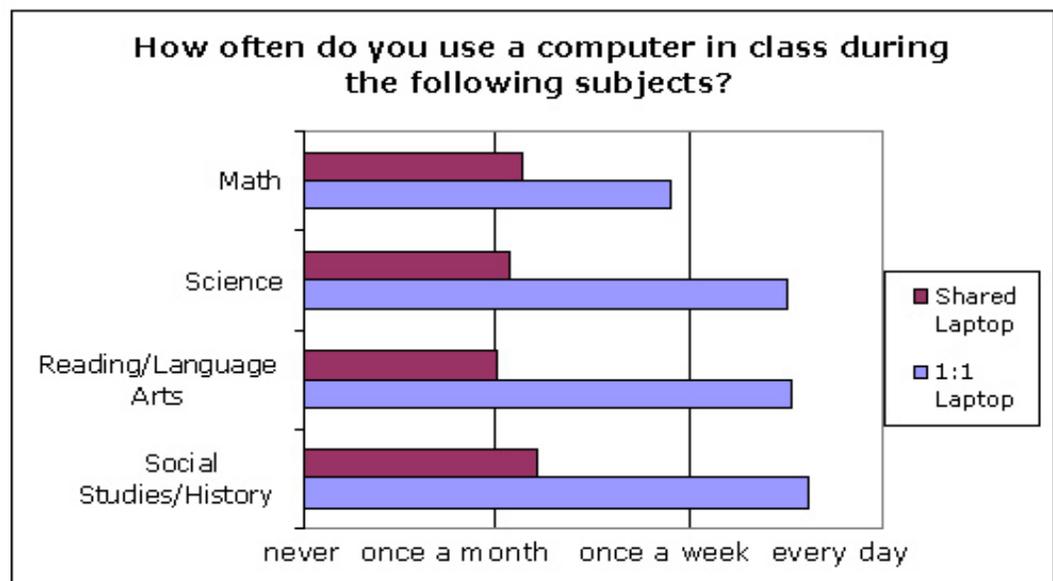
Analysis of teacher interviews also provides evidence of more frequent computer use in the 1:1 classrooms. When asked about the frequency with which students use technology, all of the 1:1 classroom teachers indicated that the increase in technology access has led to more student technology use. One of the 1:1 classroom teachers replied that "The ways in which they use technology are much more in depth: for presentations and note-taking they use PowerPoint, word processing is almost constant, the Internet has a much larger presence for science, social studies, and math. The instant gratification of available information has given the term research a whole new meaning for my students." When asked the same question, one of the shared classroom teachers did not respond, one stated that their students used technology more (with the shared laptop cart) than before, and the third respondent told the interviewer that some students in their class still never use the laptops.

Motivation and Engagement Was Higher in the 1:1 Classrooms

Student engagement is often defined by the degree to which students are on-task or by "students' willingness to participate in routine school activities" (Chapman, 2003, p. 1). Results from the checklist data, classroom observations, and teacher interviews provide evidence of higher levels of student engagement in the 1:1 classrooms as compared to the shared classrooms. On a scale that ranged from 1 (no engagement) to 5 (high engagement), mean level of engagement for students in the 1:1 classrooms was 3.8 as compared to 3.3 in the shared classrooms, a difference that is statistically significant at the .05 level (t=4.72, df=257, p<0.001).

The content analysis of the observation notes also indicated that engagement levels were higher in the 1:1 laptop classrooms. On average, observations in the 1:1 classrooms contained 6.1 references to student engagement and 4.8 references to disengagement per observation. In contrast, observations in the shared classrooms contained 4.9 references to engagement and 5.2 references to disengagement. Although these differences are relatively small, they are consistent with the other data sources.

When asked about increased engagement, one 1:1 classroom teacher responded: "Absolutely. Students appear more motivated and interested in assignments on the computer." Additionally, all four of the 1:1 laptop teachers as compared to only one of the three interviewed shared classroom teachers indicated that special education students were also more engaged. One laptop teacher also reported that increased laptop access had "leveled the playing field" between the special education students and the non-special education students.

Computers Were the Students' Primary Writing Tool in the 1:1 Classrooms

The classroom observations, student drawings, and teacher interviews all provide evidence that students in the 1:1 classrooms viewed laptop computers as their primary writing tool. In addition, analysis of observation data, student survey data, and teacher interview data provide evidence that the amount of time students spend writing was larger in the 1:1 classrooms as compared to the shared laptop classrooms. As seen in Table 2, students in the 1:1 classrooms were observed composing text on laptop computers more frequently than the students in the shared classrooms. Specifically, the 1:1 classroom observations had an average of 3.39 instances per observation where

the observer recorded at least one student composing text on a laptop compared to an average of 0.08 for the shared laptop classrooms. Interestingly, students in the 1:1 classrooms were also observed composing text on paper slightly more often than those students in the shared classrooms, with respective means of 0.44 and 0.58. Table 2 also shows that students in the 1:1 classes were nearly six times more likely (3.39/0.58 = 5.8) to be observed composing text on a laptop than with paper and pencil. Conversely, students in the shared laptop classroom were eight times more likely to be observed composing text using paper and pencil than with a laptop.

Table 2   Mean Number of Times Students Observed Composing Text Per Observation

	Shared Laptop	1:1 Laptop
Composing text on laptop	0.08	3.39
Composing text on paper	0.44	0.58

Student drawings also provide evidence of differences in student writing between the two classroom types. As seen in Table 3, the differences between the 1:1 and shared classrooms are striking. Specifically, 90.9% of the 1:1 laptop students depicted themselves writing using a laptop computer and 1% using a desktop. In the shared laptop classrooms, only 8.6% of students depicted themselves using a laptop and 2.9% using a desktop. Similarly, 86.7% of the shared classroom student drawings depicted students writing with a pencil compared to 8.1% of the 1:1 classroom drawings. The proliferation of laptop computers in the 1:1 computers is also observed in the codes related to the different technologies present in the drawing (technology that is depicted in the drawing, but not necessary in use). Here, 91.9% of the 1:1 laptop students depicted a laptop computer somewhere in their drawing compared to 8.6% of the shared classroom drawings. In other words, when asked to depict writing, students in the 1:1 classrooms were over ten times more likely to depict laptop computers than students in the shared laptop classroom.

Table 3   Comparison of Writing Tools Depicted in Student Drawings

Characteristic	1:1 laptop	Shared laptop
Student at desk	90.9%	95.2%
Student writing with pencil	8.1	86.7
Student writing with laptop	90.0	8.6
Student writing with desktop	1.0	2.9
Paper present	8.1	86.7
Pencil present	7.1	86.7
Laptop present	91.9	8.6
Desktop present	1.0	4.8

In addition, teachers remarked in the interviews that students tended to write more text and higher quality text with laptops than when they use pencil and paper. One 1:1 classroom teacher stated:

"The volume of writing has increased in all areas of the curriculum. Written responses are neater and easier to read legibly. Teaching process writing has progressed more quickly in my opinion because of the rate at which students are able to process their ideas in an aesthetically pleasing and organized way that lends itself to more efficient revising and editing."

Classroom Structure Differed Between the 1:1 and Shared Classrooms

Past research suggests that interactions amongst students and between students and their teacher differ when technology is made available at a 1:1 ratio (Russell et al, 2003; Rockman, 1998). In the study presented here, the observation checklists, content analysis of observations, and teacher interviews all provide evidence that student-teacher interactions, student-student interactions, as well as the way in which classroom activities were structured differed between the shared and 1:1 classrooms.

As seen in Figure 2, students in the 1:1 classrooms were observed working alone more often than in large groups, small groups, or in pairs. Conversely, students in the shared laptop classrooms were observed more often working as a large group than alone, or in small groups or pairs. Figure 2 also shows a significant difference between the percentage of students (averaged across all observations) that were observed working alone in the 1:1 classrooms as compared to the shared laptop classrooms. This data suggests that learning activities were most often structured in an individual format in the 1:1 classrooms and most often structured in a large group format in the shared laptop classrooms.

Figure 2   Percent of students observed working in various group sizes
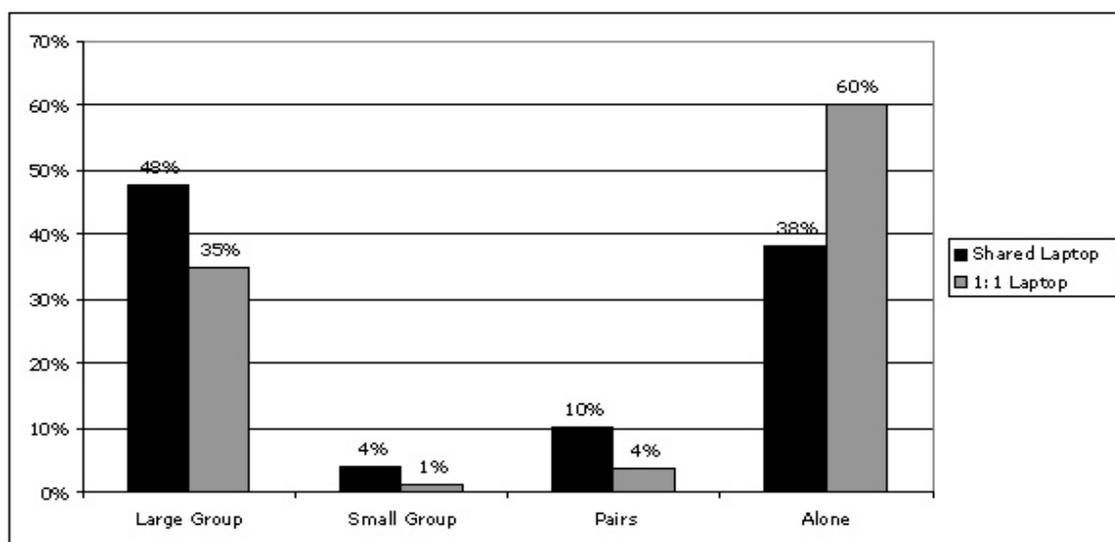
Content analysis of observation notes also reveals differences in classroom structure. As displayed in Table 4, instances of teacher led whole class discussion were observed more frequently in the shared classrooms than in the 1:1 classrooms with respective mean values of 5.86 and 3.06. In other words, teachers in the shared classrooms were observed nearly two times more frequently teaching in a whole group format than the 1:1 classroom teachers. Students in 1:1 classrooms were also observed peer conferencing nearly two times more frequently than students in the shared classrooms, with respective values of 2.78 and 1.73.

Table 4 **Mean Number of Times Whole Class Discussion and Peer Conferencing Were Noted in Classroom Observations Compared Across Setting**

	Shared Laptop	1:1 Laptop
Whole class discussion	5.86	3.06
Peer conferencing with work displayed on paper or with work displayed on laptop	1.73	2.78

Although the 1:1 classrooms contained five more students, on average, than the shared laptop classrooms, two of the three 1:1 classroom teachers reported that they were more able to individualize instruction with full access to technology. As one teacher described, "the complexity of the world wide web helps me differentiate students' individual learning needs as the group can easily work on a number of different activities." Also in the interviews, each of the 1:1 classroom teachers included comments about how 1:1 technology allowed students to learn more independently, cooperatively, and collaboratively than through traditional instruction.

The observation analysis provides confirmatory evidence that classroom practices differed between the 1:1 and the shared classrooms. Specifically, students in the 1:1 laptop classes were observed using their laptops as a peer conferencing tool and presenting their work to the class more frequently than shared classroom students. Also, students in the 1:1 classrooms were observed working independently more frequently than students in the shared classrooms.

Students in the 1:1 Classrooms Used Computers at Home More Frequently for Academic Purposes

As seen in Figure 3, student survey results indicate that students in the 1:1 classrooms reported using their home computers slightly more frequently for personal activities (music, email, chat, games), and significantly more frequently for school work than students in the shared classrooms despite nearly universal home access to technology. With respect to personal uses of computers, students from both classrooms reported that they spent more time playing games than any other use. Interestingly, for students in the shared laptop classrooms, the second most frequent use of home computers was for searching the Internet for fun. For these students, use of home computers to search the Internet for school, write papers for school, emailing, chatting, and downloading music occurred with nearly the same frequency. In contrast, students in the 1:1 classrooms reported that the second most frequent use

of their home computer was to search the Internet for school related work, followed closely by searching the Internet for fun and writing papers for school. Home use of computers for emailing, chatting, and downloading music was reported to occur with noticeably less frequency in comparison to these more academic uses. Thus, it appears that students who were provided with permanent access to a laptop in school not only use computers more frequently in the classroom, but also use computers at home for school related purposes more frequently than students in the shared laptop classrooms.

Figure 3   Comparison of mean student home computer uses.
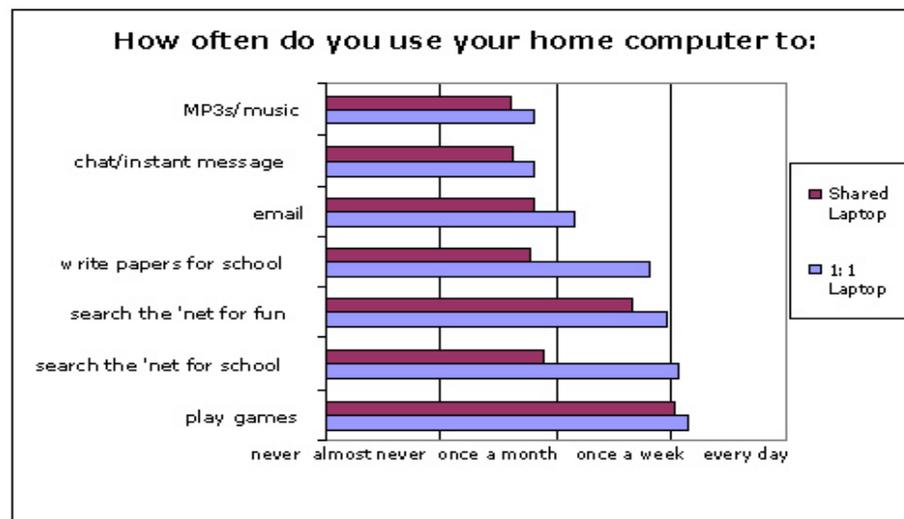
Discussion

As schools struggle to increase student access to technology without overstraining limited budgets, sharing carts of laptops among multiple classrooms has become a popular strategy for creating 1:1 access in classrooms on a temporary basis. The study presented here examines the extent to which this strategy provides a technology-rich learning environment that is comparable to a setting in which students are provided with their own laptop on a permanent basis. Although this study focuses on a limited number of classrooms in a single school and does not employ a pre-post experimental design, to the best of our knowledge, this study is the first attempt to directly compare teaching and learning activities in classrooms that provide 1:1 computing environments via these two strategies.

Beyond the focus of the research, this research is unique in several ways. The study was initiated by the school principal who contacted the authors in early 2002 seeking empirical data that could be used to compare teaching and learning between the two classroom environments. To examine differences in teaching and learning activities across the two settings, the study employed mixed methodologies that included classroom observations, teacher interviews, student surveys, and student drawings. Neither teachers nor students were randomly assigned to the 1:1 laptop classrooms,

which presents one limitation of this study. Rather, parents were given the option to have their child be part of the full laptop access classrooms. Parents who chose to have their child participate in the 1:1 laptop classrooms either bought their child a Toshiba laptop ($1800) a or applied for school based grant funding (no family was turned away). Of the $1800 investment, $200 was used to support one full time technology specialist who supported the use of the laptops and other hardware and software across both the 1:1 and shared laptop classrooms. In addition, all teachers attended district level professional development related to technology and twice a month used their faculty meetings to talk exclusively about technology issues. It is also noteworthy that the laptop computers were owned by the students, not the school, and that students were required to charge their batteries at home each night. To facilitate and support the students' use of the laptops at home, the parents formed a support network that provided technical assistance to other parents and students outside of school via phone, email, and home visits.

Clearly this research is not a study concerning a simple increase in students' computer access. The environment in which the 1:1 laptop and shared laptop classrooms was introduced shared many important characteristics including strong principal vision and leadership and due consideration for technology support, development and curriculum integration. In addition, the 1:1 laptop classrooms served students whose parents and teachers were enthusiastic about and committed to 1:1 computing. It is also important to note that although students in the shared laptop classrooms had less regular access to technology in their classrooms than their peers in the 1:1 laptop classrooms, the shared laptop students had more technology access than the majority of their peers in typical public elementary schools (Education Week, 2003).

As described above, the analyses provide evidence that when full versus shared access to laptops is provided, technology use for a variety of academic purposes increases significantly. In addition, student engagement increases, the amount of time students spend writing increases, and classroom interactions between students and teachers change. These results are consistent with prior empirical studies that indicate that full computer access is associated with increased technology use (Russell et al, 2003; MEPRI, 2003), a change in classroom structure (Russell et al, 2003; Rockman, 1998), and increases in student motivation and engagement (Rockman, 1998, MEPRI, 2003). In addition to these findings, this study provides evidence that, despite access to home computers by nearly all students, the extent to and ways in which students use technology at home also differs such that students in the 1:1 classrooms report using home computers more often for academic purposes.

Although the findings presented here do not focus on the effect of technology use on student learning, the findings have important implications for research that examines technology use and the relationship between use and student achievement. Both Cuban (2001) and Oppenheimer's (2003) work suggest that even though students' access to technology has increased over the last decade, technology is often not widely used. Cuban finds that during the past two decades "most teachers and students now have far more access than previously, but classroom use continues to be uneven and infrequent" (Cuban, 2001, p. 93). It is important to emphasize, however, that none of the classroom environments studied by Cuban or Oppenheimer begin to approximate the ubiquitous access provided in the classroom examined in the present study.

As seen in the study presented in this paper, use in a supportive environment and a relatively high access setting (i.e., 3 desktop computers permanently in the room plus a cart of laptops that is brought into the classroom for a one week period once every five weeks) resulted in relatively limited student use. However, in classrooms with full access to laptops on a permanent basis, student use rises to a level that is likely to result in increased learning across a variety of curricular areas.

Similarly, to date much of the research that has focused on the effect of technology on student learning has been conducted in settings that provide students with limited access to technology (Angrist and Lavy, 2001; Oppenheimer, 1998; Mann, 1999). In a highly publicized research study, Angrist and Lavy (2001) use data from 1996 to examine the relationship between student:computer ratios and student achievement. In addition to not actually measuring the extent to which students used technology, it is noteworthy that the schools designated as the high access schools were equipped with computers at a 10:1 ratio. The results of the study show no effect between computers and achievement. However, it is not surprising that technology, or any other academic resource, spread so thinly across students would have a negligible impact on student achievement. Looking to the future, rather than undertaking research that focuses on technology use and student achievement in relatively low access and low use settings, it seems prudent to focus this research on high access settings where the technology is pervasive. To this end, we are currently conducting research in the South Elementary classrooms that focuses on effects of computer use on student achievement as measured by the state tests and a local writing assessment

It remains to be determined what effects the high levels of use in the 1:1 classrooms studied here have on student achievement. Nonetheless, the study presented here provides further evidence that teaching and learning activities differ substantially in classrooms that are permanently equipped with technology at a 1:1 ratio. Despite the limitations of this study, the findings warrant further investigation into the effects of permanent 1:1 laptops on teaching and learning activities, while also calling into question research that focuses on the effects of technology on student achievement in settings where use is relatively limited in comparison to the 1:1 laptop classrooms studied here.

Endnotes

1 No families that wished to participate in the program were denied access due to financial constraints.

2 As described more fully in the full report, twelve of these observations occurred when a substitute was in the classroom. Since instructional practices differed when the substitute was present, these twelve observations are excluded from the presentation of findings that follows.

References

Bailey, J. (2003). Follow the roadmap to federal funds. *Scholastic Administrator.* Retrieved on December 11, 2003 from http://www.scholastic.com/administrator/backtoschool/features.asp?article=fedfund

Baldwin, F. (1999). Taking the classroom home. Appalachia, 32(1), 10-15.

Cromwell, S. (1999). Laptops change curriculum -- and students. *Education World.* Retrieved November 6, 2003 from www.education-world.com/a_curr/curr178.shtml

Cuban, L. (2001). *Oversold and underused.* Cambridge, MA: Harvard University Press.

Glennan, T. K., & Melmed, A. (1996). *Fostering the use of educational technology: Elements of a national strategy*. Santa Monica, CA: RAND.

Goldberg, A., Russell, M., & Cook, A. (2003). The effect of computers on student writing: A meta-analysis of studies from 1992 to 2002. *Journal of Technology, Learning, and Assessment, 2* (I). Available from http://www/jtla.org

Guignon, A. (1998). Laptop computers for every student. Education World. Retrieved November 6, 2003, from http://www.education-world.com/a_curr/curr048.shtml

Mann, D., Shakeshaft, C., Becker, J., & Kottkamp, R. (1999). *West Virginia's Basic Skills/Computer Education Program: An Analysis of Achievement.* Santa Monica, CA: Milken Family Foundation.

Maine Education Policy Research Institute. (2003). The Maine Learning Technology Initiative: Teacher, Student, and School Perspectives Mid-Year Evaluation Report. Retrieved November 6, 2003 from http://www.usm.maine.edu/cepare/pdf/ts/mlti.pdf

Milken Exchange on Education Technology. (1999). Will new teachers be prepared to teach in a digital age? A national survey on information technology in teacher education. Santa Monica, CA: author. Retrieved March 28, 2003, from http://www.mff.org.publications.

National Commission of Excellence in Education. (1983). A nation at risk: The imperative for educational reform. Washington, DC: U.S. Government Printing Office.

Papert, S. (1996). *The connected family: Bridging the digital generation gap.* Atlanta, GA: Longstreet Press.

Rockman et al. (1998). Powerful tools for schooling: Second year study of the laptop program. San Francisco, CA: Author.

Russell, M., Bebell, D., & O'Dwyer, L. (2003). *Use, support, and effect of instructional technology study: An overview of the USEIT study and the participating districts.* Boston, MA: Technology and Assessment Study Collaborative. Available for download at http://www.intasc.org/PDF/useit_r1.pdf

Russell, M., Bebell, D., Cowan, J. & Corbelli, M. (2003). An Alphasmart for each student: Do teaching and learning change with full access to word processors? *Computers and Composition,* 20, 51–76.

Russell, M., O'Brien, E., Bebell, D., & O'Dwyer, L. (2003) Student's Beliefs, Access, and Use of Computers in School and at Home. Boston, MA: Boston College, Technology and Assessment Study Collaborative.

Stager, G.S. (1998). Laptops and learning: can laptop computers put the "C" (for constructivism) in learning? Curriculum Administrator. Received on November 6, 2003 at: http://www.stager.org/articles/CAlaptoparticle.html

Stevenson, Ken. (1999). Learning by laptop: An experiment that allows students to tote their own terminals yields better attitudes and academic gains. *The School Administrator – Web Edition.* Retrieved November 6, 2003, from http://www.aasa.org/publications/sa/1999_04/stevenson.htm

Thompson, Bob. (2001, September 16). Learning to be wired. *Washington Post Magazine.* Available from http://www.washingtonpost.com/wp-adv/archives/front.htm

Direct Reprint Requests to:

Michael Russell