A More Complex Picture:
Laptop Use and Impact
in the Context of Changing Home and School Access

The third in a series of research studies on
Microsoft's Anytime Anywhere Learning Program

Submitted by

ROCKMAN *ET AL*
San Francisco, CA

June, 2000

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Acknowledgements

We gratefully acknowledge the extensive cooperation and support of the many people who have made this evaluation possible. We especially thank the Laptop Program coordinators and teachers from the laptop schools and the faculty, administration and students at the sites where we conducted the bulk of our research. While these schools must remain nameless, given our promises of anonymity to the administrators, faculty and their students, we owe them a substantial debt of gratitude. They exhibited great patience and offered much assistance as we went about our data collection efforts.

We also want to thank the members of the ROCKMAN *ET AL* staff and consultants who assisted us in planning and designing the research, and gathering and analyzing data, with a special nod to Michelle Weissman.

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EXECUTIVE SUMMARY

ROCKMAN *ET AL* is an independent research organization in San Francisco that for the past three years has been conducting an evaluation of Microsoft's Anytime, Anywhere Learning Program. Each student in the "Laptop Program" acquired a laptop computer loaded with Microsoft Office software, and their teachers received training on how to integrate technology into the classroom. Research on the first year experiences of the pioneer schools focused on the many challenges and successes of program implementation. During the second year of the study, ROCKMAN *ET AL* focused on the range of the Laptop Program's impacts on teaching and learning. During the third year of the Laptop Program, ROCKMAN *ET AL* continued to examine impacts on teaching and learning within laptop classrooms, and especially the ways in which laptops might be supporting a more constructivist pedagogy. ROCKMAN *ET AL* was also asked to focus on the possible impact of students' full-time laptop access on standardized test scores.

School selection for the third year of the study was based on the availability of these test scores. Our initial sample of 13 schools at 12 different sites yielded useful and reliable data from eight sites. More than 450 students and almost 50 teachers participated in one or more elements of the research. Our research also included a smaller group of matched students and teachers, in which matched Laptop and Non-Laptop groups came either from the same school (internal matches) or from separate schools with similar demographics and resources (external matches). Our matched sub-sample included over 270 students and 27 teachers.

This report portrays the findings from this group of laptop schools and a smaller group of comparison schools. ROCKMAN *ET AL* conducted surveys of teachers and students, collected logs of computer use, gathered prompted writing samples, interviewed school administrators, and analyzed standardized test scores from a variety of state- and nationally-normed assessments. This third year report presents a more complex picture of the impact of a fully implemented school Laptop Program.

STUDENT USE OF TECHNOLOGY

Access to technology has increased for all. When we began our Laptop research three years ago, laptops were often a school's first substantial exposure to technology, and Non- Laptop students often had no exposure to technology at all. This is no longer the case. In fact, our comparison Non-Laptop students often had access to computers that was substantially the same as their Laptop counterparts. At school, 63% of Non-Laptop students reported using a computer in Year 2 of our research; in Year 3, 92% of Non-Laptop students said they had used a

computer at school, compared with 99% of our Laptop students. Access outside of school is even more similar between groups. In Year 3, 96% of the Non-Laptop students reported using a computer at some point outside of school; 98% of the Laptop students said the same. In addition, 89% of Non-Laptop students said they had a computer in the home.

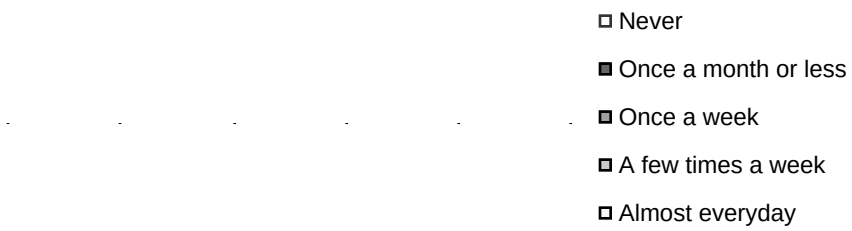
Computer access

	Laptop	Non-Laptop
% reporting computer use in school	99%	92%
% reporting computer use outside school	98%	96%
% with at least one computer at home	96%	89%
Average number of computers at home	2.3	1.5

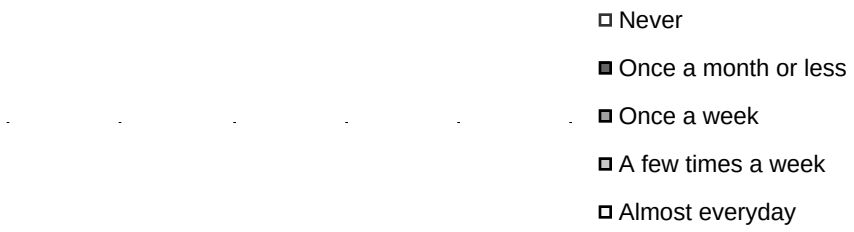
Opportunities for individual access are still greater for Laptop students. Despite increased access to computers for all, Laptop students still had greater individual access to technology. Non-Laptop teachers reported an average student-to-computer ratio of 9:1 in their classes; Laptop teachers reported a ratio of 1:1. When we asked students if they had a computer at home that was "just for you," 60% of the Laptop students said they did, while only 20% of the Non-Laptop students said the same. While almost all students have some access to computers, Laptop students still have substantially greater individual access.

Laptop students consistently show deeper and more flexible uses of technology than their Non-Laptop matched groups. Despite the increased access to computers Non-Laptop students now enjoy, Laptop students continue to show the more intensive uses of computers that were evident in our earlier years of research. On a variety of measures, Laptop students consistently show more frequent use of computers for longer periods of time than Non-Laptop students. In addition, they feel greater confidence in their computer skills on a variety of applications, and they use computers for a wider variety of tasks than do Non-Laptop students. These more intensive uses of technology for Laptop students are evident both at school and at home; however, home uses for the two groups are more similar than school uses.

Frequency of school computer use (student report)



Frequency of home computer use (student report)

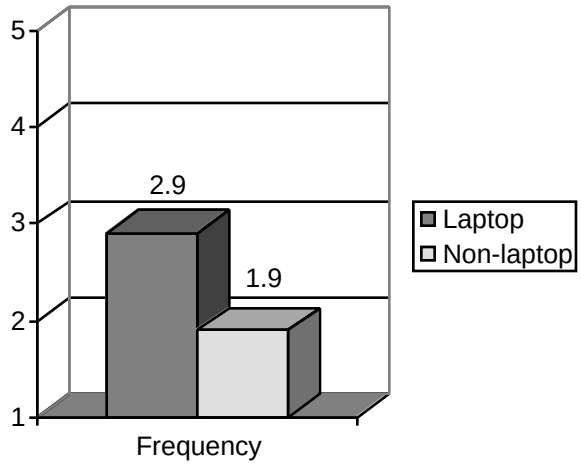


While Internet access for Laptop and Non-Laptop groups is identical at school and similar at home, Laptop students use the Internet more frequently and for longer periods of time. Both groups of students had almost universal direct classroom access to the Internet, and three-fourths of Laptop and two-thirds of Non-Laptop students reported access to the Internet at home. However, the use made of that access differs substantially. Even though teachers reported comparable classroom access, on average Laptop teachers used the Internet once a week, while Non-Laptop teachers reported average use of once a month. In fact, Laptop teachers showed the greatest gains in frequency of Internet use than for any other classroom computer application, moving from close to never three years ago to almost once a week in the current year. In addition, Laptop students used the Internet for longer periods at a time; once they were logged on, Laptop students remained online an average of 40% longer than their Non-Laptop counterparts.

Internet access at school and home

	Laptop	Non-Laptop
Access in school	91%	93%
Access at home	76%	65%

Average frequency of student internet use (teacher report)

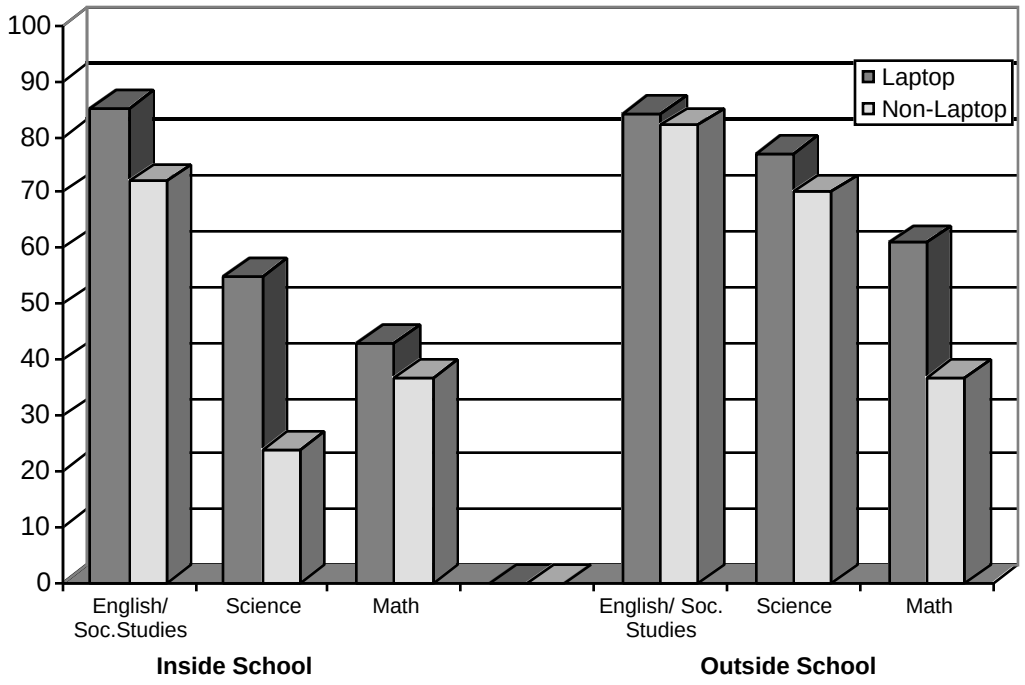


(Scale: 1-never; 2- once a month or less; 3-about once a week;
4-a few times a week;5-almost every day)

Laptop students spend more time doing homework on computers than do Non-Laptop students (on average per week). At two of our three matched sites, Laptop students spent more time completing homework on computers than did Non-Laptop students; at our external site, the differences were quite stark. Laptop teachers report assigning homework that involves computer use seven times more often than Non-Laptop teachers. However, Laptop students spend less time per week on homework overall, and, according to teacher logs, homework is assigned less often. While we don't know why this is, these differences may reflect the productivity of ubiquitous computer access or a tendency toward long term or interdisciplinary projects.

Both Laptop and Non-Laptop students use computers at home for a wider variety of tasks and subjects than they do at school. Both groups of students are using their computer resources at home within specific subjects at greater rates than they do at school. Even when their teachers are not utilizing computers in particular classes, students seem to be transferring and applying their computer skills at home to complete work in these same classes where computers are not used within school. As we found last year, computer use is most prevalent in language arts and social studies, and least prevalent in math, both in and out of school. However, in almost all cases, a greater number of students use computers for homework in a particular subject than use computers inside school. In addition, at two of three sites, both Laptop and Non-Laptop students use computers at home for a wider variety of activities than they do at school.

Percentage of students who've used computers in specific subjects at least once, in school and at home



IMPACT ON TEACHING

Laptop teachers show significant movement toward constructivist teaching practices. When we asked teachers to reflect on their practices three years ago and currently, only the Laptop teachers showed statistically significant change toward more constructivist teaching practices. These changes included more frequent uses of student-led inquiry and collaborative work, and also included departures from traditional classroom roles and changes in activity structures. Data from Non-Laptop teachers did not show any significant changes in their practice from three years ago. In a measure of more traditional teaching, Non-Laptop teachers report they employ direct instruction (a traditional practice defined on our questionnaire as the sequence "review, teach, guided practice, individual practice") almost every day, and that this has not changed at all over the last three years. In contrast, Laptop teachers have moved from employing direct instruction almost every day to about once a week in the current year. However, differences in current practices for Laptop and Non-Laptop teachers on most measures were not statistically significant, though directionally Laptop teachers were slightly more constructivist. The laptop program itself, then, may be acting as a catalyst for change.

Laptop teachers show significant gains in how often they use computers for specific academic purposes. Again reflecting on their practice three years ago and currently, Laptop teachers report significant changes in how often they ask students to use computers

to conduct research and data analyses, run collaborative and interactive projects, and create documents, graphics and multimedia presentations. Non-Laptop teachers do not show significant increases in the frequencies of these practices.

Laptop teachers' strongest catalysts for change are internal in nature. When we asked teachers to rate various catalysts for their changes in practice, Laptop teachers gave the strongest ratings to catalysts which involve more internal changes and learning, such as changes in their goals for students, in their understanding of how people learn, or staff development opportunities. In contrast, Laptop teachers gave their lowest ratings to events that were outside their control, such as changes in district policies, textbook resources, or students' ability levels. Non-Laptop teachers felt they'd been most affected by a variety of factors, both internal and external. Laptop teachers' answers seem to reflect a stronger sense of self-efficacy in the classroom, and these feelings may be contributing to their more rapid changes in pedagogy.

For both groups, the large majority of teachers who indicated a change toward more constructivist pedagogy also indicated that computers played a role in that change. When we asked teachers to reflect on changing practice, we also asked them to indicate whether computers had played a role in particular changes, such as using more authentic assessment, allowing themselves to be taught by students, encouraging students to choose their own research areas or explore topics independently, or moving away from direct instruction. In each case, more than four out of five teachers who made a change in such practices indicated that computers played a role in this change; in some cases, one hundred percent indicated a computer role. Computers themselves, then, may be acting as a catalyst for change for both Laptop and Non-Laptop teachers.

IMPACT ON LEARNING

Laptop students performed better on our writing assessment. We administered a writing assessment to all our matched Laptop and Non-Laptop students, and the resulting essays were scored blind by an independent in-house team of researchers. In two of three cases, Laptop students' writing rated stronger in all four scored areas: content, organization, language/voice/style, and mechanics. In the third case, language/voice/style and mechanics were rated higher, while the overall score was lower. For three years, teachers have reported that they think access to laptops has improved student writing; there seems to be some evidence for this assertion.

Standardized test score comparisons were inconclusive. We faced major hurdles in gathering test scores for students: in some cases, schools were unable to give us the scores; in others, especially the high schools, only a handful of students took any particular test, since the tests were not mandatory (the PSAT or the ACT, for example). In addition, many schools administered a state-specific assessment, and we were therefore unable to compare scores across school sites. Where we had matched groups, we compared Laptop and Non-Laptop scores. Where we had only Laptop groups, we ran cohort comparisons, in which

current Laptop scores were compared with the scores of the cohort who had moved though the same grade just before the Laptop Program was implemented (i.e., we compared 1999 7th grade scores with 1996 7th grade scores). We then conducted administrator interviews to inquire about other changes over time at these schools. Because we had such small groups of scores, we were unable to control for student background variables. Results were inconclusive; in some cases, current Laptop students' scores were higher, but often the differences were not statistically significant. Certainly these standardized tests for the most part were not designed to reflect the types of learning that we have found laptops support. Also, in most cases, Laptop students were only in the second year of the Program, and therefore had had their computers less than two full years. It is not surprising, consequently, that results from standardized tests were inconclusive.

Comparison groups of Laptop and Non-Laptop students show less clear differences in some areas than last year. When we first examined comparison groups of Laptop and Non-Laptop students in the 1997-98 school year, differences between the two groups were often stark. While group differences are still large for many measures, such as computer use and computers skills, in other areas differences have diminished. Last year we found that Laptop students reported using active learning strategies more often than Non-Laptop students as they read, wrote, or prepared presentations. Last year, for example, Laptop students more often took notes as they read, outlined their papers, and rewrote passages for reports. This year results are more mixed. While Laptop students more often highlight a main idea or re-read reports before turning them in, for example, Non-Laptop students more often outline their papers and information they read, look up additional information as they read, and ask questions to make sure they understand what they've read, among other items. However, this is the case only for our two internally matched sites. Our externally matched site still shows the stark differences between Laptop and Non-Laptop students we found in Year 2, and here Laptop students employ almost every active learning strategy more often than their Non-Laptop counterparts. Laptop and Non-Laptop students within the same school may be growing more similar as time passes, perhaps due to a sharing of resources, pedagogical approaches, or school philosophies.

Laptop students rate their confidence in computer skills more highly than Non-Laptop students. Laptop students continue to rate their computer skills for specific applications more highly than Non-Laptop students. Differences between the two groups were statistically significant for word processing, presentation software, Internet use, spreadsheets, databases, and webpage design. Only differences in email did not reach statistical significance, but directionally they were also in favor of Laptop students.

STUDENT AND TEACHER BELIEFS ABOUT TECHNOLOGY

Laptop students' attitudes toward computers are more positive than Non-Laptop students'. For five statements about the benefits of computers, Laptop students indicated greater levels of agreement, and differences between Laptop and Non-Laptop students were

statistically significant. Laptop students agreed more strongly that computers helped them improve the quality of their schoolwork, made their schoolwork easier to do, made it more fun and/or interesting, and helped them understand their classes better. Laptop students also indicated that they more strongly preferred doing their schoolwork on the computer. In fact, the only statement with which Non-Laptop students indicated a greater level of agreement than Laptop students was "I enjoy playing games on the computer" (the difference was not statistically significant). Laptop students seem to feel more enthusiastic about the benefits of computer use for their schoolwork.

Both Laptop and Non-Laptop students perceived specific benefits from computer use. When asked the open-ended question, "How would your schoolwork be different if you didn't use computers?", both groups of students perceived benefits from computer use. These included greater productivity in their schoolwork (primarily in writing and research), the ability to create more professional products, an increase in creative opportunities, and increases in the skill set they feel they'll need in future employment.

While both groups are enthusiastic, Laptop teachers rate computers' effects on students more positively than Non-Laptop teachers. Most teachers see the benefits of using technology for teaching and learning and, while Laptop teachers are a bit more enthusiastic about those benefits, Non-Laptop teachers are also very positive. Among the places where the differences between the two groups are most pronounced, however, are in the areas where we have seen consistent advantages in Laptop classes—in increased student research, in role shifts in the classroom, in collaboration, and in the fluency students have for using technology for a variety of purposes.

Teachers' ratings of effects of technology access on students:

	Laptop	Non-Laptop
Fluency in using technology for a variety of educational purposes	4.7	4.2
Amount of research students do	4.6	3.9
Number of roles students assume in learning	4.3	3.9
Amount of time students spend working with class or schoolmates	4.2	3.6

(ratings are based on a 5 point scale, where 1 is "very negative" and 5 is "very positive".)

All the teachers we surveyed are enthusiastic about the use of technology in the classroom. For the third year, we asked teachers to rate their enthusiasm for technology and for laptops on a 7 point scale. Both Laptop and Non-Laptop teachers are consistently enthusiastic about the benefits of technology in the classroom, rating themselves at 5.5 and 5.4 respectively. However, Laptop teachers feel computers are more essential to their teaching practices; while Non-laptop teachers rated the importance of computers at 3.6, below the neutral point on the scale, Laptop teachers averaged 4.6, a full scale point higher.

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INTRODUCTION

PROJECT BACKGROUND

In the fall of 1996, Microsoft Corporation and Toshiba America Information Systems launched the Anytime Anywhere Learning Program, also called the Laptop Program, at 29 "pioneer" school sites across the United States. Students and teachers in both public and private schools acquired notebook computers loaded with Microsoft Windows and Microsoft Office software and began to explore how best to use these powerful tools for schooling. The pilot program was designed to demonstrate that providing every student within a classroom with access to "real world" business tools would produce substantial educational benefits by supporting learning anytime and anywhere. There are now hundreds of school sites across the country that are in various stages of implementing and adapting their own Laptop Program.

ROCKMAN *ET AL*, an independent research organization in San Francisco, California, was contracted to explore and assess the experiences of these Laptop schools. The first year experiences of the pioneer schools are detailed in the June 1997 "Report of a Laptop Program Pilot." This report 15 on the challenges of program implementation, various participants' assessments of the program, and includes recommendations for schools contemplating their own program.

During the second year of the study, the 1997-98 school year, ROCKMAN *ET AL* focused on the Laptop Program's impact on teaching and learning. Selecting schools which were in their second year of a concentrated program implementation, ROCKMAN *ET AL* used surveys, on-site observation, and simulated problem-solving sessions to assess how Laptop students approached classroom tasks and integrated laptops as learning tools. The study also examined changes in teaching and how these changes might be related to ubiquitous access to laptops. In order to provide context for the findings, each group of Laptop students was compared to a matched group of Non-Laptop students from within the same school. These findings are described in "Powerful Tools for Schooling: Second Year Study of the Laptop Program." Both this report and the first year report are available on the websites of Microsoft and ROCKMAN *ET AL*.

During the third year of the Laptop Program, the 1998-99 school year, ROCKMAN *ET AL* continued to examine impacts on teaching and learning within Laptop classrooms, and especially the ways in which laptops might be supporting a more constructivist pedagogy.

ROCKMAN *ET AL* was also asked to focus on the possible impact of students' full-time laptop access on standardized test scores. Questionnaires, logs and surveys were gathered from Laptop students, and matched groups of Non-Laptop students were again included to provide context for the findings. The third year report presents a more complex picture of the impact of a fully implemented school Laptop Program.

RESEARCH APPROACH AND METHODOLOGY

Because we were asked in part to examine the impact of the Laptop Program on standardized test scores, the number of potential research sites turned out to be quite limited. Although there are hundreds of schools initiating or implementing a Laptop Program, only a few qualified for our study.

Research Sites

Site selection

Of the hundreds of Laptop Program sites, 141 responded to a program fact survey we mailed out in the fall of 1998. Many of these sites were in their first, second, or third years of implementation, while some were still in planning stages.

Our previous research on Laptop schools had shown that students and teachers often needed their first year to become familiar with the laptop computer as a tool and to begin to use the computer in ways that could have substantial impact on learning. Because we were investigating possible effects on standardized test scores, we limited our study sample to those students who were in at least their second year of the program, and who had teachers who were also teaching in at least their second year. Of the 141 sites that responded to our initial study, roughly 50 schools stated that they were in either their second or third year of implementation.

In our first year report, we described the various models that Laptop schools had adopted as they strove to provide meaningful and equitable access to the Laptop program. The concentrated model—in which each student had his or her own laptop, was able to take that laptop home, and was taught by a teacher who also had full-time access to a laptop computer—provided the most intensive laptop environment. To best understand the impact of ubiquitous computing, we chose, therefore, to work with sites that had a concentrated model. Of the 50 sites responding to us that were beyond their first year in the program, 29 schools had both a concentrated program and had students who were in their second year in the Laptop Program.

There were various other factors which further narrowed our potential study site list. Of the 29 sites above, only 12:

- √ gave standardized tests at the necessary grade levels (e.g., a group of students in their second or third year of laptop use who also took a state-level test)
- √ were in session during spring 1999 (i.e., not year-round schools on an extended break)
- √ were not a specialized program or school (special needs schools, etc.)
- √ were willing to participate in the study
- √ were willing to release test scores to us

Matching sites

Our original research plan called for studying matched groups of Laptop and Non-Laptop students. Of the 12 sites which met our criteria, four had internal matches of students—that is, the Laptop Program involved only a subset of the entire school population, and we were able to work with both Laptop and Non-Laptop students at the same school.

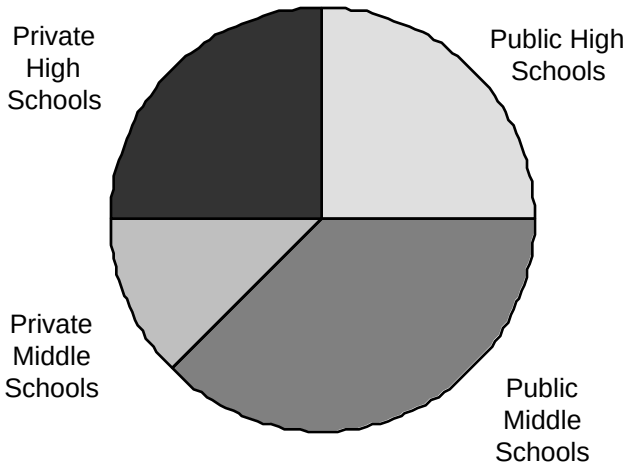
The other eight schools were whole-school implementations, and we began to look for external matches for these schools. We planned to find Non-Laptop schools in which the student population was roughly similar to that of a matched Laptop school, and schools which were willing to participate in our research. Our Laptop sites recommended possible matches, either in their local area or in their network of independent schools, and we made dozens of phone calls. In the end, however, most of these Non-Laptop schools were unable to participate in our research, and only one externally matched school agreed to take part in our study.

Site participation

In the spring of 1999 we began our research at these 12 sites (13 schools, with our one external matched site). However, in the end we did not receive data from all of our schools. At two sites, student data sets were completed and then lost before they could be mailed to us. Unfortunately, incidents of lost data occurred at two of our five matched sites, leaving us with only three matched sites for our final study. In addition, one school returned so little information that we were unable to use it in our analysis; one returned no data whatsoever; and one returned only partial data, which included student test scores but no other student instruments. We made repeated efforts to obtain the data, but circumstances and on-site concerns made obtaining it quite a problem.

For our final study, then, we have usable data from eight sites: three matched sites and five unmatched sites, one of which has only limited sets of instruments. Half are middle schools and half are high schools; five are public, and three are private.

Figure 1: Participating school sites



Instruments and Data Collection

Test score collection

Test score collection provided its own set of challenges. Some of the data were from nationally-normed, standardized tests; others were from state-level tests. Some of the assessments were being used for the first time, and thus no longitudinal data were available. Standardized tests are often administered in the spring of each school year; however, reports of student scores are returned mid-winter of the following school year. While participating sites could have teachers and students complete our surveys and questionnaires, test score data were often not under their direct control. At two of our three matched sites and at one of our unmatched sites, test score data were unavailable for several months because of database problems at the district level.

In addition, students who met our requirements—who were in at least their second year with laptops and who were in a grade level that participated in standardized testing—did not always take the tests. Some of the widely offered national tests, like the SAT, the PSAT, and the ACT, are not mandatory. At private schools, participation is close to 100%; at some of our public schools, less than 30% of our target group of students took the test.

At the schools for which we were unable to find a matched site, we had no group of comparison test scores. Therefore, we conducted a "cohort comparison"—we examined test scores for the current Laptop group and compared their achievement with the test scores of the cohort of the same grade level who had moved through the school four years earlier, before the Laptop Program began. In order to account for other influences beyond the laptops during those four years, we conducted interviews with each principal or headmaster to ascertain the changes that had occurred at their schools during the last four years (see below for description of the principal interviews).

Finally, because the United States has no national testing program, each school gave tests at different grade levels, and the tests the students took varied from school to school. While a few schools gave us PSAT scores, other schools were the only school in our sample to give a particular test. Therefore, we were not able to compare student test scores across sites, and could not construct the larger and more powerful data set that identical testing would have allowed us.

It is important to recognize that Anytime Anywhere Learning was not designed specifically to improve test scores. Although our previous research has identified many benefits of the Laptop program, differences between Laptop and Non-Laptop students' achievement test scores may not appear. Possible impacts of the Anytime Anywhere Learning program on standardized test results may not be apparent until students have more than two years' experience with using a laptop as a learning tool. Anytime Anywhere Learning may impact students' learning processes and outcomes in ways that are not measured by the standardized tests that schools currently rely on. There tends to be a disconnection between the purposes of laptop use and the skills measured by the most widely used standardized tests. Differences between the standardized test scores of

students with and without laptop access may therefore be minimal while alternative assessment tests may show significant differences between these groups.

	Grade	Private/ public	Full data returned?	Test	All students take test?	% of group w/ test scores
Matched schools:						(LT, NLT)
School Pair 1 (external)	11	public	yes	ACT	no	27%, 27%
School 2 (internal)	11	public	yes	PSAT	no	26%, 15%
School 3 (internal)	8	public	yes	SAT9	yes	98%, 84%
Laptop Only schools:						
School 4	8	public	yes	SAT9	yes	96%
School 5	8	public	yes	OH state	yes	100%
School 6	10	private	yes	PSAT	no	82%
School 7	10	private	yes	PSAT	no	87%
School 8	7	private	no	SSAT	yes	100%

Instruments

In addition to collecting student test scores, we also administered several surveys and questionnaires, and asked both students and teachers to keep logs for us. Over 460 students and 47 teachers at 9 different schools participated. All students were asked to fill out a student questionnaire, a learning strategies survey, and a computer use log; students at our matched sites were asked to complete a writing activity as well. Teachers were asked to complete a survey and a class log. Instruments are described below and are included in the appendix of this report.

Table 2: Number of participants

	All Laptop	(Matched Laptop)	Non-Laptop	Total
Student instruments				
Student questionnaire	330	(126)	135	**465**
Learning strategies survey	321	(129)	132	**453**
Computer use log	261	(161)	118	**379**
Writing activity	–	(105)	112	**217**
Teacher instruments				
Teacher survey	32	(12)	15	**47**
Class log	20	(11)	11	**31**

Table 2.1: Instrument collection by site

	Student questionnaire	Learning strategies survey	Student computer use log	Writing activity	Teacher questionnaire	Teacher class log
Matched schools:						
School Pair 1 Laptop	45	44	35	20	7	6
Non-laptop	30	27	22	21	3	4
School 2 Laptop	31	31	31	31	4	4
Non-laptop	47	47	42	32	6	6
School 3 Laptop	50	54	54	54	2	1
Non-laptop	58	58	54	59	6	1
All-Laptop schools:						
School 4	50	49	41	–	4	0
School 5	77	70	73	–	4	4
School 6	28	28	11	–	4	4
School 7	49	45	16	–	4	1
School 8	–	–	–	–	3	–
TOTAL	**465**	**453**	**379**	**217**	**47**	**31**

Student instruments.

Student Questionnaire. All of our participating students were asked to complete a background questionnaire. Students answered questions about their experience with computers, current computer use, technology skills, their school schedule, and their home environment. Four hundred and sixty-five students at seven sites completed the questionnaire.

Learning Strategies Survey. The Learning Strategies Survey asked students to rate the frequency with which they apply a variety of learning strategies when they read, write and prepare presentations for school. For example, students were asked how frequently they revise reports and write outlines for papers. Students also indicated which learning strategies they have applied with the aid of a computer. Four hundred and fifty-three students at seven sites completed the survey.

Computer Use Log. Students at each of our schools completed a Computer Use Log. Because we wanted to get computer use information for several different days, half the students began their logs on a Tuesday or Thursday, and the other half on a Monday or Wednesday. Then students recorded computer use every other day, for three days, including a weekend day if their logs happened to cover one.

Students were asked to report each time they used a computer, both in school and outside of school. Additionally, they recorded what class they used the computer for (in school), what they used the computer to do, which software/tools they used, and how many minutes they spent on the computer. If they were reporting out-of-school use, they were asked if they used the computer to complete schoolwork, and if so for which subject. Also, each day they recorded the total amount of time they spent on homework, either with or without a computer. Three hundred and seventy-nine students at eight schools completed the logs.

Table 2.2: Student computer logs

	Tu/Th	Mon/Wed	Total	Weekend days
Matched schools:				
Site 1 Laptop	18	17	35	–
Non Laptop	8	14	22	10
School 2 Laptop	15	16	31	–
Non Laptop	25	17	42	9
School 3 Laptop	27	27	54	37
Non Laptop	23	31	54	47
Laptop Only schools:				
School 4	14	27	41	27
School 5	34	39	73	28
School 6	1	10	11	2
School 7	9	7	16	8
School 8	–	–		
TOTAL	**174**	**205**	**379**	**168**

Writing Activity. A Student Writing Activity was administered only at our matched sites, where we had both Laptop and Non-Laptop students participating. Students were asked to write several paragraphs describing the activity they had learned the most from during the preceding school year. They were asked to explain why they had learned so much from this activity and what made it different from other assignments. As a pre-writing exercise they were asked to give some basic facts about the assignment and to list the steps they took to complete their project. The students were instructed to take about 30 minutes to complete the activity, and to turn in any pre-writing activities (brainstorming, outlining, creating a concept web, etc.) that they used in order to write their response.

A separate ROCKMAN *ET AL* team conducted a blind assessment of the writing activity. Team members used a rubric that reflected a four-point scale in four different areas: Content, Organization, Language/Voice/Style, and Mechanics. Benchmark papers were selected, and each student's work was scored by two different evaluators. When those scores differed, the paper was re-evaluated by both scorers. Two hundred and seventeen students at three sites completed the writing activity.

Teacher Instruments.

Teachers in both Laptop and Non-Laptop classes were asked to complete two instruments: a questionnaire and a class log.

Teacher Questionnaire. The Teacher Questionnaire asked teachers to reflect on their pedagogy, their teaching philosophy, and their classroom practice. In order to investigate change over time, teachers were asked about their current practices and about those same practices three years ago, before the Laptop Program began. In addition, they indicated whether they thought computers had played a role in any changes that might have occurred. Teachers were also asked about their technology expertise and background, their access to computers and the Internet, and their assessment of technology's impact on the classroom. Forty-seven teachers completed these questionnaires.

Teacher Class Log . Teachers chose two classes each day for five consecutive days and kept a log for these ten different class periods. They were asked to indicate on a checklist which student activities had occurred (e.g., writing, reading, problem solving, discussion), which roles they as teacher had assumed (e.g., lecturing, facilitating discussion, consulting with small groups), the activity structure (teacher led, student led, or independent) and student grouping. The teachers were asked to indicate for each period which two activities had consumed the most class time. In addition, they indicated when computers had been used for each activity. If the class had been atypical for any reason, or if they wanted to explain further, they were asked to elaborate. Thirty-one teachers kept class logs for us.

Principal Interviews.

At each school we conducted a 15-to-20-minute telephone interview with the principal, headmaster, or other administrator to get a sense of all the ways the school might have changed during the last three years, during the period that the Laptop Program was implemented. Administrators were asked about any school reform initiatives or major changes, either at a local, district, or state level, and what they felt the impacts of those efforts had been. They also answered questions about changes in teacher experience or demographics (e.g., staff turnover or professional development initiatives); changes in student demographics (student body size, socioeconomic status, etc); changes in test preparation for students; and any other changes they felt may have impacted standardized test scores or teaching and learning at their schools.

SUMMARY OF YEARS 1 AND 2: CULMINATION OF FINDINGS

Our research this year completes three years of extensive, nation-wide research on schools and classrooms that have implemented a substantial Laptop program. While each year's research design built on the findings of the previous years, in each successive study we also examined new areas and questions. To provide a context for viewing and interpreting the research findings of the third year study, below is a brief summary of our first and second year findings, and the current status of each.

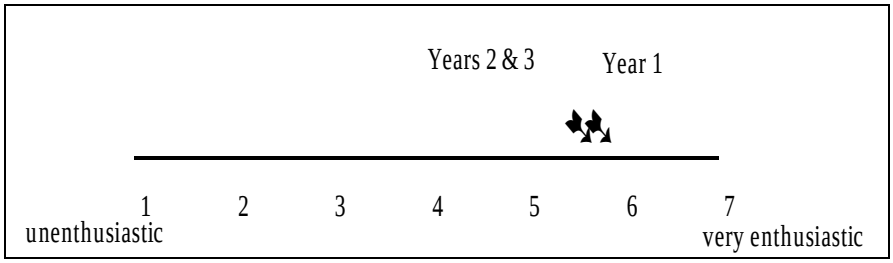
First Year Study: The Pioneer Schools

Our first year of research documented the experiences of the small group of pioneer schools that began the program. Their experiments and lessons provided important information for those who followed.

Positive attitudes. The first year report documented extremely high levels of enthusiasm among all participants—teachers, students, parents, and administrators. Respondents felt the laptops enhanced both teaching and learning, that they were highly flexible and adaptable tools, and that they could be adopted successfully in a variety of academic settings and grade levels.

In the second and third years of the study, we continued to ask teachers to rate their enthusiasm for the project on the same seven-point scale. Enthusiasm for the program, even after three years of implementation, has remained high.

Figure 2: Teacher enthusiasm for the Laptop Program



Year 1- average rating 5.8; Year 2- average rating 5.6; Year 3- average rating 5.6

Implementation models. Because the pioneer sites in Year 1 were mapping out new territory, there were many experiments on how best to utilize the available laptop resources. Some schools chose to acquire a class set of laptop computers, available to all classrooms but not the exclusive domain of any single class. Other schools scattered their Laptop students in with Non-Laptop students, and some gave a few of their limited number of laptops to each classroom to use full-time. However, by the end of the year, whether or not they were able to implement it, most participants agreed that the most effective model was the concentrated model: All students in a particular class, grade, or school have a laptop, and it is theirs to use at all times, both at home and at school. Teachers also have their own laptops, and receive intensive training on technology skills, curriculum uses, and integration.

Because we wanted to examine the most intensive uses of the laptop, in Years 2 and 3 we confined our research to those sites that were able to pursue a concentrated Laptop Program implementation model.

Challenges of equity. Laptop computers are expensive. While many sites recognized that most benefits occurred when all students in a particular class had laptops, and when Laptop students were grouped together through several subjects, many also worried about what that might mean for students unable to afford a laptop. Schools experimented with scholarships, securing low-interest loans for parents, rent-to-buy programs, and creating a set of loaner laptops.

While we did not focus on this issue in Years 2 and 3, comments from teachers and administrators during interviews and on questionnaires indicate that equity continues to be a challenge. Some sites feel their various assistance programs have provided equal access, while others are still struggling with the issue. This is a critical concern for schools and worthy of further monitoring and study.

Exposure to technology. When the Laptop Program began in the fall of 1996, only a handful of mostly private schools already had substantial technology programs. For many of the pioneer schools, the Laptop Program comprised their first significant exposure to technology in general, and to the Internet. Much of the enthusiasm we heard in the first year of the program was a reflection not only of the laptops as a particularly flexible tool but also of any exposure whatsoever to computers in the classrooms and to the World Wide Web.

Today, this is no longer the case. In the last three years, American schools have acquired technological resources at astounding rates, and Internet connections are commonplace; studies report that almost all schools—and more than half of all classrooms—have an Internet connection. In addition, students have access to home computers in much greater numbers. In Years 2 and 3, when we used Non-Laptop students for comparison purposes, we found that often these students had extensive computer access and exposure, especially at home. Therefore, the Laptop Program does not necessarily constitute a first exposure to technology, but rather a particular kind of exposure: Students have their own computer; it is highly mobile; and they have the same set of software resources no matter where they are working.

Changes in pedagogy. In our first year's research we threw a wide net to begin to understand the impacts laptops could have in schools. As a small part of our research, we asked teachers to report on their perceptions of changes in their pedagogy, such as changes in their teaching style or methods. We found that teachers felt they were doing more project-based work, more student-centered or student-led work, and more collaborative work. Even as early as their first year with the laptops, teachers felt they needed to make substantial changes in their pedagogy in order to take advantage of this new tool. These findings spurred us to look at these changes in more detail in both our second and third year research, as outlined below.

Second Year Study: Focus on Teaching and Learning

Inspired by the changes in classrooms that our pioneer school participants described during their first year in the program, we focused on impacts on teaching and learning during our second year of research. In order to deepen our understanding, we spent a lot of time on-site, observing and interviewing students and teachers about what we saw.

Comparison groups. We worked with groups of both Laptop and Non-Laptop students during Year 2. These matched groups of students attended the same school and often shared teachers with our Laptop students; they provided an excellent comparison group as we examined the effects of the laptops. During Year 3, we continued to use comparison groups as we investigated the Laptop Program.

Impacts on learning. During Year 2, we spent a total of 60 days on site at four different schools, examining what went on in classrooms; we also administered problem solving activities and ran focus groups. We found that Laptop students participated in more project-based instruction than Non-Laptop students; that they wrote more often and produced writing of higher quality; that their research and analysis skills were stronger; and that they completed more presentations than Non-Laptop students. Additionally, during our problem solving simulations, we found that Laptop students more readily engaged in critical thinking and displayed more instances of higher-order thinking than their Non-Laptop counterparts.

Impacts on teaching. During our time on site, we used an observation log to note what roles teachers played in the classroom, and how much time they spent in various activities. We shadowed students (both Laptop and Non-Laptop comparison) and teachers, closely monitoring how they spent their time. We found that Laptop teachers spent less time lecturing than did their Non-Laptop counterparts, and they spent more time consulting and conferencing with individuals and small groups of students. Laptop students spent more time collaborating with their peers than did Non-Laptop students. These findings are consistent with the style of a constructivist classroom. In Year 3, we further explored the idea that laptops were facilitating more constructivist teaching.

Technology access, use, and skills. During Year 2, we explored how Laptop students use their computers. In comparison with Non-Laptop groups, we found that Laptop students used computers more frequently, for longer periods, more appropriately, and had more advanced technology skills. We also found that the laptops seemed to extend the school day, as Laptop students spent a greater percentage of their out-of-school computer time completing school tasks. During Year 3, we continued to examine students' use of computers as schools nation-wide increased their technology resources.

Third Year Study: A Shifting Focus

Our Year 3 research was shaped by the request to examine possible impacts on student achievement, primarily standardized test scores. We selected sites based on their test-giving schedule and their willingness to share test data, as outlined above. However, we also continued to examine teaching and learning inside classrooms. While we were unable to go on site, as we did in Year 2, we did receive questionnaires, logs, and/or surveys from over 450 students at seven schools. In addition, 47 teachers answered an extensive set of questions about their teaching practice and philosophy, and 31 filled out a ten-day log of classroom practice. With this generous cooperation from students and teachers, we were able to expand our findings on computer access and use, influences of the laptops on classroom practice, changes in teaching over time, and student writing.

STUDENTS' USE OF TECHNOLOGY

TECHNOLOGY ACCESS

Over the past three years, access to technology in schools and homes in the United States has increased at a breathtaking rate. While there are substantial differences based on income and often race, the number of families with school-age children who have a home computer exceeds fifty percent, and the students-to-computer ratio continues to decline, now in the neighborhood of 7-to-1. In addition, according to a recent study by Grunwald (*Children, Families, and the Internet 2000*. Grunwald Associates, P.O. Box 908, San Mateo, CA 94403, info@grunwald.com), access to the Internet has increased dramatically over the past several years, tripling since 1997, up 40% in the past year. Grunwald's data indicate that more than 70% of all teenagers are connecting with the Internet at home or in school. Fourteen million children sign on to the Internet from school; 18 million children, ages 2-17, connect from home for a non-duplicated total of 25 million. The National Center for Education Statistics reports that 95% of schools and more than 60% of the classrooms are linked to the Internet. Teachers are also gaining access to technology and are rapidly and frequently being offered the training to use it. Across the country, almost all schools are making progress towards acquiring and using computers for teaching and learning.

When the Laptop Program was first introduced, only a handful of participating schools, often private ones, had extensive technology resources. As described above in our summary of the first year report, for many schools the Laptop Program initially provided the first substantial technology access for teaching and learning, and the comparison, Non-Laptop schools had only modest computer access and resources. Three years ago, Laptop schools often went from very limited access to immediate and ubiquitous access, while Non-Laptop schools had perhaps only a few computers in the library or in a lab. However, this is no longer the case, and the technology gap has narrowed considerably.

Students in many schools are getting substantial access to computer time in their classrooms, a lab, or in their school library. At these sites, they can usually gain access to the Internet; some have email accounts, and most use the software applications and tools that Laptop classes have had since they joined the program. At home, too, the Non-Laptop students not only have access to computers to play games and do their homework, but also use the Internet to conduct research and communicate with their friends. Laptop students are not as unequaled as they were several years ago. While not all students have their own computer, many do have sufficient access to be comparable with Laptop students in critical ways.

Computer Access

While we only have data from Non-Laptop students for Years 2 and 3 of our research, even within that small time frame, access has increased significantly for Non-Laptop students. Our data for in-school computer access for Non-Laptop students indicate that:

Year 2: 63% report using a computer at school (yes/no question)
Year 3: 92% report using a computer at school at some point (frequency question)

(In comparison, 99% of the Laptop students in Year 3 report using a computer at school at some point)

Out-of-school computer access data for Non-Laptop students shows that:

Year 2: 80% report using a computer at home (yes/no question)
Year 3: 86% report using a computer at home (yes/no question)
Year 3: 96% report using a computer outside of school at some point (frequency question).
(In comparison, 98% of the Laptop students in Year 3 report using a computer outside of school at some point)

We also asked our matched group of Laptop and Non-Laptop students how many computers, if any, they had at home. Since we were working with concentrated Laptop classrooms, where students can take their laptops home, Laptop students automatically had at least one computer to count. However, it was clear that our comparison students had substantial access at home as well. While 96% of the Laptop students reported that there was at least one computer in the home, 89% of the Non-Laptop students said the same. Laptop students reported an average of 2.3 computers in their home, while the Non-Laptop comparison students reported 1.5 computers in the home, on average.

However, while both Laptop and Non-Laptop students have substantial access to computers at home, the type of access may be different. We asked students if they had a computer at home that was "just for them"; a significantly larger percentage of Laptop students (60%) replied that they did, in comparison to Non-Laptop students (20%). While over half of our Laptop students have sole proprietorship over their computers, four out of five of our Non-Laptop students must share their computers at home.

Table 3: Computer access at home

	Laptop	Non-Laptop
Average number of computers at home	2.3	1.5
% with at least one computer	96%	89%
% with computer for "own" use	60%	20%

While computers are present in the home at almost equal rates for both groups, and both Laptop and Non-Laptop students have at least minimal exposure to technology at school, individual access to computers at school is still much greater for Laptop students. On

their class logs, teachers indicated the student-to-computer ratio for each of their classes. Laptop classes averaged 1:1; Non-Laptop classes averaged 9:1.

The gap in computer resources between our Laptop and Non-Laptop students has narrowed considerably. In some respects, their access is almost equivalent. However, opportunities for individual access are still much greater for Laptop students.

Internet Access

Laptop and Non-Laptop students also seem to have similar access to the resources of the Internet. All of the teachers in our matched groups report that their school has Internet access. All teachers except one in each group report that their *classrooms* have Internet access; they all state they have a direct connection (as opposed to a dial-up or modem connection). Access from home is more dissimilar, but still reflects relatively comparable levels of access.

Table 4: Internet access at school and home

	Laptop	Non-Laptop
Access in school	91%	93%
Access at home	76%	65%

TECHNOLOGY USE

Laptop and Non-Laptop students now have more similar access to technology than they did three years ago. However, evidence suggests that this access is utilized in very different ways. Laptop students use computers more frequently, for longer periods, for a wider variety of uses, and have higher confidence in their computer skills, despite the more similar access. Below, we examine differences in technology use between the matched groups in school, outside of school, with the Internet, with homework, and by individual subjects and activities.

Computer Use: Inside School

Frequency

Even though the vast majority of both Laptop and Non-Laptop students report that they have used computers in school at some point, and so have some type of access, the frequency of that use varies widely. Many of our measures reveal that Laptop students use computers significantly more often.

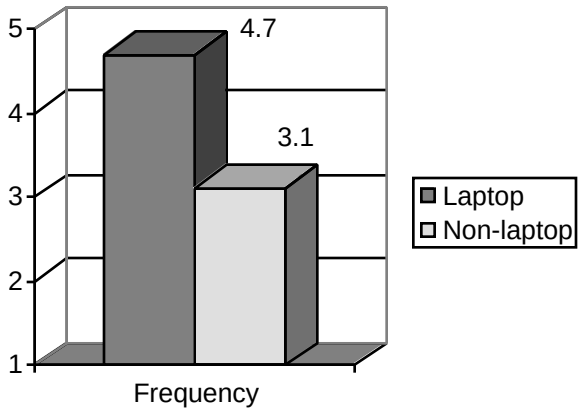
When asked how often they use computers in school, 83% of the matched group of Laptop students indicated “almost everyday.” Only one-fourth (25%) of the Non-Laptop students use computers in school this often. In fact, almost half—47%—of the Non-

Laptop students say they use a computer at school only once a month or less. Only 4% of the Laptop students say they use a computer at school this infrequently.

Figure 3: Frequency of school computer use (student report)

Given their access to computers, students with full-time use of a laptop are more likely to use that computer in school. Laptop students use their computers almost every day in school, while Non-Laptop students use a computer about once a week on average. The difference between the two groups is statistically significant.

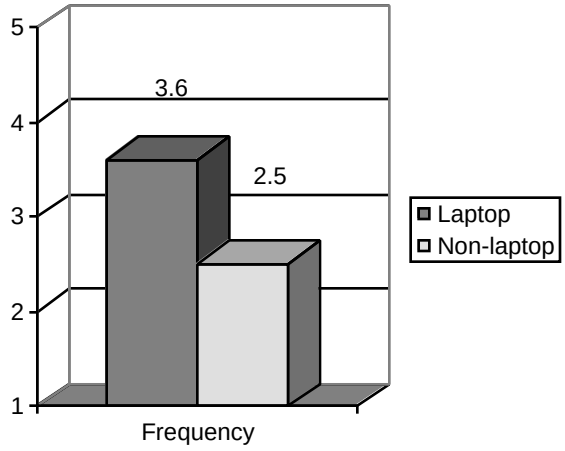
Figure 4: Frequency of computer use in school (student report)



(Scale: 1-never; 2- once a month or less; 3-about once a week;
4-a few times a week;5-almost every day)

Teachers were also asked to estimate how often a typical student in their classes used a computer. Laptop teachers reported far more frequent use of computers during their classes than Non-Laptop teachers, and differences between the two groups are statistically significant.

Figure 5: Frequency of computer use in school (teacher report)



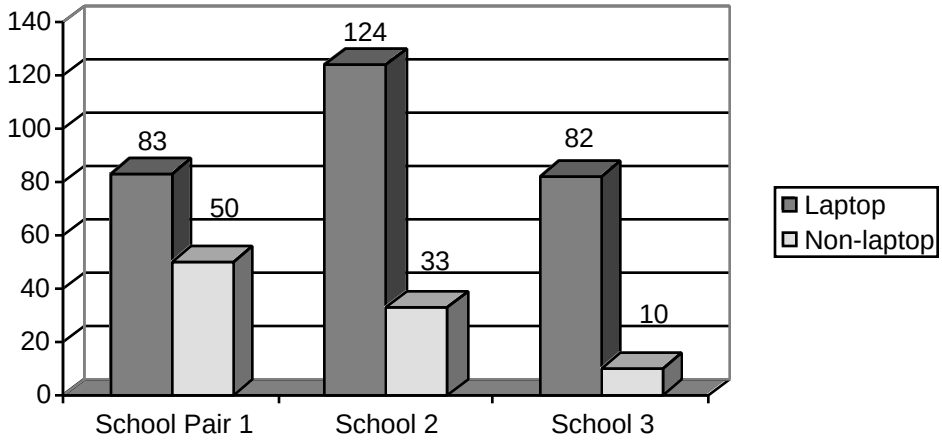
(Scale: 1-never; 2- once a month or less; 3-about once a week;
4-a few times a week;5-almost every day)

For both Laptop and Non-Laptop groups, student reports of computer use are higher on average than teacher reports. This probably reflects the fact that students are talking about all their classes put together, while teachers are talking only about their own classes.

Duration

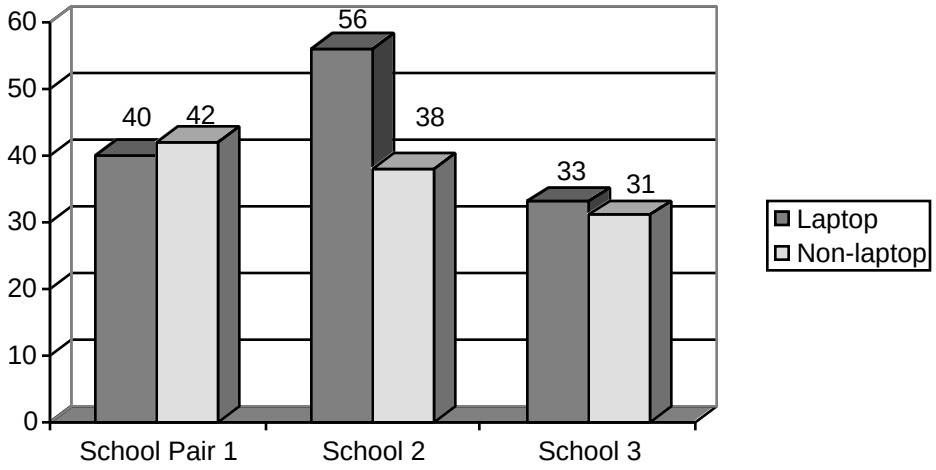
The measures above reflect how *often* students used their computers—i.e., how many days per week they sit down in front of a computer. Laptop students also use their computers for longer periods each day. At all three matched sites, Laptop students report far higher average minutes of computer use each day at school, up to eight times as much at one site. These data come from student logs and are consistent with the data obtained in previous years.

Figure 6: Average minutes of computer use per day in school



In addition, in two of three cases, Laptop students use the computer for longer periods once they get on. Longer periods may allow for more intensive work time.

Figure 7: Average duration of a single session on the computer, in minutes

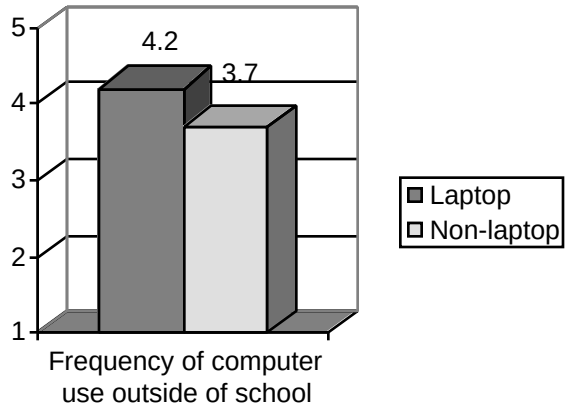


Computer Use: Outside School

Frequency

While Laptop students use computers much more frequently than Non-Laptop students at school, outside of school those differences diminish somewhat. The differences, however, are still statistically significant. Both groups seem to use computers at home a few times a week, but students report a half-point difference on a five-point scale.

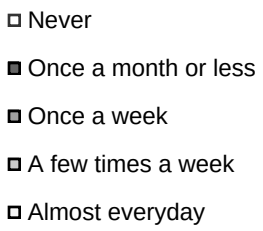
Figure 8: Frequency of computer use at home (student report)



(Scale: 1-never; 2- once a month or less; 3-about once a week; 4-a few times a week;5-almost every day)

In addition, while 47% of Non-Laptop students report they use computers at school once a month or less (see above), only 17% of Laptop students say that they use computers at home that infrequently. This compares with 8% of the Laptop students who report using computers at home only once a month or less. About half (54%) of the Laptop students report using a computer at home "almost everyday," while about one-third (32%) of the Non-Laptop students report using computers at home this frequently. Frequency of use, then, seems much more similar at home than at school for our matched group of students.

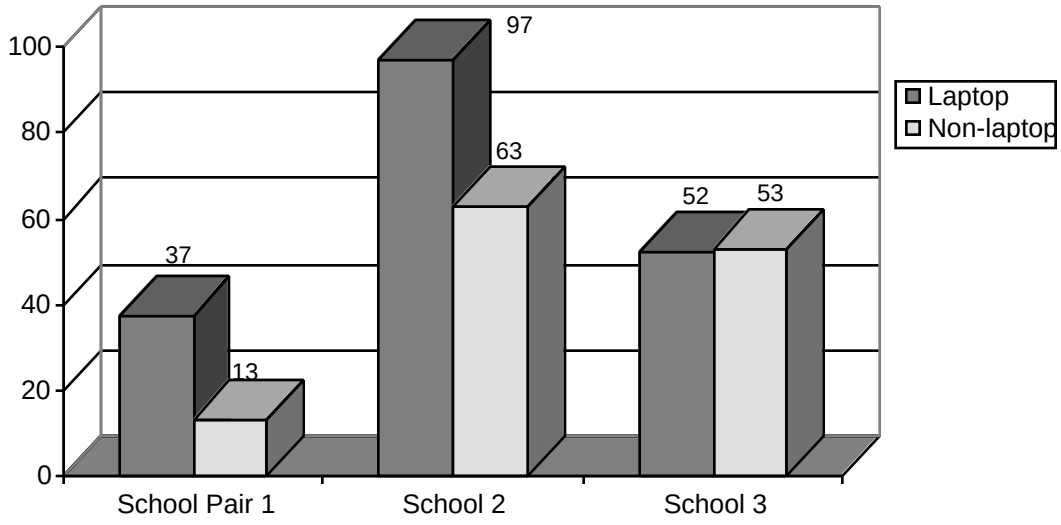
Figure 9: Frequency of home computer use (student report)



Duration

How long students spend on computers on the days they use them outside of school is still quite different between Laptop and Non-Laptop groups. At two of our three matched sites, Laptop students spend far longer on the computer than their Non-Laptop counterparts, up to three times as long at one school:

Figure 10: Average daily computer use outside of school, in minutes

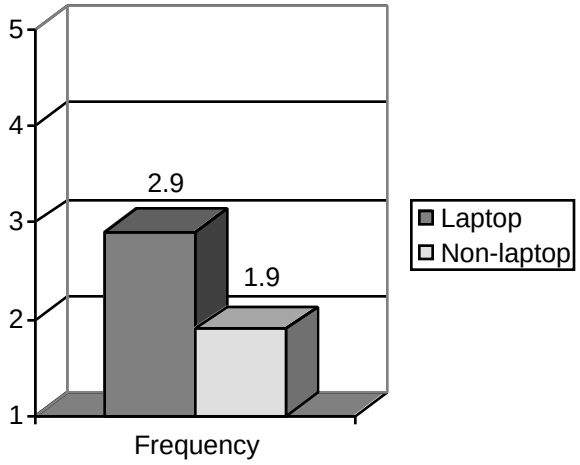


Note also that Laptop students at school pair 1 and school 2 did not log any weekend days, unlike the rest of the groups. Their reports of longer periods on computers all occurred after school on weekdays, when they had less time at home.

Internet Use

Again, while both Laptop and Non-Laptop students have similar access to the Internet at home and identical access within classrooms (see above), the use they make of that access differs significantly. Laptop teachers report that their students use the Internet in their classes about once a week on average; Non-Laptop teachers say about once a month. Differences are statistically significant.

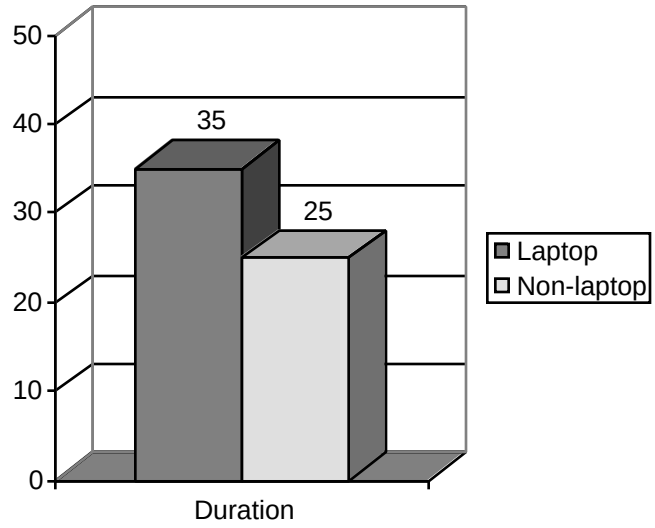
Figure 11: Average frequency of student internet use (teacher report)



(Scale: 1-never; 2- once a month or less; 3-about once a week;
4-a few times a week;5-almost every day)

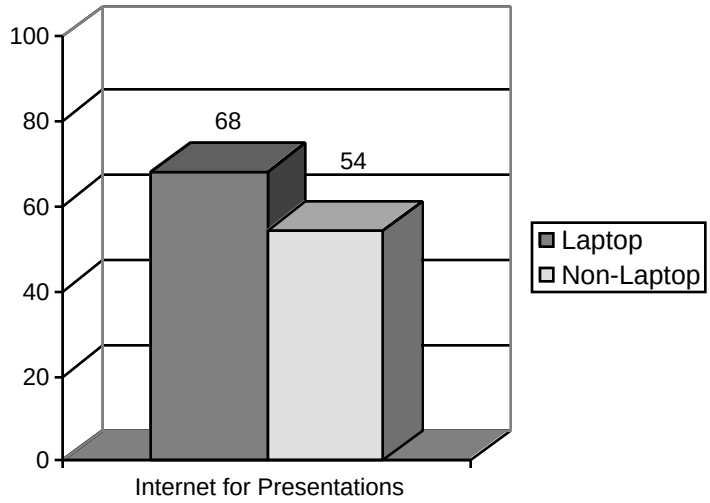
In addition, how long students spend using the Internet once they begin also differs significantly. Laptop students use the Internet in class for periods almost 50% longer than their Non-Laptop counterparts:

Figure 12: Average duration of a single session using the Internet, in minutes



Laptop students also report using the Internet to prepare presentations more often than Non-Laptop students. The difference, again, is statistically significant:

Figure 13: Percent of students reporting Internet use for presentations



While student access to computers and to the Internet has grown more similar for Laptop and Non-Laptop groups, the use students make of that access continues to differ substantially.

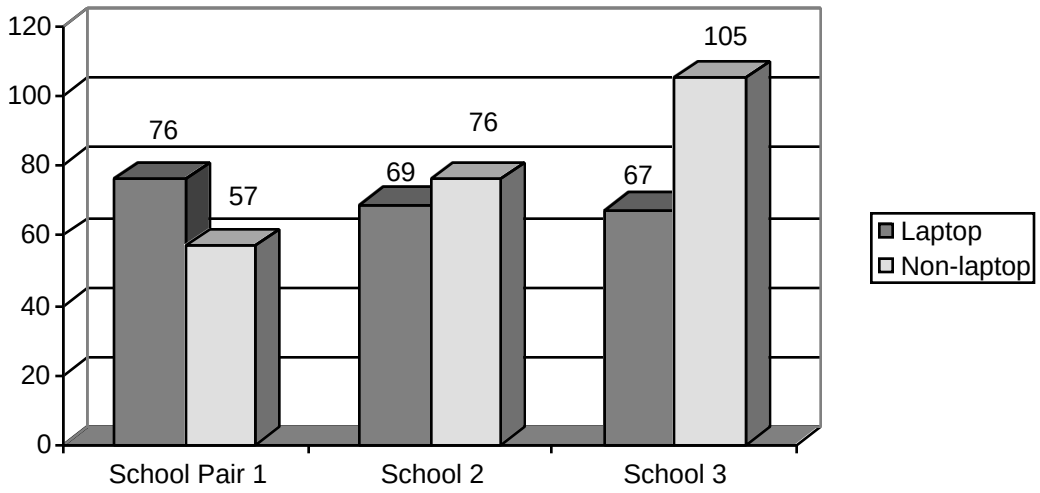
Homework

Our findings on homework in Year 3 differ from our findings in the second year of our research. Several differences in research approach may have contributed to these changes. Data on homework in Year 2 were gathered through shadowing students and conducting daily interviews, while data in Year 3 were obtained through individual and unsupervised student logs. Because of the intensive nature of a shadow study, data in Year 2 reflected information from a total of 16 Laptop and Non-Laptop students; data on homework in Year 3 come from 379 students. Finally, Non-Laptop students had greater access on average to computers in Year 3 than they did in Year 2, and our findings certainly reflect this change.

Amount of homework

On average, Non-Laptop teachers report assigning more minutes of homework each week (169 minutes) than do the Laptop teachers (159 minutes). At two of our three matched sites, Laptop students also report spending less time on homework than their matched Non-Laptop counterparts. (Note again that Laptop students at School Pair 1 and School 2 did not log any weekend days, unlike the rest of the groups).

Figure 14: Students' average daily homework, in minutes (student report)



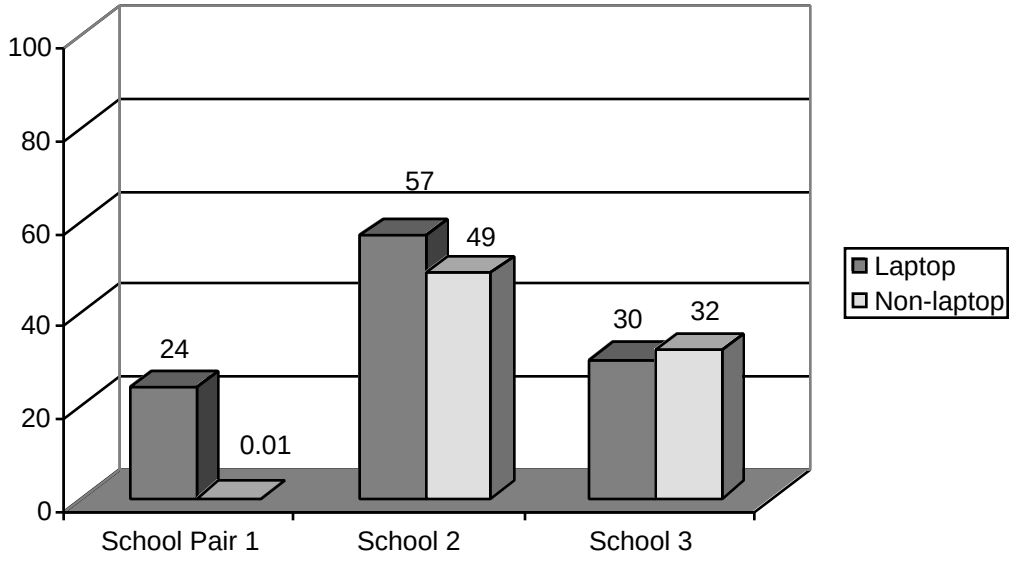
These measures reflect the amount of homework assigned in minutes, i.e., how long it took students to complete their homework. We also have evidence that Non-Laptop teachers assigned homework more frequently than their Laptop counterparts. Roughly half (52%) of Non-Laptop teachers' logged class periods included a homework component, while only one-third (36%) of Laptop teachers' logged classes did.

Homework on computers

We did find, however, that at two of three schools Laptop students completed a greater percentage of their homework on the computer than did Non-Laptop students, even though both groups average more than one computer at home. Because we are measuring

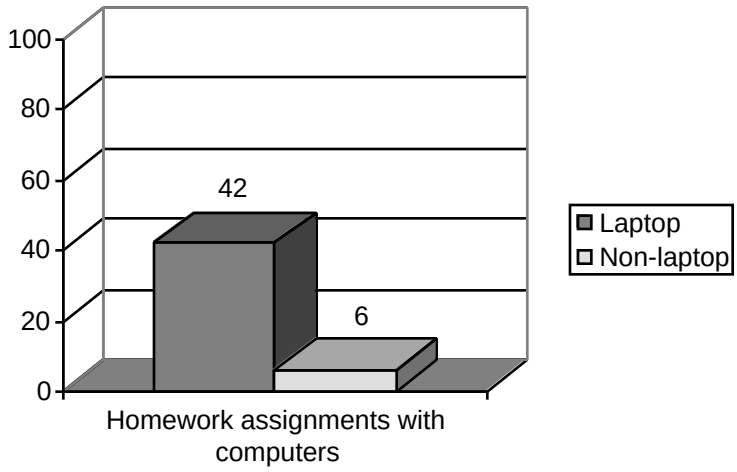
homework by the amount of time it took to complete it, rather than what students were actually asked to do, it may be that Laptop students have similar assignments but simply complete their homework more efficiently by using their computers.

Figure 15: Percentage of all homework completed on computers (student report)



Use of computers for homework seems to be encouraged by Laptop teachers; our teacher logs show that Laptop teachers assigned homework which involved computer use seven times more often than Non-Laptop teachers.

Figure 16: Percentage of homework assigned which involved computer use

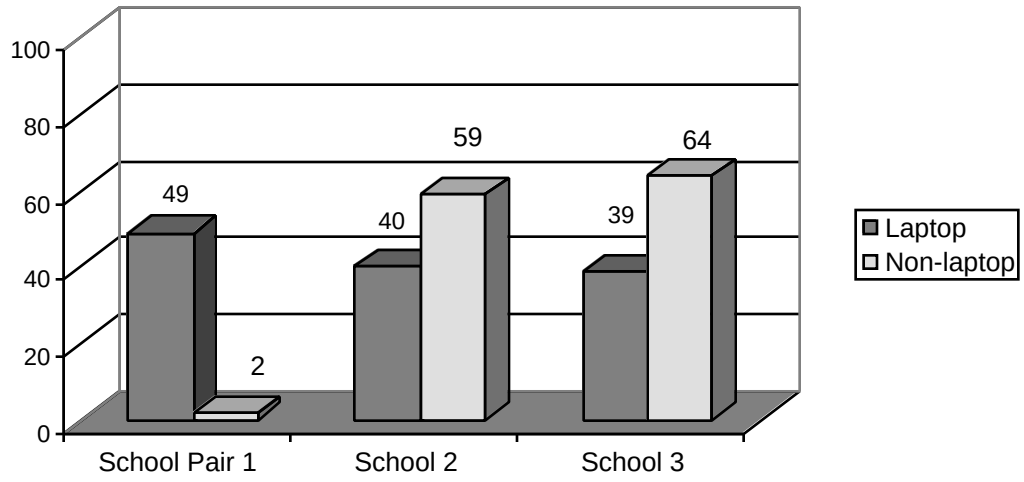


Again, then, Laptop teachers may be considering the effect of computer use when estimating how much time their homework assignments might require.

Outside-school computer use and school-related tasks

In two of three sites, we found that Laptop students spent a smaller percentage of their overall computer time working on school-related assignments than did Non-Laptop students. In contrast, for Year 2, we found that Laptop students spent a greater percentage of their out-of-school computer time working on school-related assignments than did the Non-Laptop students.

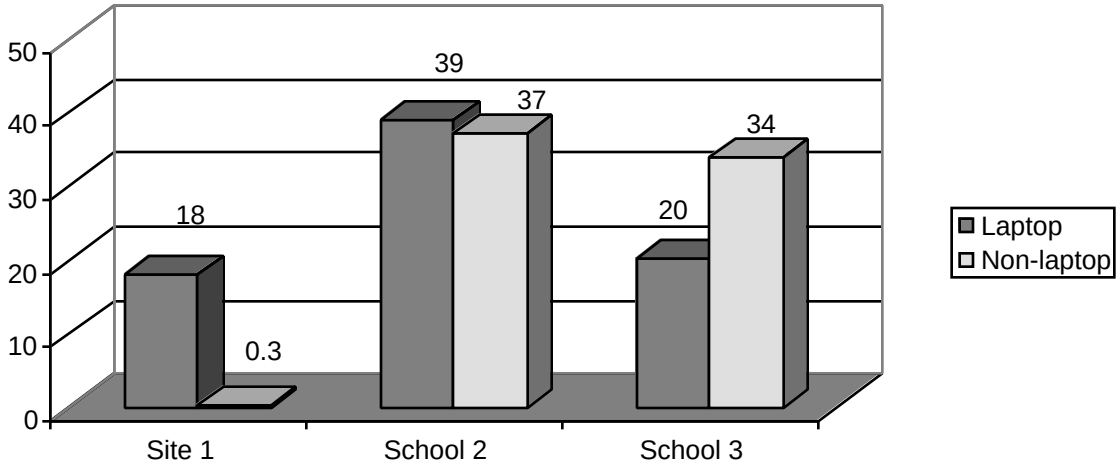
Figure 17: Percentage of outside-school computer use related to schoolwork:



At two of three sites, then, Laptop students are spending a large amount of time on their computers for work that is not directly related to school.

However, it is also important to note that at two of the three sites, Laptop students actually spent *more* minutes per day on average on their computers completing school-related tasks than did their Non-Laptop counterparts. Because they spent so much time on their computers in general, the percentage of time that is school-related shrinks.

Figure 18: Average minutes per day spent on the computer doing school related tasks

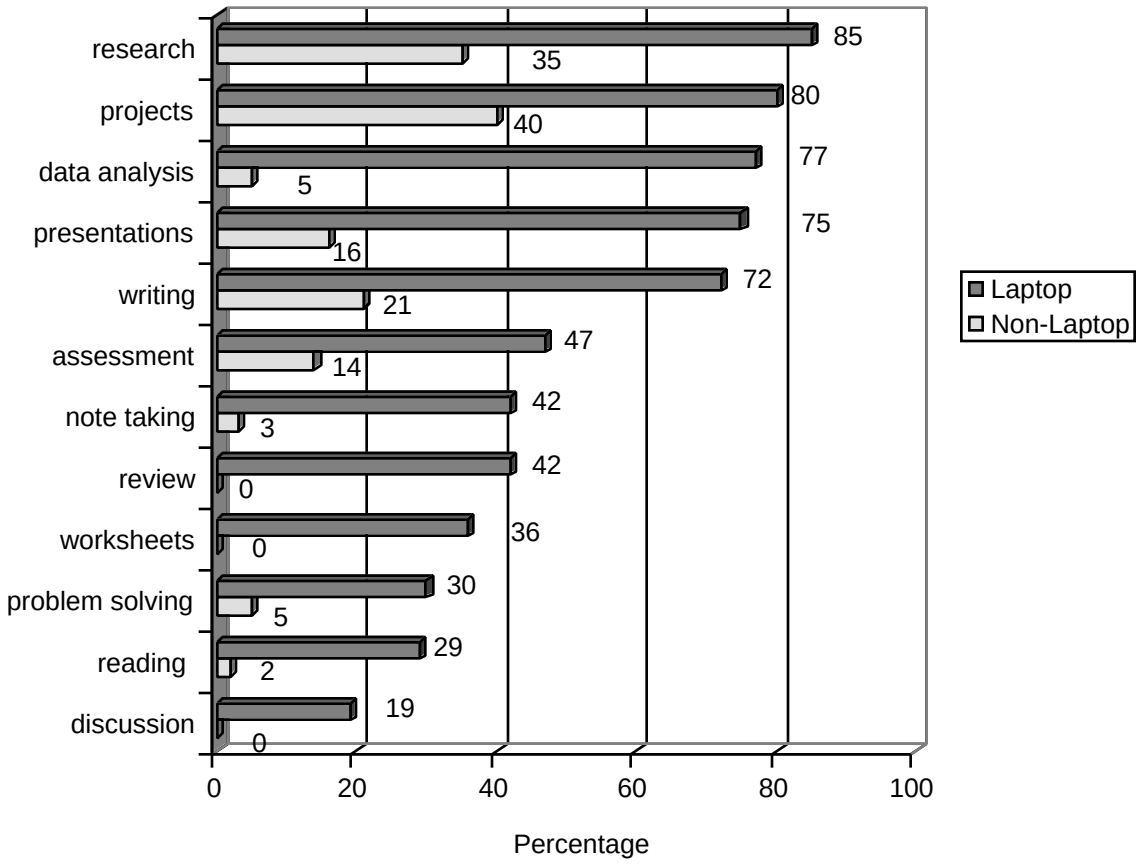


Activities and Subjects

Computer use by activity

According to their classroom logs, Laptop teachers employ computers far more often in a wide variety of tasks than do their Non-Laptop counterparts. Each time they recorded a particular classroom activity, we asked teachers to indicate if they used computers to complete that task. In every case, Laptop teachers used computers far more regularly.

Figure 19: Percentage of time classroom activities involve computer use (teacher report)

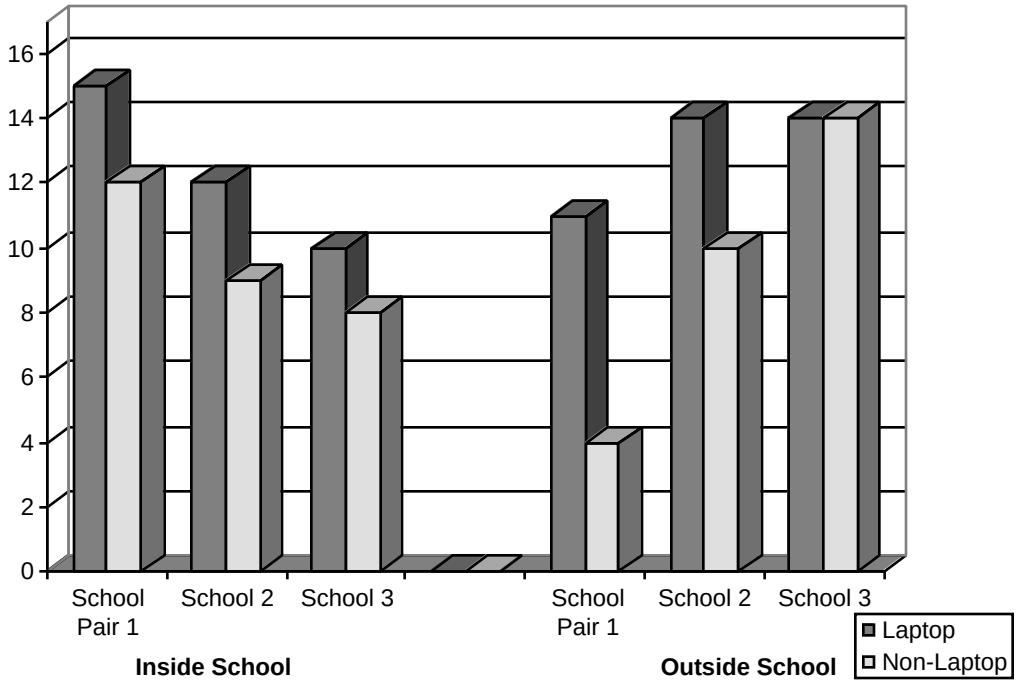


In almost all cases, Laptop students also recorded a wider variety of uses for their computers during the three days they kept logs for us. Students recorded what they did on their computers both inside and outside of school, and we coded their responses into 17 categories. These categories included presentations; research; writing (composing); word processing; database work; assessment; taking notes; email; Internet surfing; chat room participation; web page design; playing games; graphics; using subject-specific software; computer studies; "homework" (when content was unspecified); and "other," which included non-specific responses (i.e., "work," "assignment") and responses that

were not frequent enough to code ("doing translations", vocabulary, spelling, playing music, monitoring, etc.)

When we examine student computer logs for activities during school, in each case laptop students record a larger variety of computer uses than their non-laptop counterparts, and a larger number of "other" activities as well. When we examine the logs for computer time outside of school, Laptop students at School Pair 1 and School 2 again report a wider variety of computer uses than their Non-Laptop counterparts, while Laptop and Non-Laptop students at School 3 record the same number of different activities. Again, Laptop students also indicated a larger number of responses we coded as "other."

Figure 20: Number of different student activities coded



How students divided their time among these various activities is harder to categorize. Our analysis of the logs is based on number of incidences of a particular activity recorded, rather than the duration of any one activity. That is, if a student spends 10 minutes surfing the Internet and 60 minutes doing homework, these activities still get 1 count each for that day. From this analysis, then, we cannot generalize about the amount of time spent, but rather the number of discrete times a particular activity was performed.

In general, both Laptop and Non-Laptop students indicate that, inside of school, academic activities are performed most often. These activities include writing, research, assessment, and presentations. Outside of school, as we indicated above in the section on homework, Laptop students at two sites report a larger percentage of non-academic activities than do their Non-Laptop counterparts. However, again, since this measure does not reflect the duration of a particular activity, and Laptop students spend longer

periods of time on their computers anyway, a larger percentage here does not necessarily indicate a greater amount of time.

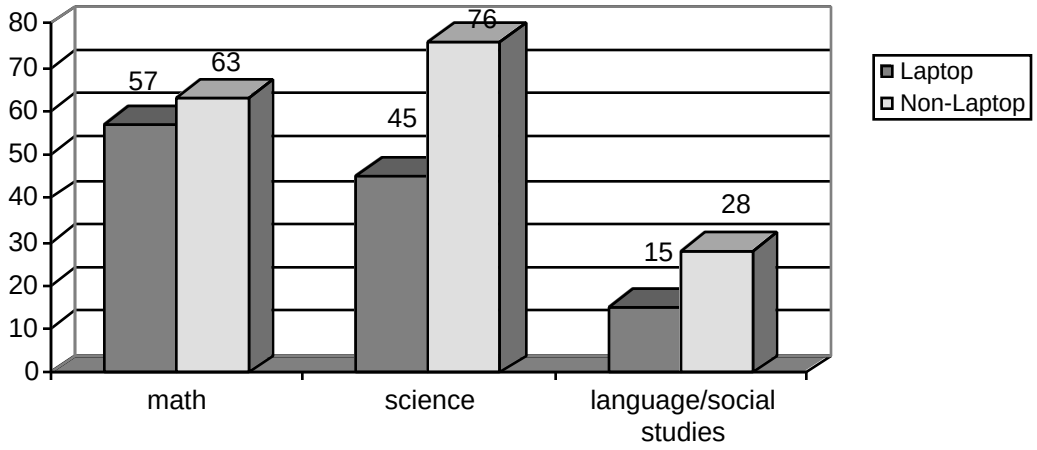
Table 5: Top three computer activities by site, as a percentage of all discrete uses

		Activity 1	Activity 2	Activity 3
Inside School				
School Pair 1	Laptop	Email (25%)	Other (12%)	Internet (8%)
	Non-Laptop	Word processing (19%)	Email (18%)	Writing (16%)
School 2	Laptop	Writing (30%)	Research (20%)	Presentations (18%)
	Non-Laptop	Research (41%)	Writing (36%)	Presentations (8%)
School 3	Laptop	Assessment (44%)	Other (18%)	Writing (16%)
	Non-Laptop	Presentations (23%)	Charts (18%)	Writing (15%)
Outside School				
School Pair 1	Laptop	Email (24%)	Writing (23%)	Games (14%)
	Non-Laptop	Email (70%)	Games (17%)	Internet (9%)
School 2	Laptop	Internet (18%)	Email (15%)	Games (15%)
	Non-Laptop	Writing (23%)	Internet (20%)	Research (13%)
School 3	Laptop	Games (19%)	Homework (16%)	Surfing (16%)
	Non-Laptop	Writing (17%)	Presentations (15%)	Internet; Games (12%)

Computer use by subject

Students were asked if they had *ever* used a computer during school in each of their core subjects this year. Note that this measure does not reflect how frequently computers are used in any given subject, but rather whether they have ever been used at all, even just once. Again, Laptop students' computer use was significantly higher in each subject. However, different subjects reflect different computer uses, revealing that even with Laptop schools computer use varies markedly by subject.

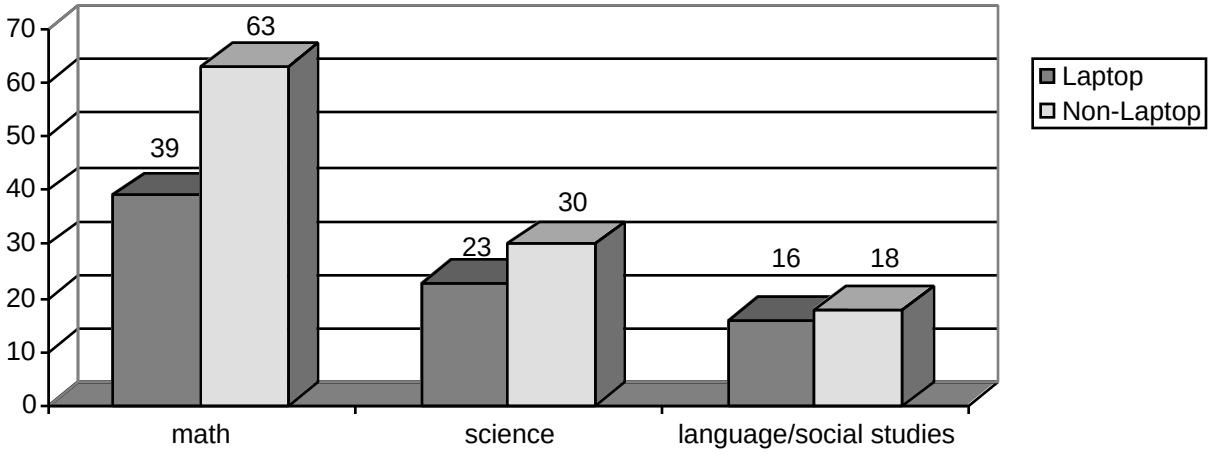
Figure 21: Percent of students who say they have NEVER used a computer in these subjects during school:



For both groups, computer exposure is most prevalent in language and social studies classes, and least prevalent in math. Only one in five Non-Laptop students had ever used a computer in their math classes, and less than half of the Laptop students had done the same. In each case, differences between Laptop and Non-Laptop students are statistically significant.

However, computer use by subject changes dramatically when students are asked about their computer use outside of school. Both Laptop and Non-Laptop students are utilizing their out-of-school computer resources to do homework in subjects in which they may never use a computer during class time.

Figure 22: Percent of students who say they've NEVER used a computer to do homework in these subjects:



While only one in four Non-Laptop students has ever used a computer during their science classes, for example, almost three in four have used a computer to complete science homework. In fact, this utilization of out-of-school computer resources erases almost all the statistically significant differences between Laptop and Non-Laptop students on this measure. In science, English, and social studies/history, there is no significant difference between the two groups: statistically, the same percentage of Laptop and Non-Laptop students have never used a computer in these subjects for their homework. Only in math does the difference between the two groups remain statistically significant.

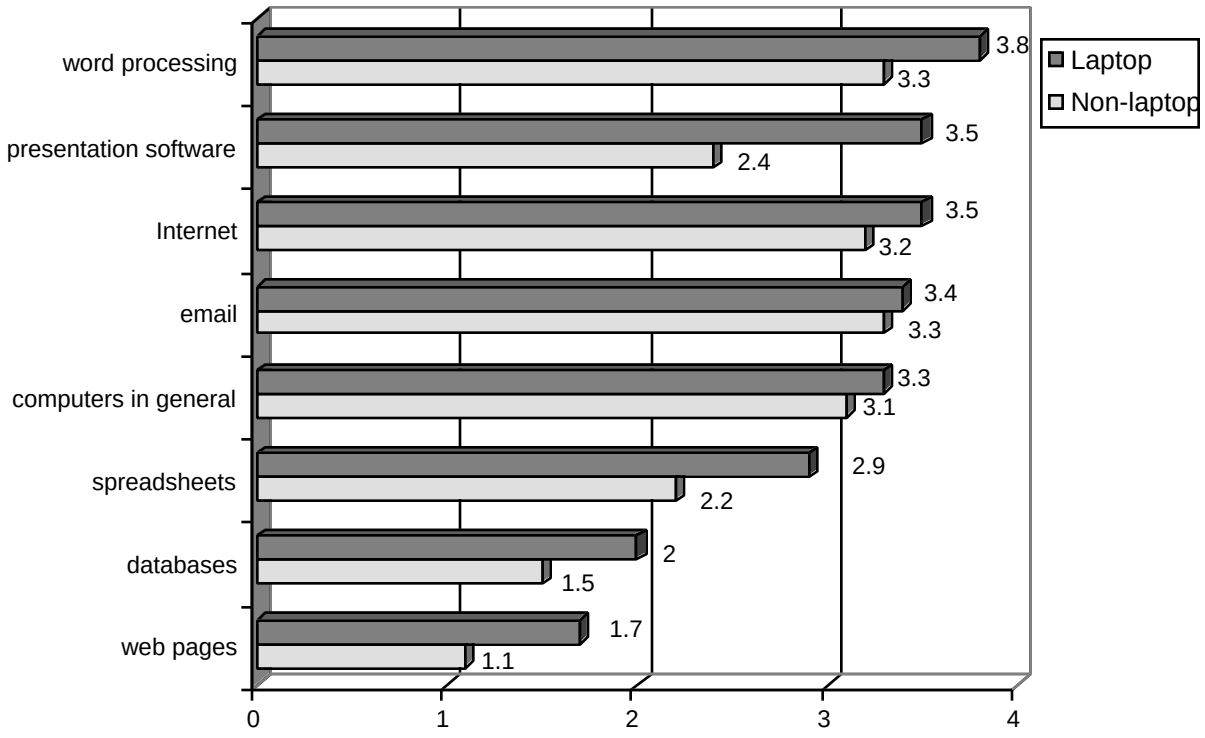
Both groups of students are using their computer resources at home within specific subjects at greater rates than they do at school. Even when their teachers are not utilizing computers in particular classes, students seem to be transferring and applying their computer skills at home, finding additional uses for their computers outside school to accomplish school work.

STUDENTS' TECHNOLOGY SKILLS

While access and exposure to technology have evened out as Non-Laptop students have gained technology resources, Laptop students still seem to use computers at much higher rates, especially in school. This greater use seems to result in students with greater technology skills.

We asked students to rank their expertise on various computer applications. In each case, Laptop students' rankings were higher, and in all but one case (email), these differences were statistically significant:

Figure 23: Students' self-assessment of technology skills



0-I never used this application; 1-I always need help; 2-I sometimes need help:
3-I rarely need help; 4-I never need help; 5-I help other people; I am an expert

While Non-Laptop students have greater exposure to computers than ever before, computer use is still significantly more intense for Laptop students, most noticeably in school. Laptop students use computers more frequently, for longer periods, for a wider variety of uses, and have higher confidence in their computer skills.

IMPACT ON TEACHING

As we summarized above, findings from as early as the first year of the Laptop program indicated that the laptops may serve as a catalyst for teachers to pursue more constructivist teaching. These findings are similar to those of Hank Becker, Ron Anderson and their associates at the University of California at Irvine in their large survey study, *Teaching, Learning, and Computing: 1998, A national survey of schools and teachers*. This study examined teachers' use of computers, their classroom pedagogy, and their school context. (For further information, see the study website: www.crito.uci.edu/tlc/html/tlc_home.html.) It is reassuring that the conclusions of other researchers have found a strong relationship between access to computers for teaching and learning and constructivist strategies in the classroom. They note, however, that access is only one element of the relationship; that training in computer use, and the subject matter in which it is used, also contribute to the strength of the relationship.

Constructivist pedagogy holds that students, not teachers, become the center of instruction, and that students' interests lead their inquiries as they seek to construct their own knowledge of the world. While teachers certainly interpret and use constructivist theory in different ways, aspects of constructivist pedagogy often include:

- √ discussion rather than lecture;
- √ teachers facilitating students' own investigations rather than imparting knowledge;
- √ emphasis on thinking skills over content;
- √ individual and student-led inquiry rather than whole class activities;
- √ simultaneous multiple activities rather than one activity for all;
- √ small group and individual work rather than whole group work;
- √ emphasis on depth over breadth;
- √ content of a lesson following from students' interests rather than a pre-set curriculum;
- √ teachers learning from students and students acting as teachers;
- √ collaborative work;
- √ a departure from textbooks as the principal knowledge source;
- √ an emphasis on long term student projects; and
- √ authentic assessment, which evaluates student products rather than using tests to gauge learning.

CURRENT PRACTICE

We asked our 47 Laptop and Non-Laptop teachers to describe their own teaching philosophies by indicating their level of agreement with various statements about

pedagogy (see appendix for a copy of this questionnaire). We also asked each group about various aspects of their teaching practice, both currently and three years ago.

The results were more complex than our previous research indicated. On most of our measures applied in Year 3, there were no statistically significant differences between current philosophies or practices of our matched Laptop and Non-Laptop teachers. For each group, the level of agreement with a constructivist philosophy was most often just off the center, or neutral rating, slightly in favor of the constructivist pedagogy, but rarely more than one full scale point off the midpoint.

Even though differences between the two groups were not statistically significant, on most measures (28 of 34 different items, or 82%), Laptop teachers indicated a greater agreement with or practice of constructivist pedagogy than Non-Laptop teachers. Measures on which Laptop teachers indicated a more constructivist philosophy or practice included:

- teacher as facilitator rather than expert (several measures);
- emphasis on thinking skills over content (several measures);
- interest-driven curriculum over specific content;
- multiple activities and movement around the classroom (several measures);
- use of student-driven curriculum (several measures);
- use of student projects (several measures);
- not using homework to answer textbook questions;
- choosing complex ideas over those easily graspable;
- assessing student products rather than tests (authentic assessment);
- collaborative work;
- teacher as learner and student as teacher; and
- student-led inquiry (several measures).

The few measures (5 of 34, or 15%) where Non-Laptop teachers indicated a greater level of agreement with or more frequent practice of constructivist pedagogy were:

- choosing depth over breadth in curriculum content;
- downplaying the need for a quiet classroom;
- allowing students to help establish their assessment criteria;
- allowing students to review and revise their own work; and
- not assigning students to answer questions from their textbooks.

Using the textbook as a primary guide through units was exactly the same for each group, at “about once a week.”

While the findings point in the predicted direction for Laptop teachers, they do not achieve a level of statistical significance. With a larger number of teachers in our sample, however, many of the differences between the two groups on these items would

reach statistical significance. It is worth noting the consistency of the findings for Laptop teachers this year with their reports from previous years' research.

CHANGES IN PRACTICE

Teacher-Reported Change

However, when we examined reported change over time, we discovered that Laptop teachers' practices had changed significantly between three years ago and now. In almost all cases, a greater percentage of Laptop teachers indicated a change in practice between three years ago and now, when compared to their Non-Laptop counterparts. In each case, the change was toward more constructivist teaching.

Table 6: Percentage of teachers who indicate they've changed the frequency of these practices/types of assignments from three years ago to this year:

	Laptop	Non-Laptop
Students teach other students	90%	46%
Students teach teachers	83%	40%
Students explore topic on their own	80%	46%
Students work on long projects	80%	38%
Evaluate products not tests	75%	40%
Students work in groups	70%	23%
Multiple activities	67%	27%
Students review own work	60%	31%
Students select own research areas	60%	31%
Students write more than a page	60%	38%
Move away from direct instruction	42%	13%
Use textbook as primary guide less often*	33%	40%
Let student interest influence topic*	33%	40%
Students answer textbook questions less often*	30%	38%

* In these three cases, a larger percentage of Non-Laptop teachers report change.

As displayed above, in 10 of 14 cases, over half the matched Laptop teachers noted that they changed the frequency of a particular practice between three years ago and now. In contrast, in no case did more than half the Non-Laptop teachers report a change in practice.

Degree of Change

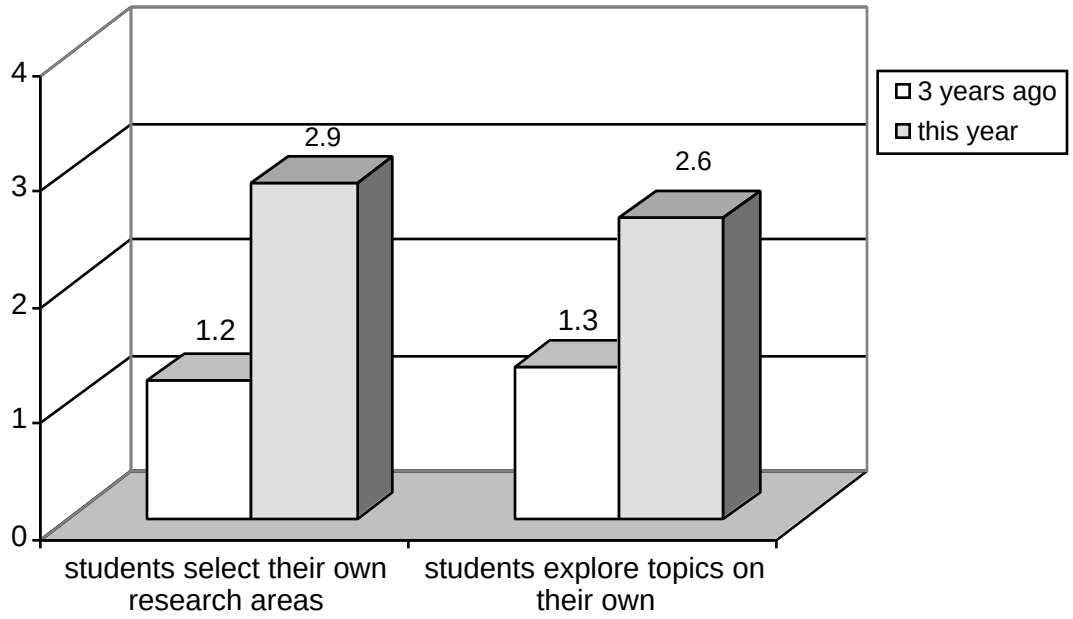
On each of the measures described above, teachers indicated on a five-point scale how frequently they practiced a particular constructivist approach three years ago and currently. In almost all cases, the degree of change over time that Laptop teachers indicated as a group was statistically significant. This was not the case for Non-Laptop teachers. While Non-Laptop teachers reported some change, as a group none of the change was significant. Often, Laptop teachers report that three years ago they employed a particular constructivist practice *less often* on average than Non-Laptop teachers – but *more often* currently, resulting in a larger degree of change.

These differences in the degree of change Laptop and Non-Laptop teachers report over time is especially important when we consider that these are findings from within our matched group. That is, at two of three sites, these Laptop and Non-Laptop teachers are teaching within the same school, and, with the exception of the Laptop Program, they have access to the same resources. The Laptop Program itself, then, may be acting as a catalyst for change.

All of the differences reported below are statistically significant.

Matched Laptop teachers' change in practice

Figure 24: Student-led inquiry

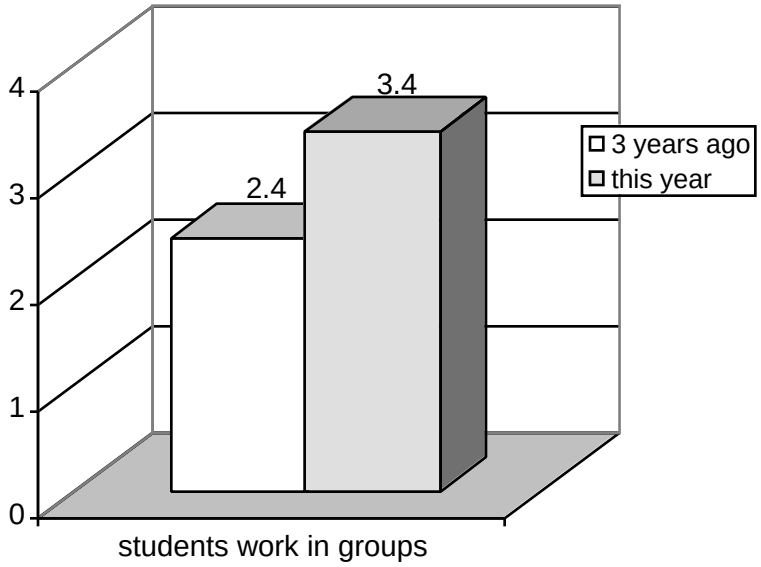


(Scale: 0-never; 1-rarely; 2-about once a month; 3-about once a week; 4-almost every day)

In two different aspects of student-led inquiry, Laptop teachers report that their practice has changed significantly since the implementation of the Laptop Program. Teachers allow students to select their own research areas almost once a week, compared with only

a few times a year three years ago, and their students explore these topics on their own much more frequently as well.

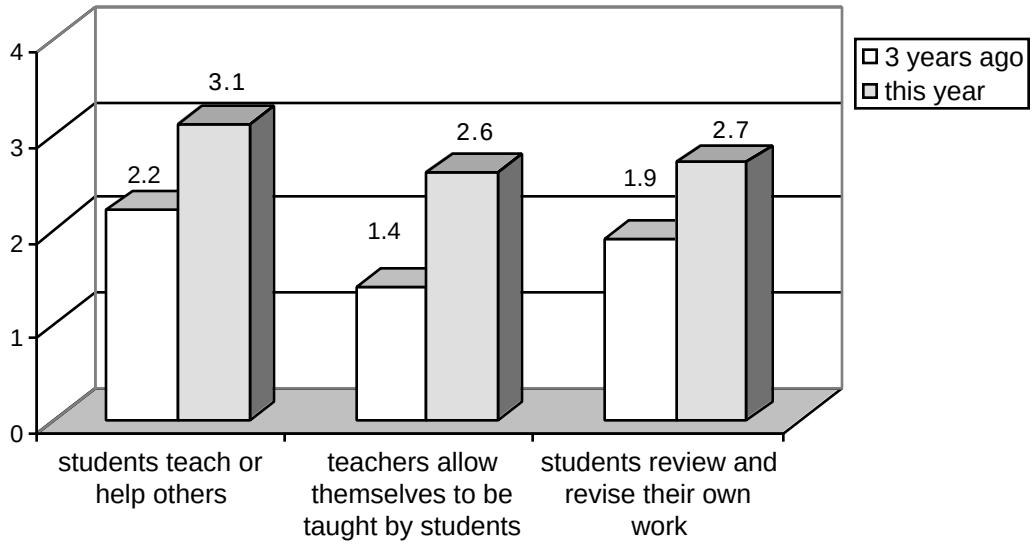
Figure 25: Collaborative work



(Scale: 0-never; 1-rarely; 2-about once a month; 3-about once a week; 4-almost every day)

Laptop teachers incorporate group work for students several times a week on average, compared to a few times a month previously.

Figure 26: Role changes

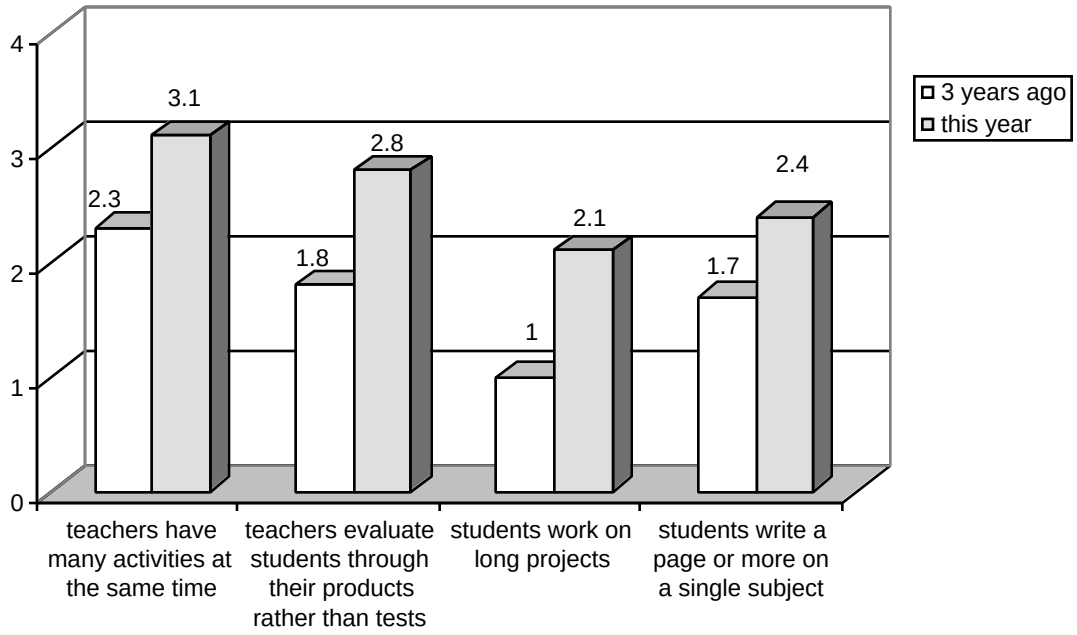


(Scale: 0-never; 1-rarely; 2-about once a month; 3-about once a week; 4-almost every day)

Laptop teachers report a variety of role changes in their classroom since the implementation of the Laptop Program. Students now teach other students more

frequently than before, and they also review and revise their own work more often. The largest change occurred in how often teachers allow themselves to be taught by their students. In fact, this was the only measure on which Non-Laptop teachers reported statistically significant change as well, from an average of 1.9 three years ago to 2.5 on our scale. However, the degree of change is still larger for the Laptop teachers.

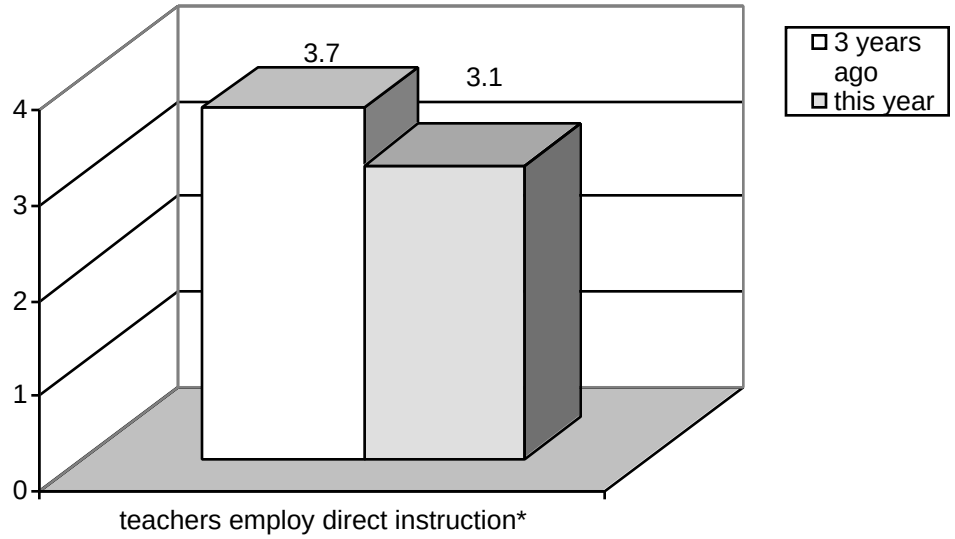
Figure 27: Activity structure



(Scale: 0-never; 1-rarely; 2-about once a month; 3-about once a week; 4-almost every day)

Laptop teachers report a variety of changes in their classroom activity structure. As we heard in our first two years of research, Laptop teachers report they are doing more project-based work and that students are writing more often than before. Teachers also say that they allow simultaneous multiple activities more often, and that they employ at least one element of authentic assessment—assessing students based on actual products rather than tests.

Figure 28: Moving away from traditional teaching



(Scale: 0-never; 1-rarely; 2-about once a month; 3-about once a week; 4-almost every day)
*defined on this questionnaire as: review, teach, guided practice, individual practice

Non-Laptop teachers report they employ direct instruction almost every day (3.8 on our scale), and that this has not changed at all over the last three years. In contrast, Laptop teachers are employing traditional teaching methods less often than they were before, only once a week on average.

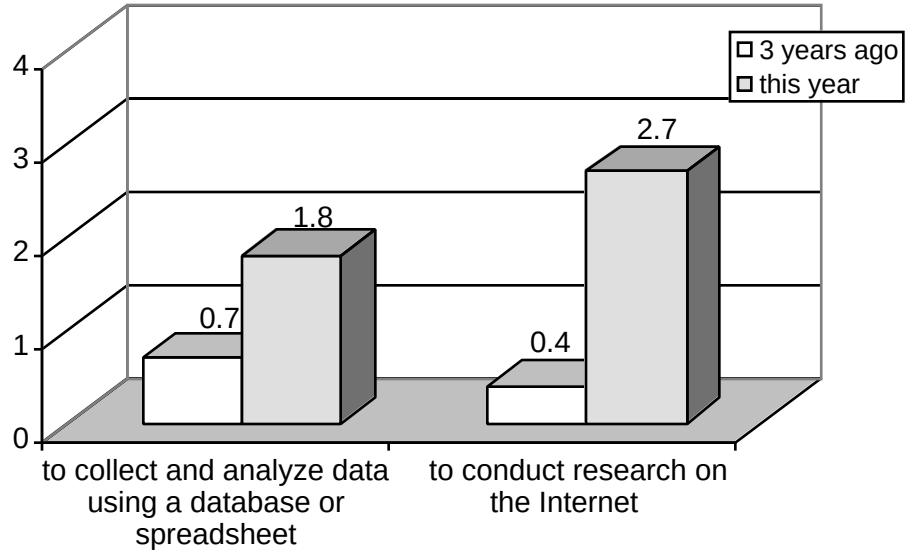
As seen above, our research indicates that Laptop teachers have changed their teaching methods significantly over the last three years, while Non-Laptop teachers have remained much the same in their practice.

Changes in Computer Use

We also asked teachers to reflect on their uses of computers three years ago and currently. We asked them how often they had students use computers to analyze data, facilitate research, conduct collaborative projects, give multimedia presentations, create documents and other tasks. Results were similar: On many items, Laptop teachers had made significant changes in their practice between three years ago and now, while Non-Laptop teachers remained about the same. All the differences outlined below are statistically significant.

Changes in student uses of computers:

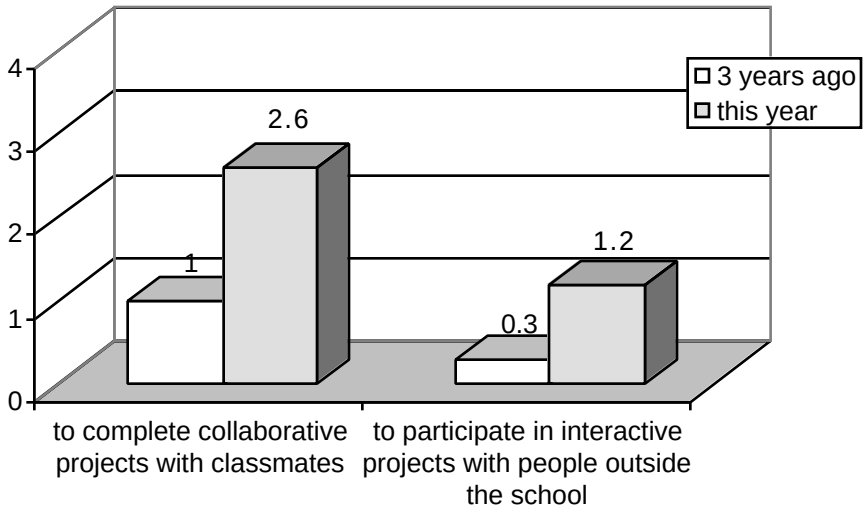
Figure 29: Research and data analysis on computers



(Scale: 0-never; 1-rarely; 2-about once a month; 3-about once a week; 4-almost every day)

Laptop teachers have made significant changes in how often they use computers for student research and data analysis. In fact, research on the Internet showed the greatest changes of any measure, from closer to "never" than "rarely" three years ago to almost once a week in the current year.

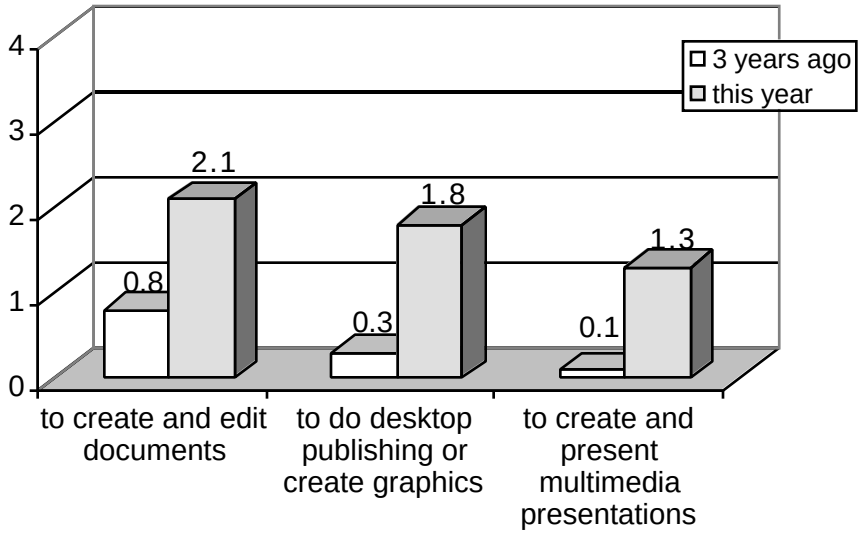
Figure 30: Collaborative and interactive projects on computers



(Scale: 0-never; 1-rarely; 2-about once a month; 3-about once a week; 4-almost every day)

Laptop teachers have also made significant changes in the frequency with which they employ computers for collaborative student projects, both within and outside of school.

Figure 31: Documents, graphics, and multimedia presentations on computers



(Scale: 0-never; 1-rarely; 2-about once a month; 3-about once a week; 4-almost every day)

Laptop teachers have made significant changes in how often they ask students to use computers to prepare documents, graphics, and multimedia presentations. Non-Laptop teachers also made significant changes in how often they ask their students to create and edit documents on the computer: Their average went from 1.1 three years ago to 1.5 this year. This is the only measure on which Non-Laptop teachers made statistically significant changes in computer use.

Laptop teachers also reported their students were publishing web pages, writing computer programs, and using content-specific applications for drill and practice more often now than three years ago. However, these changes were not statistically significant and uses in these categories were very minimal—between rarely and never in all three cases. (The same is true for Non-Laptop teachers in each case.)

While differences in current practice were not statistically significant between Laptop and Non-Laptop teachers, in all but one case (writing computer programs) Laptop teachers reported their students used computers more often for these tasks than Non-Laptop teachers.

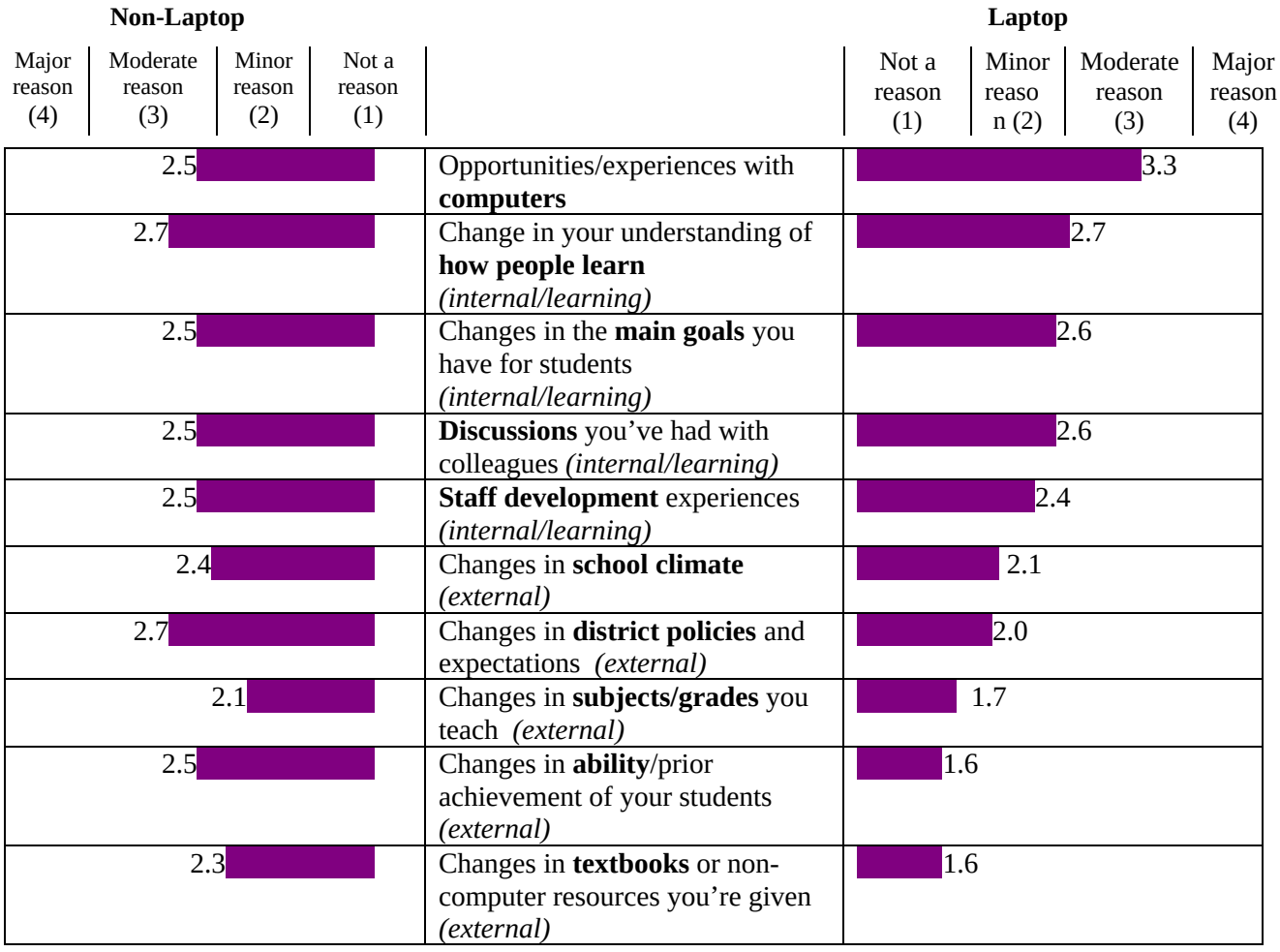
CATALYSTS FOR CHANGE

Catalysts

After we asked teachers to consider how they had changed their practice over the last three years, we wanted to know to what they might attribute these changes. We asked them to rate the importance of ten different catalysts for change on a four-point scale, where 1 was "not a reason" and 4 was "a major reason."

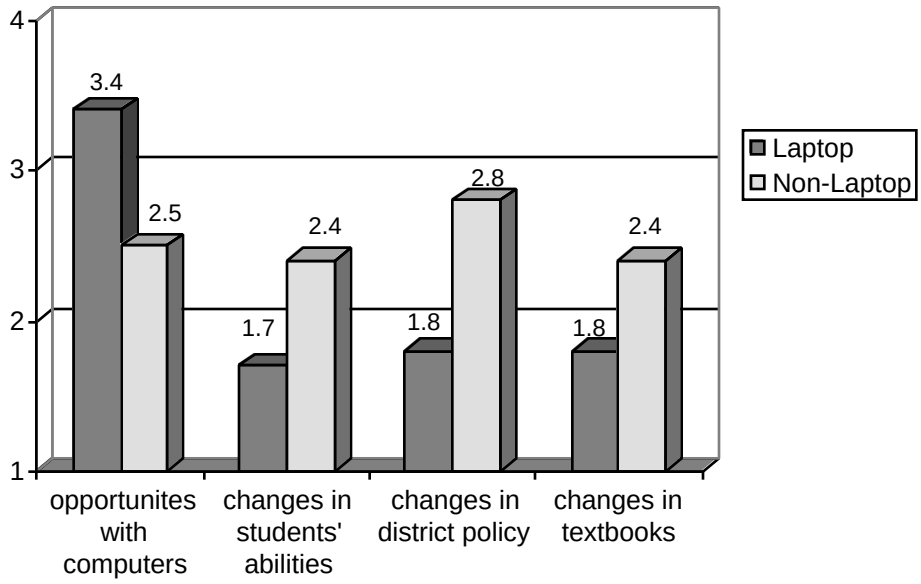
When we look at the answers from our Laptop teachers, an interesting pattern emerges. The reasons for change they rate the highest are those that have to do with opportunities for learning and changes in their attitudes or understanding—that is, changes that are more internal in nature. The reasons they give the least weight to are those things that are not in their own control, such as district policies—things that are external to them. In contrast, the Non-Laptop teachers felt they had been most affected by a variety of factors, both internal and external.

Figure 32: Teachers' ratings of catalysts for change, internal/external locus of control



There were four items on which differences between our whole Laptop group and our Non-Laptop teachers were statistically significant. It is interesting to note that for the majority of our external catalyst items, or items that were not within the realm of the teachers' control, Non-Laptop teachers' ratings were significantly higher than Laptop teachers'. Figure 34, below portrays the items where the difference between Laptop and Non-Laptop teachers was statistically significant:

Figure 33: Rating reasons for change where differences were significant



(Scale: 1-not a reason; 2-minor reason; 3-moderate reason; 4-major reason)

These differences are interesting because they reveal the controlling issues that cause changes in teaching and learning in the classroom. When we talk about teacher self-efficacy—the sense of control that teachers have over their responsibilities for instruction and their management of student learning—the Non-Laptop teachers often focus on external issues, the external locus of control. For the Non-Laptop teachers, activities beyond their control—such as district policy, student abilities, and textbooks—may have more to do with the changes that have taken place in their classrooms than other issues within their control. Laptop teachers, in contrast, tend to see the change in their pedagogy as a consequence of what they do. Laptop teachers locate the impetus for change internally.

Computers' Role in Changes Over Time

We also asked teachers to indicate whether computers had played a role in any change within particular classroom practices. On all 14 items, over half the Laptop teachers who indicated they had made changes in this practice felt that computers had played a role. In

fact, in 12 of 15 items, over three-fourths of the teachers felt computers had played a role in their changing practice.

Table 7: Percentage of Laptop teachers reporting a change in practice who indicate that computers played a role in that change

Changing Classroom practice	Percent reporting computers impact on change
Evaluate student products vs. tests	100%
Teachers being taught by students	100%
Students explore topics on their own	94%
Students review own work	92%
Moving away from direct instruction	90%
Students choose own research areas	90%
Students work on long projects	87%
Students work in groups	86%
Multiple activities	83%
Student interests influence topics	82%
Writing page or more	80%
Students teach other students	79%

Non-Laptop teachers who made a change in their instructional practice also say that computers played a role in these changes, sometimes at even higher frequencies than the matched Laptop group. While Non-Laptop teachers report changes in their practice at lower rates, those who do change attribute a role to computers just as often or more often than Laptop teachers. Computers themselves may be acting as a catalyst for change for both of our teacher groups. The kinds of instructional elements we explored in this question, for both Laptop and Non-Laptop teachers, are those related to constructivist pedagogy, where technology can support the changes desired.

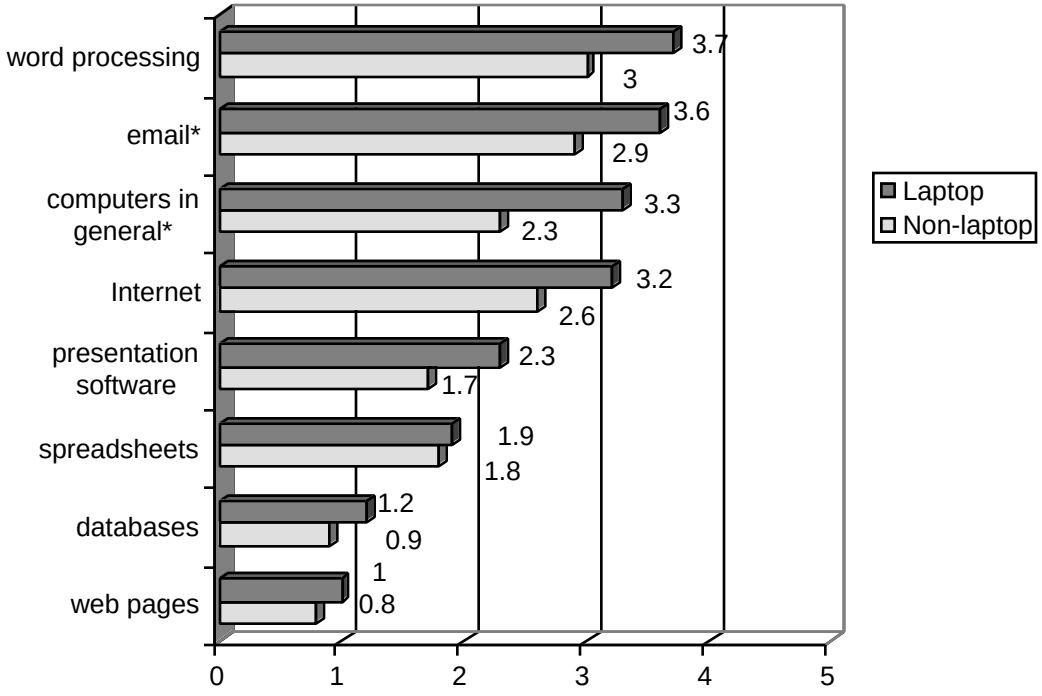
TEACHERS' TECHNOLOGY SKILLS

We asked teachers to rate their expertise with various computer applications using the same measures and scale we employed with students (see above). Interestingly, for both Laptop and Non-Laptop groups, in all cases students rated their skills more highly than their teachers did.

Laptop teachers did report a higher level of confidence in their technology skills than Non-Laptop teachers did. However, these differences were only significant in two

cases—computer use in general and email. As we reported above, Laptop students were statistically higher than Non-Laptop students in every category except email. Teachers in our matched sample seem to feel very similar levels of confidence in their technology skills. This may reflect again similar levels of access to computers and to professional development in gaining technology skills. Teachers' self-assessments are displayed in Figure 34 below.

Figure 34 : Teachers' self-assessment of technology skills



Scale: 0-I never used this application; 1-I always need help; 2-I sometimes need help: 3-I rarely need help; 4-I never need help; 5-I help other people; I am an expert. * = statistically significant

IMPACT ON LEARNING

As with every technology and almost every educational intervention, the critical question is the impact that the change can have on student learning. Why do we make changes, why make the effort, if not for the possible impact on learning? A more difficult question is how to measure the learning that is taking place. For many educators, parents, policy makers, and business leaders, the outcomes need to focus on standardized achievement measures—either national or state—that are easily comparable across schools or groups of schools. Others see a different set of outcomes that deal more with the process of learning (mastering the skills involved with learning), or they focus on more specific issues related to content. We have selected several student learning issues for the research we have undertaken, one of which, technology skills, has been discussed earlier in this report. The following section addresses our findings in three additional areas: the impact of laptop use on students' writing, the impact of the Laptop Project on standardized assessments, and the laptops' impact on measurements of student learning strategies.

WRITING

As early as the first year of the Laptop program, teachers we interviewed praised the effects they felt the laptops had on student writing. During our second year of research, when asked which academic skill had been most directly affected by laptops, teachers identified writing as the instructional area most influenced by full-time access to laptop computers. Respondents offered a range of reasons, outlined below, as to why the laptops had made a difference.

In Year 2, teachers reported that Laptop students wrote more than Non-Laptop students and that their writing was of higher quality. Year 2 teachers felt students' writing improved because the laptops allowed easier editing than handwritten drafts, and therefore students were more willing to edit and rewrite multiple times. Research on writing in schools indicates that the more students revise and edit, the better writers they become; laptops support these strategies in class and at home. Further, the growth in group work and project-based instruction encourages collaborative writing and peer editing. Teachers also found that they were able to comment directly on electronic versions of documents within a student's file, and students could consider and incorporate this feedback more readily. Teachers felt that grammar and spell-check programs provided immediate feedback on errors, and that students benefited from using these features. Computers also allowed for more polished and professional-looking products; some teachers felt this allowed students to take more pride in their work and encouraged students to spend more time on their writing.

In order to examine some of these teachers' hypotheses, in Year 3 we administered a standard writing activity to our three matched groups of Laptop and Non-Laptop students. We asked students in Laptop and Non-Laptop classes within the same schools to write for 30 minutes about the instructional project or activity they felt they had

learned the most from over the past year. They were asked to give reasons for their statements and to defend their answers. A total of 217 students provided us with usable responses for analysis.

Writing Prompt Content: Educational Projects

While we wanted to assess the quality of students' writing, we were also interested in what they had to say in response to our prompt. We asked them to describe the one project or activity completed this school year that they felt they'd learned the most from.

The issues covered by the student essays ranged quite broadly—in complexity, scope, creativity, and impact. Many students noted that they had learned process skills within their chosen project. For example, one student described how her group defined the problem, made an outline of questions, came up with a list of people who could answer them, went to library, did interviews, put the paper together, and prepared charts. She noted that "…we were able to work at our own pace and…we were able to choose our own topic…." "Other assignments given to us are required of all students and we are each given the exact same project." An example of an in-depth project for Non-Laptop students was a math essay and video, for which one student noted, "The facts about Newton's life didn't sink in" until [the student] was required to create a video.

The qualities that made projects inspiring to students were the choice of topics, having time to do a good job, depth of their research, and awareness of teachers' high expectations for the student. This is true for both Laptop and Non-Laptop students; however, having access to laptops often set the conditions for these qualities to take root in the classroom.

For some students, working within a group was a central positive experience. One student noted that he was challenged by working with group members who were not entirely reliable. "I learned a bit better to work with people and how to split up work that needed to be done."

Some students noted in their essays that making presentations and teaching others seems to have helped students learn. A Laptop student said that he had to "learn how to teach material to a class." A Non-Laptop student said, "Not only was I the teacher but I was also the taught.. . . to be taught and then to teach."

Some of the more proficient samples, in both the Laptop and Non-Laptop classes, showed an awareness of technology as a useful tool—as a way to organize and present information, and, in the case of the Internet, as a valuable resource and an efficient way to do research. A few students in both Laptop and Non-Laptop classes said that they could not have done their projects without computers. One of the Non-Laptop students remarked, "Computers help keep things organized." Another student commented that she had learned how to use online catalogues as well as the Internet, and that she had experimented with different search engines. In describing the activity from which he had learned the most, one student said, "I learned a great deal from this activity because many

sites had different statistics so I had to compare different sites to weed out the false information. This made me read much more information and that, in turn, helped me to memorize it better." This student explained that "weeding out false information" is better than when "you can just copy and paste your way along. You don't even have to read the information to write a report anymore. Any idiot can sound like a professional if they just copy their work off the Internet."

Among the projects that generated the clearest expressions of enthusiasm in students' essays were those that combined hardware, software, Internet inquiry, use of databases, and some kind of public presentation. These included projects on family heritage, on the Bill of Rights (using PowerPoint), and creating Civil War web pages. A few students demonstrated an awareness that computers had helped improve their writing and self-evaluation skills by facilitating their ability to review and revise their work.

Students in Laptop classes enjoyed using technology, especially when it offered a new way of doing projects. One student noted the importance of knowing how to do research electronically, in order to do the work assigned in high school and college and to avoid looking "foolish if you ask the librarian how to work the computer." Students also expressed pride in their technology skills. When describing a math project for which he researched a company, studied financial information, and created a PowerPoint presentation, one student said his project gave him a chance to "do some things I'm good at, in a class I'm not so good at."

Writing Outcomes

An independent team of ROCKMAN *ET AL* researchers conducted a blind evaluation, scoring the student essays using a standard rubric. The team used this rubric to evaluate student responses in four areas: content, organization, language/voice/style, and mechanics. Evaluators asked the following questions:

Analysis Questions for Scoring Student Writing Samples

Content:
Did the student accomplish the task set out in the prompt?
Is the project clearly explained?
Is there enough information to communicate his/her point?
Does the student defend his/her answer?

Organization
Is the essay coherent?
Does it follow a logical order?
Does the paragraphing reflect that order?

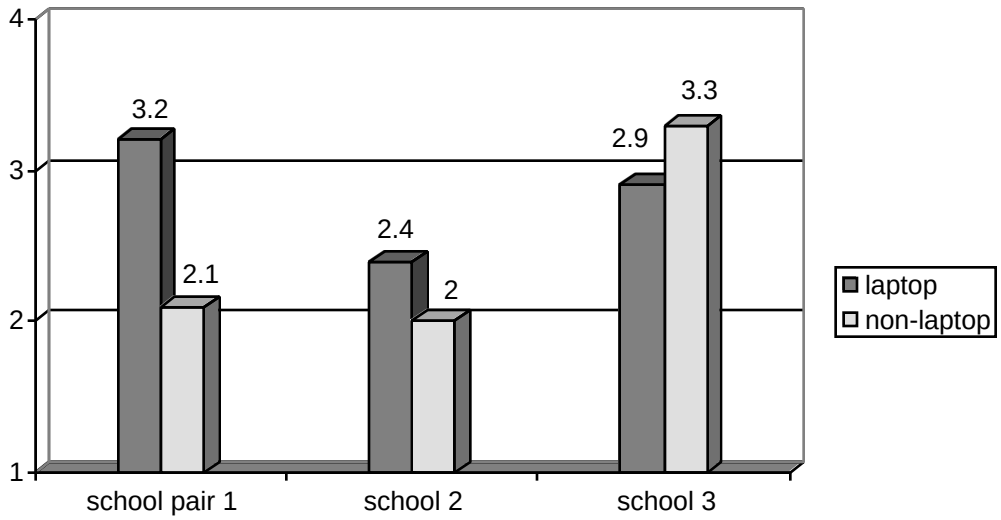
Language, Voice, Style
Does the student seem engaged in the project?
Does the voice of the student come through the words?
Is the language rich? Precise?
Does the student choose words carefully and use everyday words skillfully?
Are sentence patterns varied?

Mechanics, Conventions, Presentation
Does the student have a good grasp on standard writing conventions (spelling, punctuation, grammar, capitalization, usage, etc.)?
Does the student use the conventions to enhance the writing and engage the reader?
How distracting are the errors—would a little editing fix it; do the errors interfere with reading and meaning?

At two of the three matched schools, Laptop students outscored their Non-Laptop counterparts on each of the four measures. At School 3, results were mixed.

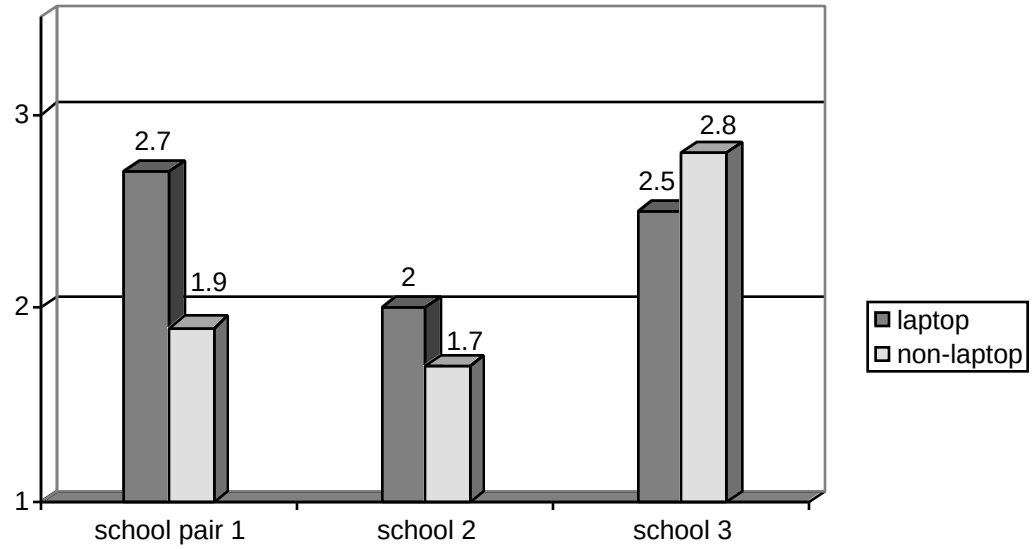
Each of the following figures represents one of the four scoring issues—content, organization, language, and mechanics. In Figure 36, we have provided an overall score for the three groups of Laptop and matching Non-Laptop students.

Figure 35: Student writing scores for Content



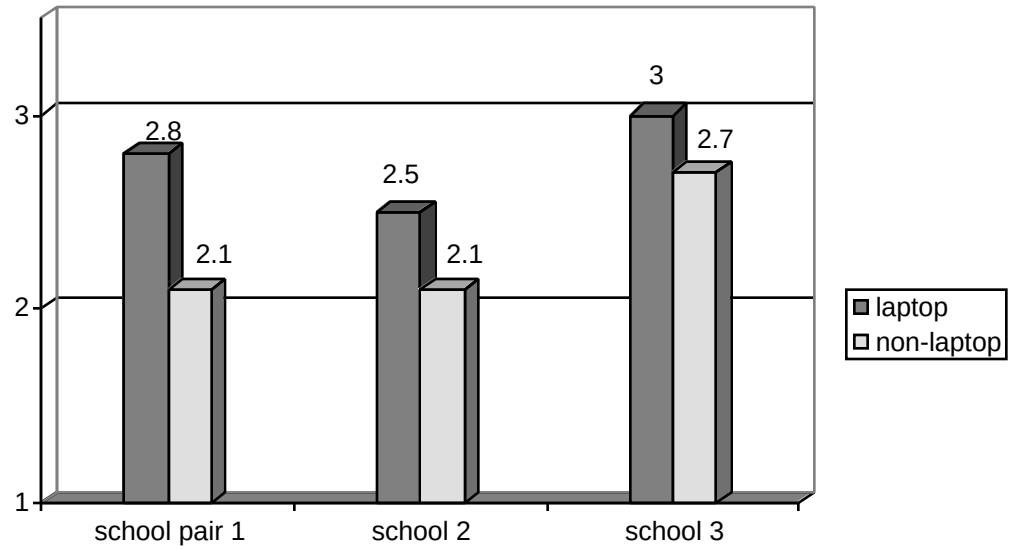
For content scores, differences in all three cases are statistically significant.

Figure 36: Student writing scores for Organization



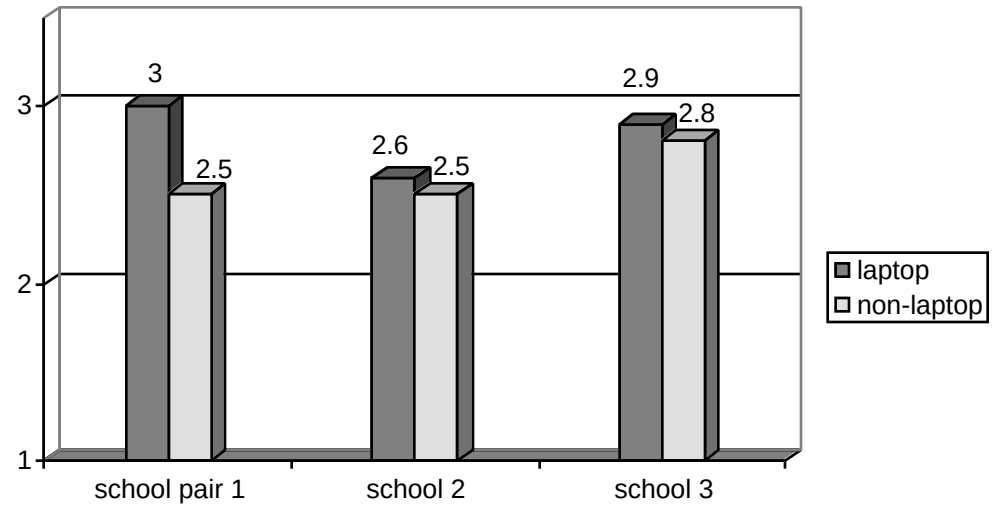
For organization scores, differences in all three cases are statistically significant.

Figure 37: Student writing scores for Language, Voice, Style



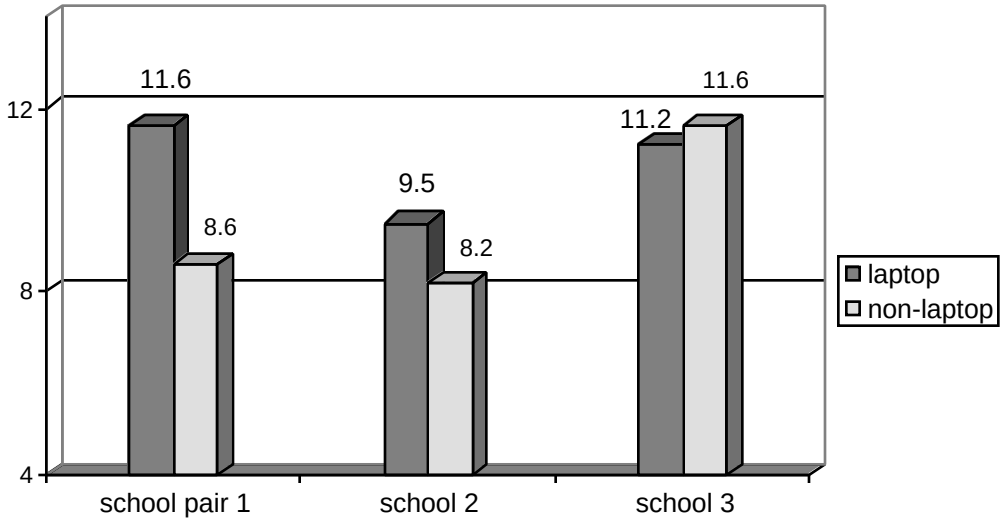
Again, differences in each case are statistically significant.

Figure 38: Student writing scores for Mechanics



For mechanics, only the differences for School Pair 1, our externally matched site, are significant.

Figure 39: Student writing scores for Total Score



With the total scores, differences for School Pair 1 and School 2 are significant; differences for School 3 are not.

Two of the three school sites in this study presented significant differences in favor of Laptop students in writing performance on all of the elements of the rubric. The third site presented modest differences which were not statistically significant and were in favor of the Non-Laptop students on half of the elements and for the total score.

Improved writing—as noted by teachers and by students, as well as in the evidence from this study—suggests the power and value of technology access. What is clear from both

Laptop students and those with substantial access to computers is that technology is a useful tool to support all elements in the writing process—from organization to research to the actual writing and presentation.

STANDARDIZED TEST SCORE COMPARISONS

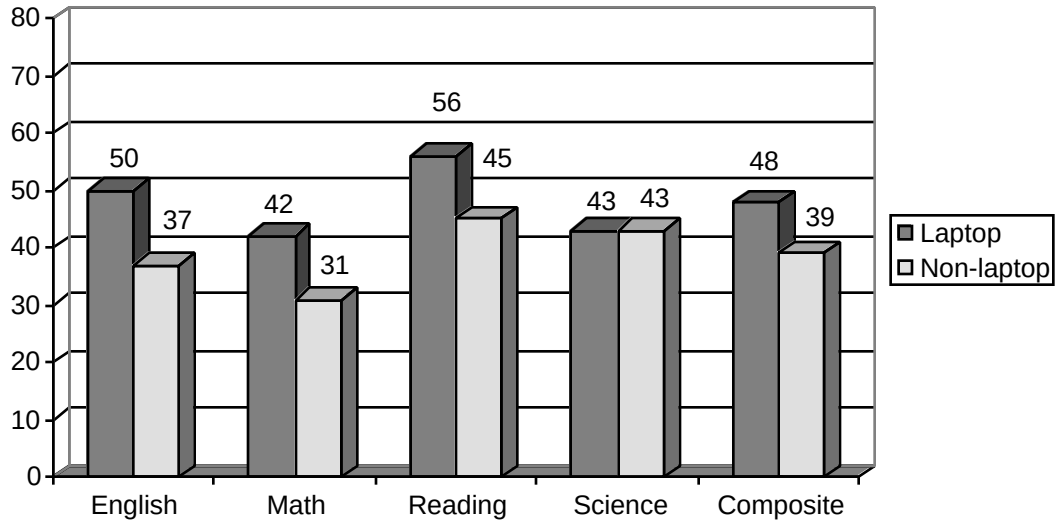
As noted in our discussion about study site selection, we found it quite difficult to find groups with which to compare academic achievement on widely-used, standardized assessments. In addition, we faced difficulties in gathering test score data; the low participation of students at some sites hampered this component of our study. Our initial plans called for a study that would control for a variety of student, teacher, and classroom background variables in our matched sites (variables such as socio-economic status and parents' education, as well as teacher skill and experience levels and issues of constructivist pedagogy). We expected to relate these variables to the assessment outcomes for students and identify the contribution of these attributes, and also of full-time computer access. However, fewer sites chose to participate, comparison schools were not easy to locate nor willing to participate, and as data we had hoped to receive was lost, we ended up with too few student scores to make this kind of comprehensive study feasible. With the data we received, we can only provide gross comparisons between Laptop and Non-Laptop students on standardized tests. We review our findings, below, with groups of participating schools and data collection strategies; first are the matched sites, followed by the schools in which we compared today's students with earlier school cohorts.

Matched Sites

At two of our three matched sites, less than 30% of our students took any standardized test during the time-frame we specified (i.e., after they had had the laptops for at least a full year). With such small groups, we were unable to control for various background factors, and we simply compared Laptop student test scores with Non-Laptop student scores at each of our three matched sites. There were no statistically significant differences between the two groups at any of the sites.

School Pair 1. Site 1 is an external match of two different schools in close proximity, in a relatively rural setting. The Laptop students who were in at least the second year of the program were 11th graders, and were no longer taking mandatory tests. Of the 75 students at these two schools who had submitted questionnaires, logs, and/or surveys, only 20 students (27% at each school) took a standardized test (the ACT) within the time-frame we specified. However, the two groups took the test at different times: Non-Laptop students mostly took it in the spring of their junior year, while Laptop students took it in the fall of their senior year. Laptop students' scores, therefore, reflect an extra seven months of schooling. While Laptop students' scores are higher on this test, differences for this group size are not statistically significant.

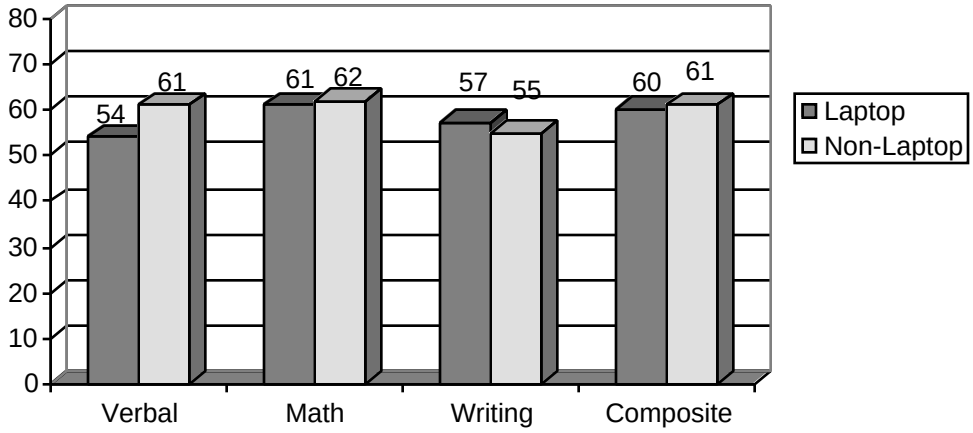
Figure 40: School Pair 1 comparison of matched schools on ACT percentile scores



School 2. At School 2, one of the pioneer laptop high schools, students who met our testing requirements were also 11th graders, and again very few took a common standardized test during the year we specified. Some students took the SAT, but the largest group took the PSAT. Even so, only eight Laptop students and seven Non-Laptop students (26% and 15% of each group, respectively) took the test. Students took the PSAT during the fall of their junior year, after they had had the laptops for only one full year.

While Non-Laptop students obtained higher verbal, math, and composite scores on average, and Laptop student scores were higher in writing, no differences were statistically significant.

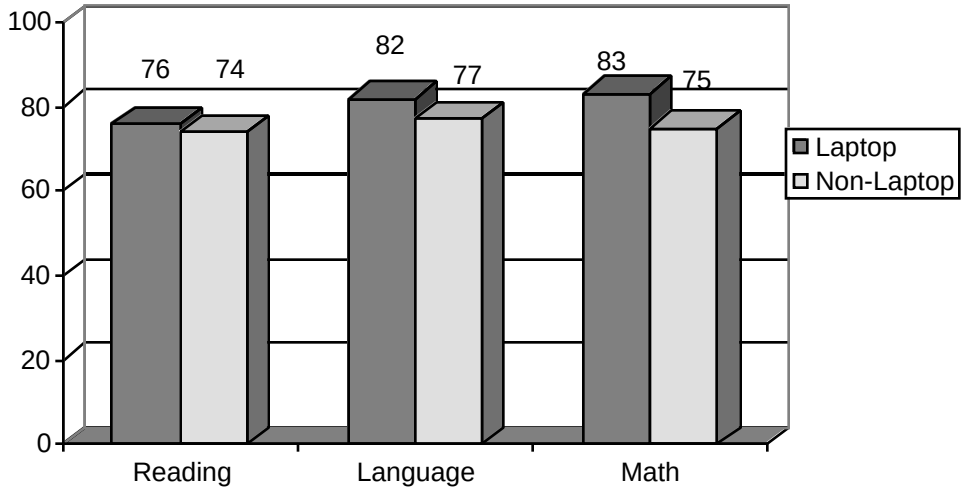
Figure 41: School 2 comparison with a school on PSAT scores



School 3. At our third matched site, a pioneer middle school, all students took the required California state test, the SAT-9, in the spring. We were able to gather test scores for 49 Laptop students (98% of our group) and 49 Non-Laptop students (84% of our group). Laptop students had had their computers for 1-1/2 years at that point.

While Laptop students' average scores are higher, differences between the two groups are not statistically significant.

Figure 42: School 3 comparison with a school on SAT-9 scores



Cohort Comparisons

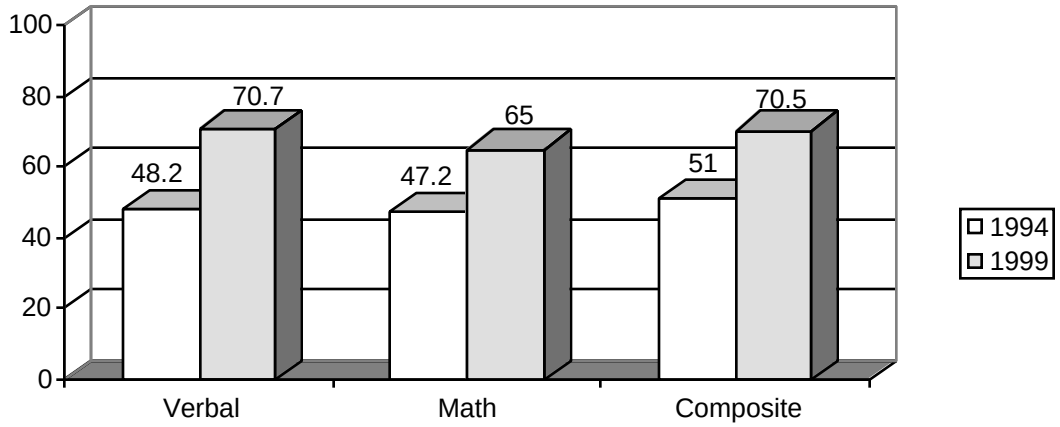
Four of our Laptop-only schools were able to collect student test score data for us. Because we did not have a matched group of Non-Laptop students for these schools, we conducted internal cohort comparisons. For each school, we compared current test scores with the scores of students of the same grade who had attended the school just before the Laptop program was implemented. For example, if a school adopted the Laptop program in 1996, we compared current seventh graders' test scores with 7th grade test scores from 1995. We also interviewed principals and headmasters in order to learn more about other changes their schools might have made in the same time period that might have influenced student learning outcomes.

Results from the test score analyses were mixed. In some cases, scores rose; in others, they declined; and in some cases, differences were statistically significant. There are no consistent attributes of the assessment outcomes for Laptop and Non-Laptop students.

Laptop-Only High Schools

At an independent high school, School 7, Laptop students took the PSAT in the fall of their junior year, at the beginning of their third year of the Laptop program. We were able to gather 29 students' scores from 1994 and 53 scores from 1999. PSAT scores rose dramatically between 1994 and 1999. Differences are statistically significant.

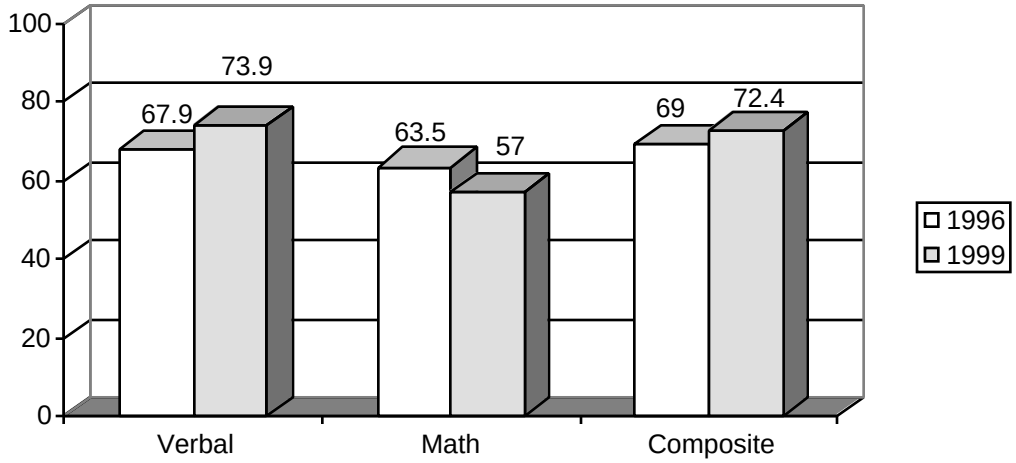
Figure 43: School 7 Cohort comparison on PSAT scores



During interviews, administrators initially reported no major changes at this school in the last four years except for the Laptop program. However, when we asked if they would then attribute these score changes to the Laptop Program, they responded negatively, explaining that the school's reputation had grown in recent years and that they had begun screening student applicants more carefully. They felt they were able to choose students who were "more able," and that this change, then, would account for the score differences. The Laptop Program, while it might attract some better students into the school, did not have a direct impact on test scores, according to administrators' views.

School 6. At another private high school, School 6, an all-girls school, students took the PSAT in the fall of their junior year, at the beginning of their third year of the Laptop program. We received test scores for 25 students in 1996 and 23 Laptop students in 1999. In this case, verbal and composite scores rose, while math scores declined. None of these differences, however, were statistically significant.

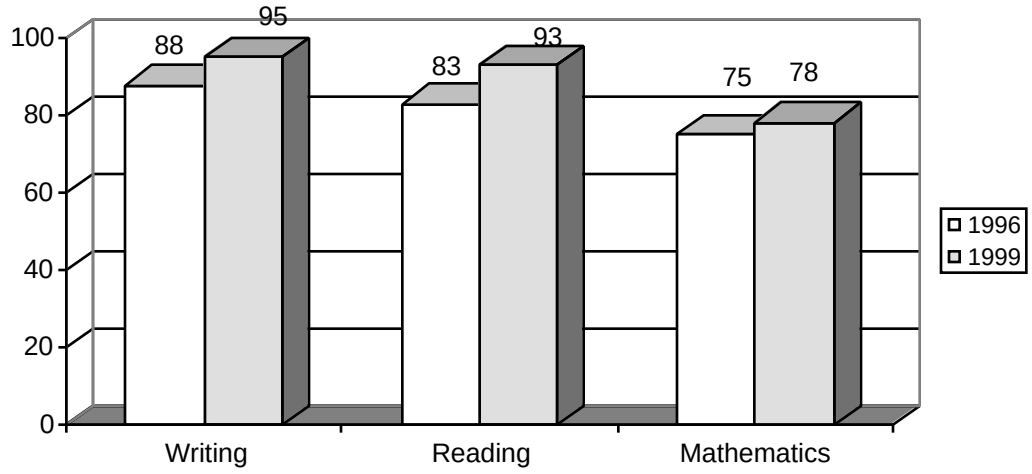
Figure 44: School 6 Cohort comparison on PSAT scores



Laptop-Only Middle Schools

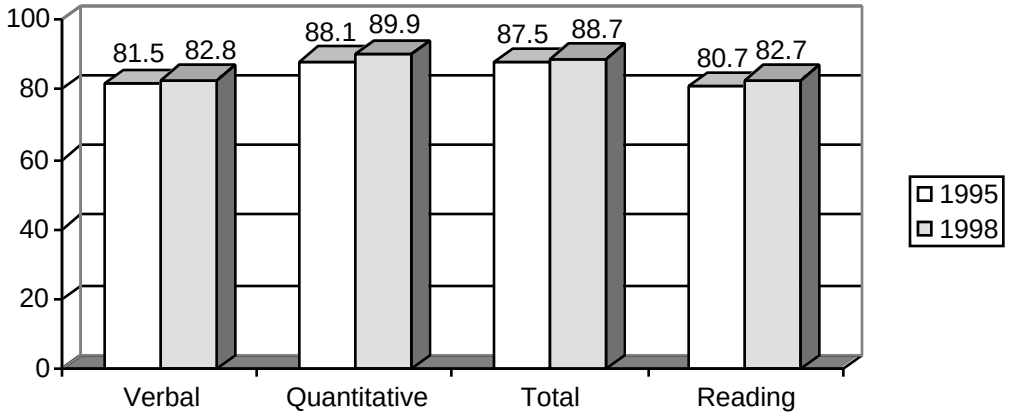
We also worked with three middle schools. At one public school, School 5, students took an Ohio state proficiency exam in the fall of their 9th grade year, at the beginning of their third year with laptops. In 1996, the year before the Laptop program was implemented at this school, the state only reported pass/fail rates for each school, without individual scores. Examining just the pass/fail percentages for each group, "pass" percentages improve in 1999. However, differences are only statistically significant in one category, reading.

Figure 45: School 5 Cohort comparison on Ohio Proficiency Test pass rates



School 8. At another middle school, School 8, a private school, 7th grade students take SSAT, an admissions test for independent schools. The test measures verbal and quantitative abilities and reading comprehension. The SSAT was taken in December, when our target group of students had been in the Laptop program for about 1-1/2 years.

Figure 46: School 8 Cohort comparison on SSAT percentiles



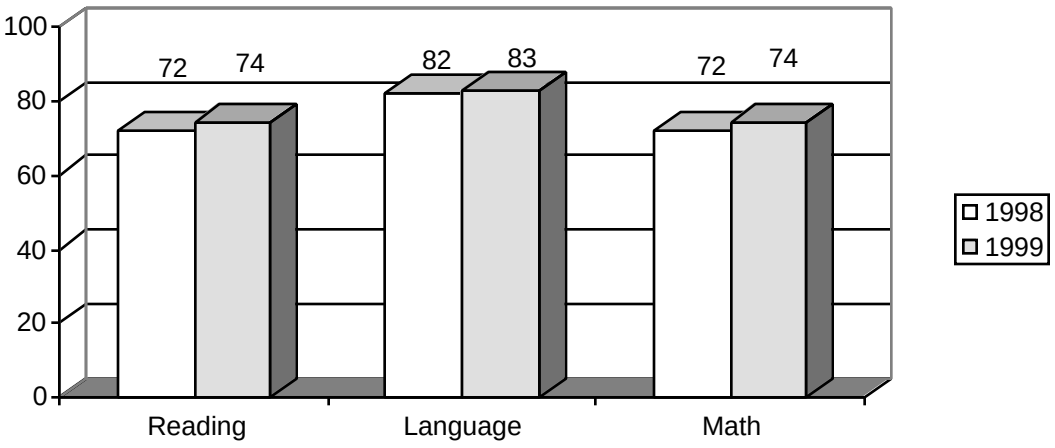
Our target group of Laptop students performed better than their predecessors on the SSAT; however, the differences are not statistically significant.

School 4. Our final public middle school, School 4, has both Laptop and Non-Laptop students; however, the Non-Laptop students' data were lost before they could be mailed to the research team. Therefore, we looked only at Laptop students' scores at this site.

Laptop students took the required California state test, the SAT-9, in the spring of their 8th grade year, when they had used the laptops for 1-1/2 years. California's state testing program is new, and so there are no SAT-9 scores for any cohort before the Laptop program began. We did, however, gather test scores from one year previously, for the same group of Laptop students, when they had used their laptops for half a school year.

While scores increased, differences between the two years are not statistically significant.

Figure 47: School 4 Cohort comparison on SAT percentiles



Summary

These findings from the comparisons between Laptop and Non-Laptop students and between Laptop students and their earlier cohorts are quite mixed. Significant differences were not easy to find and were even more difficult to interpret. Saddled with a wide variety of achievement tests and small samples of students from each school, we are unable to report reliable findings. The more in-depth analyses we had hoped to apply were not possible given the small numbers of student scores on any single test and the limitations of the data sets from the participating schools that were—and were not—available to us.

A look at the data from these participating schools indicates that for many schools, there is a slight difference in favor of the Laptop students. This finding is occasionally statistically significant but not consistent; nor are these differences easily understood and explained based on what we know of the interventions. From what the students report doing in class and at home, the computer is clearly a tool to accomplish their work—conducting research, analyzing data, organizing information, writing, and making presentations. Non-Laptop students in sites where we made direct comparisons have universal access to computers at home, and do some of the same computer activities as do Laptop students. However, these are neither the content of standardized tests applied in the participating schools, nor are they the process skills usually needed to be successful on these tests. The curriculum content covered by the participating teachers and their students, and the competencies and abilities that students brought to the testing setting are likely to contribute more to the outcomes than ubiquitous access to computers.

In an earlier section of the report, we described some of the methodological concerns of using standardized tests to assess achievement associated with the implementation of a Laptop Program. We were unable to overcome these barriers in our efforts. Moreover, the difficulties in ascribing cause are even greater in a situation like the Laptop Program, where other changes are taking place in the schools, where the implementation of laptops may result in changes in pedagogy that have greater influence over the outcomes on standardized tests than other in-school variables. Our findings illustrate the frustrations of seeking to explain and interpret inconsistent outcomes on inconsistent measures and to associate those changes with the availability of a tool. While students may end up being more productive, more effective writers, more able to handle complex, real-world projects, or better able to master skills that will do them well in college and on the jobs they will hold, these attributes do not appear on the standardized assessment measures used here. This does not mean that the Laptop Program did not impact academic achievement, just that we were unable to identify outcomes during this study given the measures applied in the participating schools.

STUDENT LEARNING STRATEGIES

Survey Results

In Year 2, we administered the Learning Strategies Survey for the first time. The survey asked students to estimate how frequently they used a particular strategy when reading, writing, or doing presentations, such as creating an outline, re-reading, or revising. In Year 2, we found that Laptop students reported that they took notes and highlighted while reading more often than Non-Laptop students. Laptop students also applied several writing strategies more often than Non-Laptop students, including rewriting passages from public documents, revising reports and papers, and outlining their papers.

In Year 3, our findings are not as clear. Many differences which were statistically significant last year aren't this year; in other cases, Non-Laptop students report using specific strategies significantly more frequently than Laptop students. In some cases, Non-Laptop students report higher frequencies in Year 3 than they had in Year 2; in some cases, Laptop students report lower frequencies; and in some cases, both occur.

Unlike in Year 2, Non-Laptop students this year reported outlining their papers, their presentations, and information they read more often than Laptop students. On a scale from 1 to 5, with 1 being "very rarely" and 5 "very frequently," Non-Laptop students' responses averaged 3.4 (between "sometimes" and "frequently") for both outlining papers and outlining presentations. In contrast, Laptop students' responses on these two items averaged 3.0 ("sometimes"). For outlining information they read, Non-Laptop students averaged 3.2, while Laptop students averaged 2.5 (halfway between "rarely" and sometimes"). All differences are statistically significant.

Several other learning strategies were also employed more frequently by Non-Laptop students. Items where differences were statistically significant were:

- looking up new words in the dictionary while reading;
- looking up additional information to help them understand what they've read;
- writing a summary about what they've read;
- asking questions to make sure they understand the material;
- having a classmate read or edit reports and papers before turning them in;
- writing in general;
- creating note cards to refer to during presentations.

For some of these items, it's possible Laptop students are interpreting the terms as pen and paper tasks. For example, Laptop students may create guides on their Laptops for use during presentations, but might not be thinking of that task as "creating note cards." Similarly, "writing" can mean the act of composing a report, or can mean the task of physically writing by hand. In fact, we do have evidence that "writing" is interpreted as a pen and paper task by both Laptop and Non-Laptop students. On one survey question, students were asked to circle the strategies that they had ever employed while on a

computer. For "writing reports/papers," 73% of the Laptop students and 64% of the Non-Laptop students report having used a computer to write papers (the difference is not statistically significant). However, for "writing," a few items later, only 8% of Laptop and 5% of Non-Laptop students report using a computer. Obviously, in this case most are thinking of "writing" as something other than the writing reports they reflected on earlier.

Laptop students do employ other learning strategies more frequently than Non-Laptop students. Items where differences were statistically significant in favor of Laptop students were:

- underlining/highlighting a main idea;
- reading information from several sources to prepare a report;
- putting ideas from published documents into their own words;
- re-reading reports and papers before turning them in for a final grade.

Externally vs. Internally Matched Sites

However, when we examine our findings school by school, a different picture emerges. At our two internally matched schools, where students may have the same teachers and both students and teachers share common resources, the picture above is accurate. Laptop and Non-Laptop students seem roughly equal, and in many cases Non-Laptop students employ learning strategies more frequently than Laptop students. However, in our externally matched site. "School Pair 1", Laptop students seem to exceed their Non-Laptop counterparts on almost all measures. At this site, on the Learning Strategies Survey, Non-Laptop students report using only one learning strategy more often than Laptop students: writing a summary of what they've read. On every other measure, differences are either not statistically significant or Laptop students report employing a strategy more frequently than Non-Laptop students. At this site, Laptop students more frequently:

- take notes while they read;
- underline or highlight a main idea;
- write reports;
- have a classmate read and edit their reports;
- write papers together with other students;
- re-read papers before turning them in;
- work with other students; and
- use information for a variety of sources.

All of these differences are statistically significant.

On many of our instruments, in fact, data from School Pair 1, our externally matched site, more closely resembles the data we gathered last year, while data from our other two internally matched sites seems to have shifted. It is tempting to say that perhaps this external match is simply a poor match—one school has more resources, better teachers,

serves different students, or is in some way significantly different from the other school. However, the principal from the Non-Laptop school at this site went to great lengths to convince us that the two schools were identical. During his interview, he repeated several times that "there are no differences between us and [the other school]," and seemed amused that we would want to compare and contrast the two school sites. He stressed his school's technology resources: the school moved into a new building two years ago and every room has Internet access and more than one computer. All teachers are networked to each other; the computer lab has 25 computers and the media center has 30; and there is a set of 40 Laptops available to teachers (but not students).

On a variety of measures, results from our in-school matches of Laptop and Non-Laptop students have grown more equivalent since last year, while our out-of-school match reflects the greater divergence we saw before. Those students with access to technology, or in proximity to classes with ubiquitous computing, are becoming more alike in the ways they report using computers. We can imagine a series of reasons why this should occur. As schools acquire more technology, as teachers receive preparation to use the computers and computer labs they have for instructional tasks, and as students increasingly gain access to computers at home, there is a good reason to expect that Non-Laptop students will acquire the skills and strategies that we saw with Laptop students only two years ago. And as teachers within a school where some but not all classes are using laptops, we can see that ideas for the use of whatever computers are available will be shared—among students if not among the teaching staff.

Even so, in many instances, we have continued to find a consistent and often statistically significant benefit in the direction of those teachers teaching Laptop students and those students in Laptop classrooms. These benefits are consistent with what we have seen in earlier years: greater technology skills, more constructivist pedagogy, greater use of computers out of school for school-related work, and a greater range of technology use for teaching and learning. What we haven't seen—and perhaps we aren't able to capture the right data—are the substantial gains on standardized assessment measures.

TEACHER AND STUDENT BELIEFS

We asked both teachers and students about their attitudes toward technology, and how they felt technology affected schools and learning.

STUDENTS

Students indicated their level of agreement with six statements about computers. The response scale ranged from "strongly disagree" (1) to "strongly agree" (6). Students were asked if they preferred using computers for schoolwork, if computers made schoolwork more interesting, easier, or more understandable, and if computers helped them produce work of higher quality. Students were also asked if they enjoyed playing games on computers.

In all six cases, answers for both groups on average were higher than the neutral point on the scale; that is, each group agreed to some extent with the statement, and no group disagreed. In five of six cases, Laptop students indicated a greater level of agreement with the statement than Non-Laptop students, and in these five cases, differences between the two groups were statistically significant. Laptop students have a more positive attitude towards the application of computers for school activities and learning than do Non-Laptop students.

On the final statement, "I enjoy playing games on computers," Non-Laptop students indicated greater agreement than Laptop students, though the difference was not statistically significant. Interestingly, this statement reflected the highest level of agreement by Non-Laptop students.

Table 8: Student attitudes towards computers for school work

Attitude Statement	Laptop	Non-Laptop
Computers help me improve the quality of my schoolwork	5.0	4.7
Computers make schoolwork easier to do	4.9	4.3
Computers make schoolwork more fun/interesting	4.8	4.1
I prefer to use computers to do schoolwork	4.6	4.1
Computers help me understand my classes better	3.9	3.5
I enjoy playing games on computers	4.8	5.1

Students also answered an open-ended question about how they felt their schoolwork was affected by computers. They were asked, "how would you schoolwork be different if you didn't use computers?" All students, Laptop and Non-Laptop, middle and high school, private and public, tended to answer the question within several general categories. These included:

Writing and editing: As we have heard before, students felt the computers allowed them to write better reports and papers and to do more extensive editing. They felt editing was easier on the computer, and therefore they did more of it; they also appreciated the spelling and grammar checks. One student wrote, "I'm sure my work would suffer [without computers]. Programs such as Microsoft Word make reports so much easier. Spelling and grammar checks really save time." A middle school student wrote, "I take more chances with using big words because of spell check."

Neatness and professional product: Many students said their work was much neater with computers, and looked "more professional." They said they felt prouder of these products. Several also commented that their handwriting was so hard to read that their grades would have been lower had they not been able to type their work, and so credited using the computer with earning them higher grades.

Impact on amount of work: Some students also felt that using the computers allowed them to turn in better projects because the computer made their work more efficient. They felt that working without computers would have taken longer and therefore their reports would have been shorter. One student wrote, "[Without computers] schoolwork would be a lot more work and tougher to do. Presentations would not be as good." Another wrote, "I wouldn't complete schoolwork without it."

Interest and creativity: Some students felt computers kept their interest better than pen-and-paper tasks, and therefore they worked longer and harder. One student wrote, "I enjoy using the computer so I'd get bored if I didn't." Another wrote, " [Without computers] I wouldn't get to dress it up as much as I do now or add some of the creativity [to schoolwork]."

Research: Students also appreciated having access to the Internet in order to do research. These benefit was mentioned more often by the high school students. One student wrote, "[Without the computers] we wouldn't know what was going on other than through the newspaper."

Organization: Laptop students felt that computers helped them keep their work organized; they felt they didn't lose their work when it was all on their own computers.

Impact on the future: Several students said that access to computers allowed them to learn the computer skills they felt they would need later either in college or in the workforce.

Neutral or negative impacts: A few Non-Laptop students wrote that they didn't use the computers; a few of both groups felt their schoolwork would not be different without computers. One Laptop student said, "The more I use computers the more I think there is something better I could be doing." And a Non-Laptop student wrote, "I don't think computers will help a child learn better, just easier." Overall, however, the majority of comments praised the effects of computers on schoolwork.

For the most part, students saw the benefits of using computers on their productivity in school and out, on the skill set they have for the future, and for the creative opportunities it offers them.

TEACHERS

We asked teachers to rate the effect that felt technology access had had on various student outcomes. Teachers used a 5-point scale, where 1 was "very negative" and 5 was "very positive." In every case, teachers rated technology's effects positively.

In most cases, Laptop teachers rated the effects of technology more positively than Non-Laptop teachers. Note that in only one case, "number of behavior referrals" for Laptop teachers, did any average rating go below 3.0, the neutral point ("no effect") on the scale, and for this item, lower is better; the effect they saw was fewer behavioral referrals in the Laptop classes. For our matched group of teachers, in only two cases were these differences statistically significant: "Students' fluency in using technology for a variety of educational purposes" and "Amount of time students spend working with other students in their class/school." When we compared all of our Laptop teachers (matched and unmatched) with all our Non-Laptop teachers, these two items remained significant and two others reached significance: "Amount of research students do" and "number of roles students assume in learning." Results are displayed below.

Teachers' ratings of effects of technology access on students:

	Laptop	Non-Laptop
Fluency in using technology for a variety of educational purposes	4.7	4.2*
Amount of research students do	4.6	3.9**
Number of roles students assume in learning	4.3	3.9**
Amount of time students spend working with class or schoolmates	4.2	3.6*
Amount of choice students have in selecting projects/assignments	4.2	4.1
Students' motivation to learn	4.2	4.0
Students' independence as learners	4.1	3.9
Student engagement and interest in school	4.1	4.1
Overall level of academic achievement	4.1	4.1
Communicating ideas with others outside the school	3.9	3.7
Depth of students' understanding in subjects you teach	3.9	3.7
Higher-level thinking skills (e.g., problem solving)	3.9	3.8
Breadth of students' understanding in subjects you teach	3.8	3.9

Amount of schoolwork students do at home	3.7	3.6
Students' ability to set their own pace for learning	3.5	3.6
School attendance	3.3	3.4
Number of behavior referrals	2.7	3.1

*the differences between matched laptop and non-laptop teachers for these items are statistically significant.
** For these items, differences become statistically significant when we compare our larger group of laptop teachers with our non-laptop teacher sample (i.e., whole group, not matched group only).

We also asked teachers how enthusiastic they were about technology and about laptops in particular. Teachers responded on a 7-point scale, where 1 was "unenthusiastic" and 7 was "very enthusiastic." Results are displayed below for matched Laptop teachers, Non-Laptop teachers, and our whole sample of Laptop teachers (matched and unmatched). All groups, including the Non-Laptop teachers, are enthusiastic about the impacts of technology in the classroom.

	Non-Laptop	Matched Laptop	All Laptop
Enthusiasm for use of technology in the classroom:	5.5	5.4	5.6
Enthusiasm for laptops:		5.4	5.6

We also asked teachers to indicate how essential they felt students' use of computers was to their current teaching practices. Again, teachers responded on a 7 point scale, where 1 was "not at all essential" and 7 was "extremely essential". While Non-Laptop teachers had been equally enthusiastic about technology as Laptop teachers, they felt technology was less essential to their teaching.

	Non-Laptop	Matched Laptop	All Laptop
How essential are computers for your teaching?	3.6	4.2	4.6

Most teachers see the benefits of using technology for teaching and learning and, while Laptop teachers are a bit more enthusiastic about those benefits, Non-Laptop teachers are also very positive. Among the places where the differences are most pronounced are in the areas where we have seen consistent preferences for Laptop classes—in students' research, in assuming a range of roles in the classroom, and in collaboration.

CONCLUDING PERSPECTIVES

As a consequence of a variety of federal and state initiatives, as well as the decreasing costs of computers, access to computers and to the Internet for all students has grown dramatically at both school and home. As a result, access to technology is quite different than it was when the Anytime Anywhere Learning Program started. Teachers are increasingly knowledgeable about how to use technology effectively, especially in schools where resources are plentiful; and those who are not yet able to engage technology well have substantial access to professional development opportunities. When we look at how students and teachers use computers to accomplish the work they have, we see major changes in what is done in school, how it is accomplished, and what skills and abilities are improved.

Changes in the classroom

Teachers in Laptop classrooms have changed their instructional strategies dramatically over the past few years, moving towards constructivist ideals and pedagogy. In comparison, while Non-Laptop teachers report using constructivist strategies, they have not changed over the past three years: they still use as much direct instruction as they have in the past. It is the change identified among Laptop teachers that is important to consider. These changes appear to be coming from their evolving views of how teaching and learning should take place, how resources should be used and how classrooms should be organized. We believe that the presence of ubiquitous computing has been a catalyst for this change, providing a stimulus for modifying traditional behavior and for exploring options for new teaching-learning paradigms. We have reported more independent student efforts, more collaborative work, more project-based learning, and significantly less direct instruction in Laptop classrooms from the very beginning and throughout our three years of research. Teachers themselves also believe that the availability and use of the laptops has contributed to the changes they acknowledge.

Homework has been part of this change. Use of computers for homework seems to be encouraged by Laptop teachers; our teacher logs show that Laptop teachers assigned homework which involved computer use seven times more often than Non-Laptop teachers. And Laptop students actually spent more minutes per day on average on their computers completing school-related tasks than did their Non-Laptop counterparts. This may also reflect a productivity factor in having ubiquitous computing, and having substantial access to the Internet at school and at home. A great deal of work gets accomplished during the school day, and yet the students see ways of completing assignments on their computers at home, across the spectrum of subjects. Both students and teachers appear to see the opportunities made available by laptops and have found ways to engage those opportunities productively.

Ubiquitous access has its benefits, even in comparison to above-average access at home and school. Access doesn't necessarily equal use, and many of our comparison students who had considerable access at school and universal access at home did not achieve the

same skill level and breadth of use as the Laptop students. While Non-Laptop students have greater exposure to computers than ever before, computer use is still significantly more intense for Laptop students, most noticeably in school. Laptop students use computers more frequently, for longer periods, for a wider variety of uses, and have higher confidence in their computer skills. One-to-one, full time computer availability increases the amount and flexibility of use, yielding a greater range of application to accomplish schoolwork and homework. Students have changed the way they work, where they work, and often the kind of work they do when they participate in a Laptop Program, one where they have full time access to a computer. And teachers, too, are developing a sense of self-efficacy when it comes to teaching and learning with technology and ubiquitous laptop classes.

Among the more consistent findings from each year of the studies we have completed is the report from Laptop teachers about the variety of role changes in their classroom since the implementation of the Laptop Program. Students now teach other students more frequently than before, and they also review and revise their own work more often. Perhaps the most dramatic change is in how often teachers allow themselves to be taught by their students.

Finally, students are increasingly doing more writing on the computer. As teachers incorporate elements of process writing into their assignments (multiple drafts, peer reviews, editing), educators are likely to see an improvement in the quality of writing produced by middle and high school students. And, as seems to be in development at the time of this report writing, those institutions that request writing samples on high-stakes tests may soon allow students who have always written their essays on a computer to do so—and we will likely see increases in test scores.

Test scores

With the exception of standardized test scores, we have found a consistent and often statistically significant benefit in the direction of those teachers teaching Laptop students and those students in Laptop classrooms. These benefits are similar to those we have seen in earlier years: greater technology skills, more constructivist pedagogy, greater use of computers for school-related work at home, improved writing, and a greater range of technology use for teaching and learning. What we haven't seen are the substantial gains on standardized assessment measures that many policy makers, legislators, parents and critics of technology in school are seeking.

When we started this effort, we had expectations of exploring achievement test scores in relation to the Laptop program, but our expectations were tempered by the concern that, whatever the outcome, we could not easily attribute causation to the mere presence of the laptop computers and software or even the changes in classroom pedagogy associated with laptop use. At it turned out, our ability to gather sufficient student achievement data to explore the questions in depth was limited, and while we continue to believe that causal relationships will be difficult to make, we aren't in a position of having to make those choices. Student achievement based on traditional measures of academic grades

and standardized tests do not tap into the nature of schoolwork accomplished with ubiquitous laptop access. For the most part, students aren't asked to conduct research online, organize large bodies of information, or make presentations on the tests they have to take, yet that's what Laptop students spend their time doing. There is a disconnect between the classroom and home uses of the computer and the assessments we tend to use.

One might think that Laptop students are learning additional content and learning it better, but that may be more a condition of what the teachers are asking of their charges and what the students are bringing to the classroom in terms of previous experiences and family background. Project learning may be increasing in Laptop classrooms, but that doesn't necessarily lead to broader student knowledge that might yield results on standardized tests. Writing skills may be improving, but yet we ask students who consistently write, re-write and edit on the computer to write in long hand, constraining their opportunity to write the way we teach them to write. Massachusetts is undertaking trials of using computers for student essays on standardized tests and many test development companies are exploring computer-based testing of both simple multiple-choice items and more complex question forms. Perhaps over the next few years we will see options for Laptop students to demonstrate that their facility with computers and the strategies they have mastered with ubiquitous computing will pay off on formal and widely-recognized metrics.