

**POWERFUL TOOLS FOR SCHOOLING:
SECOND YEAR STUDY OF THE LAPTOP PROGRAM**

A Project for
Anytime Anywhere Learning by Microsoft Corporation
Notebooks for Schools by Toshiba America Information Systems

Submitted by

ROCKMAN *ET AL*
San Francisco, CA

October, 1998

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Acknowledgements

We gratefully acknowledge the extensive cooperation and support of the many people who have made completion of this evaluation possible. We especially thank the Laptop Program coordinators and teachers from the “pioneer” laptop schools and the faculty, administration, students and parents from the four sites where we conducted the bulk of our research. These sites are: Cincinnati Country Day School, Forest Ridge School of the Sacred Heart, the Clovis Unified School District in California and the Federal Way School District in Washington. Very special thanks go to Annette Bitter, Rob Darrow, Joseph Gotchy, Janet Graeber and Joyce Rudowski who graciously and patiently assisted us with request after request to find yet another participant for yet another one of our studies.

We also want to express our gratitude to the members of the ROCKMAN *ET AL* staff and the consultants who assisted us in gathering and analyzing data and who helped to create this report.

Melissa Chessler
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POWERFUL TOOLS FOR SCHOOLING: SECOND YEAR STUDY OF THE LAPTOP PROGRAM

EXECUTIVE SUMMARY

In the Fall of 1996, Microsoft Corporation and Toshiba America Information Systems began a Laptop Pilot Program at 29 “pioneer” school sites across the United States. Participating students acquired and regularly used Toshiba notebook computers loaded with Microsoft Windows and Microsoft Office software. 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.

ROCKMAN *ET AL*, an independent research organization in San Francisco, CA, was contracted to explore and assess the laptop program implementations. The early experiences of the participating schools are detailed in the June, 1997 “Report of a Laptop Program Pilot,” available on the web sites of Microsoft, Toshiba and ROCKMAN *ET AL*.

During the 1997-1998 school year, ROCKMAN *ET AL* tracked the experiences of teachers and students at selected pioneer schools during their second year of the Laptop Program. In these programs, participating students have full-time access to notebook computers both in school and at home. The second year study explores when and how the computers are used, their impact on teaching and learning, and participants’ assessments of their experiences in the program. Our findings point to significant learning and student and teacher accomplishments in skill development, applications of technology for schoolwork, and improved critical thinking.

Research Approach and Methodology

The second year study gathered information from both middle and high schools through a series of processes and instruments that were designed to support and validate each other. These approaches include:

- Teacher survey on classroom implementation, completed by 144 teachers;
- Student surveys on technology skills and learning strategies, completed by more than 450 students, including a comparison group of Non-Laptop students;

- Shadow studies of and interviews with students and teachers in the 7th and 10th grades, conducted over several days, which captured data for 48 student days and 12 teacher days, and included a comparison group of Non-Laptop students;
- Comprehensive student data from simulated problem-solving tasks, administered to 23 small groups of Laptop students and 6 groups of Non-Laptop students in 7th and 10th grades; and
- Students' detailed descriptions of their favorite projects and activities, provided by more than 400 students, including a comparison group of Non-Laptop students.

Collectively, this is a complex and rich set of data. We found consistency in the outcomes of these multiple approaches which, in turn, increases our confidence in the findings we report and their implications.

Students' Use of Technology

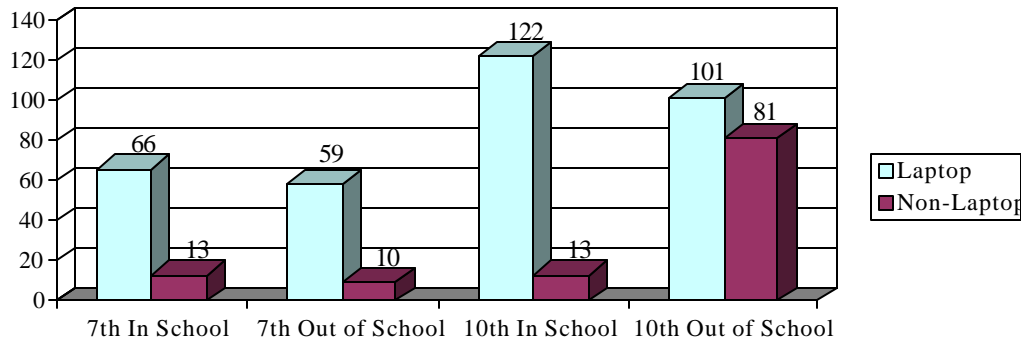
A primary goal of the Laptop Program is to demonstrate that full-time access to “real world” business tools produces substantial educational benefits by supporting and facilitating learning. We begin by portraying the frequency, context and purposes of students' computer use. Our descriptions are supported by data gathered from shadow studies and teacher and student surveys.

Laptop students spend more time using computers

In the shadow studies, seventh grade Laptop students used computers as much in a day as Non-Laptop students used them in a week. Tenth grade Laptop students used computers in school more than two hours per day, over nine times as much as the Non-Laptop students.

When we combine school-related use of the notebook computers in and out of school, we find that middle school students spend almost two hours per day— and high school students spend more than three-and-one-half hours per day— using computers for academic work. In laptop program pioneer schools, it appears that the notebook computer and applications software have become indispensable tools for accomplishing the work of schooling.

Average Daily Computer Use, In Minutes



Laptops appear to extend the school day

Laptop students spent substantial amounts of out-of-school time completing schoolwork on their notebook computers. Seventh grade Laptop students spent ten times as much out-of-school computer time on schoolwork as 7th grade Non-Laptop students. Tenth grade Laptop students spent 48% more out-of-school computer time on schoolwork than 10th grade Non-Laptop students.

The frequency with which we found Laptop students to be using their notebook computers for homework is not surprising given teachers' claims that they assign homework requiring laptop use on a regular basis across the five core subjects.

Laptops are frequently used in core subject area classes

Laptop students who participated in our shadow study made frequent use of their notebook computers during their core subject area classes. Observations from our 7th grade shadow studies revealed notebook computer use in almost half of the students' core subject area class periods, most often in their English/social studies and science classes. Tenth graders used notebook computers in over half of all core subject area class periods, including English, social studies, science and foreign language classes.

In addition, when computers were used, they were used for substantial amounts of time. Both 7th and 10th grade Laptop students used their notebook computers for about half an hour each time their work called for use of this tool.

Laptop students in public schools use the computer more often than private school Laptop students

Laptop students who attended public schools used their notebook computers more frequently and for more of the class time than the Laptop students who attended private

schools. Public school students in both the 7th and 10th grades used their notebook computers in a higher proportion of core subject area classes and during a greater proportion of class time than the private school students.

Purposes of in-school laptop use vary by grade level and subject

Seventh grade Laptop students used their notebook computers most frequently for research and writing. During science classes, research accounted for over half of all laptop use. In interdisciplinary English/social studies classes, writing and research occurred equally often (about 40% each.)

Tenth graders used their notebook computers most frequently for writing and note taking. Writing accounted for over almost half of laptop use in English, foreign language and science classes. Note-taking accounted for almost half of laptop use in science and about a third of laptop use in English and foreign language classes. In social studies, students most often used laptops to conduct research.

Students choose tools appropriate to the task

Students' decisions about when to use the computer were based primarily on issues of efficiency and the desired quality of their final product. Laptop students almost always used their notebook computers for writing assignments, stating various reasons: to use the editing tools, to avoid rewriting by hand, and so that the final product would look neater. Paper and pencil were chosen when students needed to do something fast, such as jot something down, draw a diagram in their notes, or solve math problems.

Students and teachers make use of a subset of software

Microsoft Word is the program most frequently used by both teachers and students; the program is used for a variety of purposes, including producing assignments, editing, creating brochures and graphic organizers, and taking notes. The Internet is the second most commonly used tool, followed by Excel and PowerPoint. In addition, many teachers seem to be combining software applications in their assignments to students. The programs most often combined were the same ones most commonly used, and in the same order of frequency.

More computer use results in more proficient students

Laptop students' experience with multiple software applications results in greater proficiency with each of these tools. Laptop students have more confidence in their knowledge about software applications and most believe they are knowledgeable enough to teach others.

Impacts on Teaching and Learning

The Laptop Program may be particularly well suited to supporting technology's promise of radically changing teaching and learning. The changes that we document in our report fit well with the expectations for technology's role in education outlined in the SCANS (1992) report and other reform documents and studies.

Laptop students spend more time engaged in collaborative work than Non-Laptop students

Two-thirds of the Laptop teachers we surveyed stated that the amount of cooperative learning and group work in their classrooms has increased since the start of the Laptop Program. Laptop students reported a higher frequency of writing reports and papers in collaboration with other students than Non-Laptop students. During our shadow study, Laptop students engaged in group work more than twice as often as their Non-Laptop counterparts. Teachers see students asking each other questions and depending on their peers for information, ideas, and editing, as well as for technical help.

Laptop students participate in more project-based instruction

Three-fourths of the teachers who participated in our survey state that project-based instruction has increased since the introduction of the laptops in their classrooms. During our shadow study, Laptop students participated in twice as much project-based instruction as Non-Laptop students.

Laptops lead to more student writing and to writing of higher quality

In response to an open ended question, more than one-third of the surveyed teachers named writing as the academic outcome or skill that has been most directly affected by use of the laptops. Some teachers said simply that writing had generally improved; others said that students were doing more writing more often. Several teachers talked about the ease of editing, improved spelling and grammar, greater numbers of revisions and quicker production of drafts and final products. One teacher added that greater efficiency allowed more time for research, so that students' research also improved.

Laptop students claimed to write reports and papers more frequently than Non-Laptop students did. Seventh grade Laptop students were also more likely to write original stories than 7th grade Non-Laptop students from the same school.

Laptops increase access to information and improve research and analysis skills

Teachers who responded to our survey felt that access to both the Internet and CD-ROMs affects the quality of students' research projects, allows for a greater variety of assignments, and enhances their ability to analyze information. Eighty-seven percent of the

teachers who completed our survey and 92% of teachers who participated in our shadow study interviews claimed that students' use of Internet research has increased since the project began.

Many teachers also noted that greater access to information requires students to be more thoughtful about which sources they use and why. Students have to make more decisions, especially pertaining to research, because of the vast amount of information now available to them. Teachers maintain that the laptops not only increase access to information, but also provide a means for compiling and organizing information in compelling ways.

Laptop students prepare more presentations than Non-Laptop students

According to both students and teachers, students with notebook computers gain more experience with preparing and delivering presentations than Non-Laptop students. Teachers mentioned communication skills, including making presentations and speeches, as an academic outcome or skill that has been affected by use of the laptops. Teachers believe that Laptop students' presentations are better organized, and that doing more presentations helps students feel more comfortable with presenting.

Teachers and students take on different roles when students have laptops

Teachers become facilitators

In our shadow study, we observed that teachers in Laptop classes spent more time consulting and conferencing with individuals and groups than teachers in Non-Laptop classes. Differences were most pronounced in high school, where Laptop teachers spent almost twice as much class time consulting than Non-Laptop teachers did. Teachers in our surveys also reflect on the way their role has changed, from a director of learning to a facilitator of learning.

Teachers spend less time lecturing

The amount of lecturing in classrooms has decreased since the inception of the Laptop Program, according to forty-one percent of the teachers we surveyed. Shadow study observations support the teachers' claims; lecturing occurred during 34% of 10th grade Non-Laptop students' class time but only during 21% of Laptop students' class time.

Students become collaborators

As noted above, Laptop students spend more time collaborating with their peers than Non-Laptop students. In our survey, forty-one percent of teachers who felt that laptop use most significantly affected teachers' and students' roles noted this trend.

Students direct their own learning

Teachers felt that the laptops allow students to express themselves more creatively and to work more independently. Many teachers commented that their classrooms are now

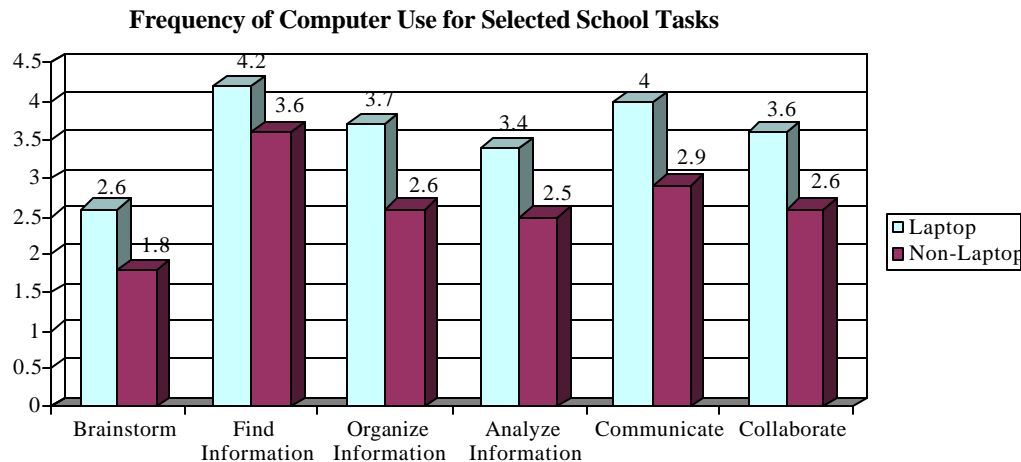
more student-centered, where students lead their own inquiries and direct their own learning, and teachers assist students as needed.

Laptop students report a greater reliance on active learning strategies

Laptop students more frequently rely on active learning and study strategies when reading and writing for school. Laptop students indicate that they take notes while reading, highlight, rewrite, revise, and outline at higher rates than Non-Laptop students.

Laptop students use computers to accomplish complex school tasks

Laptop students report they use computers more frequently than Non-Laptop students to find, organize, analyze and communicate information. They also use computers more when brainstorming to generate ideas and collaborate with other students.



NOTE: Students rated each item on a 5-point scale. 1 = never; 2 = rarely; 3 = sometimes; 4 = frequently; 5 = always

Both Laptop and Non-Laptop students indicated that they use Word and the Internet in the service of these tasks. Laptop students also use PowerPoint for multiple purposes. When students were asked to explain why they chose particular tools to accomplish these complex tasks, 25% of the Laptop students noted at least one advanced feature of the program which offered a strategic advantage in accomplishing schoolwork. In contrast, only 8% of Non-Laptop students mentioned a particular feature. Types of advanced features that students mentioned include tables, outlines, bullets and bookmarks- features that would help them access or organize information more effectively.

Laptop students readily engage in problem solving and critical thinking

During our problem-solving simulations, seventh grade students explored the complex challenges of reintroducing wolves to national parks. Groups of four to seven students were asked to choose and defend one of three positions in preparation for a public debate about the issues.

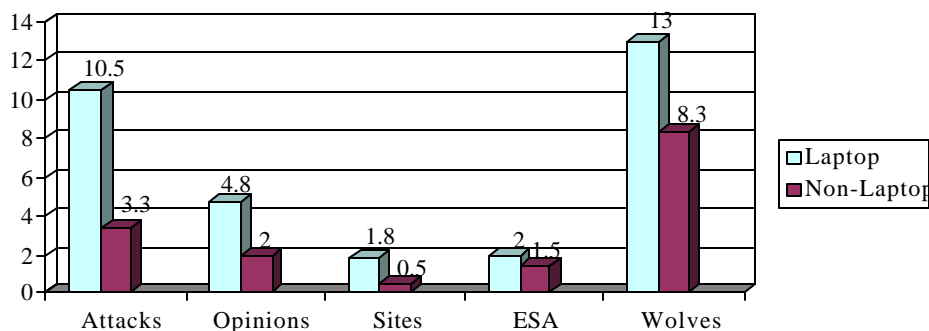
Laptop students applied critical thinking skills more readily than Non-Laptop students. Laptop students immediately became engaged in addressing the controversial nature of their problem, gathering and evaluating evidence related to the alternative perspectives on the issue, and developing a strategy for supporting their own position on the matter. In contrast, Non-Laptop students tended to ignore the real-life controversial aspects of their problem. They seemed to view their task as a request to write a descriptive report rather than to take and defend a position on the matter in a public forum. Several lines of evidence support these interpretations of our findings.

Identifying information needs

Laptop students sought *more* information—and *more varied* information—about the situation they were asked to consider than 7th grade Non-Laptop students. Laptop and Non-Laptop students sought general information about wolves and information about endangered species at similar rates. However, Laptop students were more likely to pursue information about interested groups' points of view, about sites involved in the issue (such as Yellowstone Park), and about wolf attacks (of interest to farmers who want the wolves removed).

These differences support the idea that Laptop students are thinking creatively about various aspects of the real-life controversial wolf issue, whereas Non-Laptop students are perhaps following established procedures typically used when gathering information for school reports. The differences can easily be seen when Laptop and Non-Laptop students from the same school (and with the same experimenter) are compared.

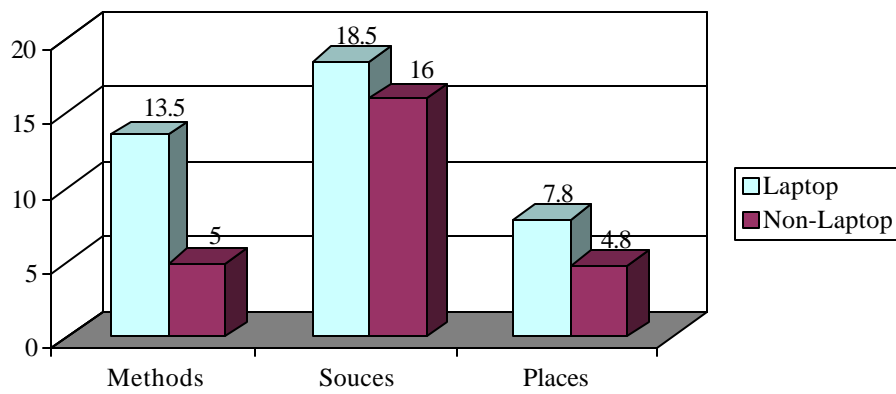
**Average Number of Information Items Produced By Student Groups
Within the Same School**



Locating information

Laptop students suggested a greater variety of methods for finding information relevant to their problem. Students in the Laptop groups offered a wide range of suggestions for investigating the wolf issue, including site visits, interviews with scientists and park rangers, petitions, and wolf tracking devices. In contrast, Non-Laptop students offered fewer methods and showed a greater reliance on standard print and media sources such as encyclopedias, books and the generic Internet. Comparisons within the same school best illustrate the issue.

Average Number of Items Produced By Student Groups
Within the Same School



The differences that we found between the Laptop and Non-Laptop students' ideas for locating information would not surprise the Laptop students' teachers. Eighty-five percent of the teachers who completed our Teacher Survey believe that laptop access has resulted in students' use of a greater *variety* of sources in research projects. Eighty percent of these teachers claim that laptop use has increased the *number* of sources used in research projects.

Applying higher order thinking skills

Laptop students showed greater evidence of applying higher-order-thinking skills to big-picture, strategic issues rather than to information gathering and procedural issues. Both Laptop and Non-Laptop students sometimes offered a rationale for how or why they would gather information related to the wolf problem. Such explanations were coded as applications of higher-order-thinking skills (HOTS) when they explicitly illustrated students' causal reasoning, and when that reasoning was considered both complex and meaningful in relation to the wolf problem.

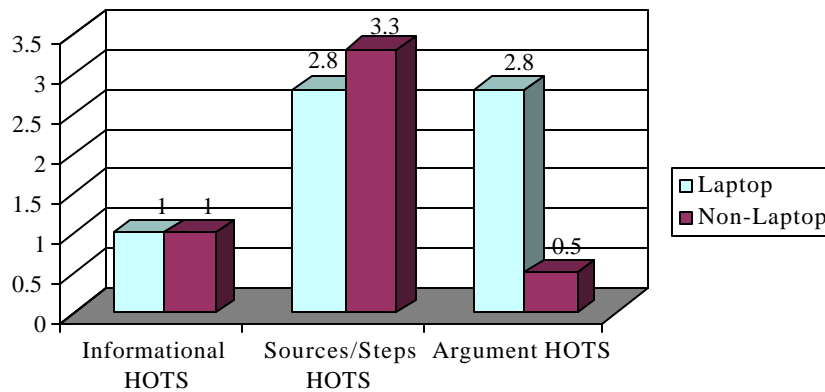
Three types of higher-order thinking skills were identified. Both groups of students displayed equivalent degrees of informational HOTS, which provide a rationale for seeking a particular piece of information. Non-Laptop students actually displayed more

Source/steps HOTS, which provide a rationale for a particular way of or procedure for gathering information.

Laptop students showed greater evidence of argument-related higher-order-thinking skills than Non-Laptop students. Argument HOTS provide a rationale for using a particular argument or strategy in order to gain support for one of the positions on the wolf issue; they relate to “the big picture”. This difference between the two groups adds further support to the claim that Laptop students are thinking critically about how to defend their position on a real-life controversial issue, while Non-Laptop students viewed their task as a request to write a descriptive school report.

The similarities and differences are best seen in comparisons of Laptop and Non-Laptop students attending the same school.

Average Number of Higher-Order Thinking Skills Produced by Student Groups Within the Same School



Teachers attribute students’ critical thinking skills and problem-solving proficiency to their use of laptops

The majority of teachers believe laptop use has had a positive impact on students’ thinking processes. Second only to writing skills, teachers report that critical thinking is the academic outcome or skill that has been most directly affected by use of the laptops. Teachers noted that laptop use stimulates analytical thinking, including synthesizing material and manipulating information. Teachers feel that the laptops encourage more problem-solving and critical thinking by students, in part because laptops provide students with a large number of choices that, in turn, demand advanced decision making skills.

Teachers’ perceptions of what is transpiring in their classrooms are consistent with the conclusions from our problem-solving simulations and our student surveys. Again and again, our findings suggest that full-time access to notebook computers motivates students to apply active learning strategies and critical thinking to their schoolwork.

Teachers believe laptops benefit students' learning in general, but significant, ways

In addition to the many specific ways in which round-the-clock access to laptop computers appears to have a positive impact on students' learning, most of the teachers we surveyed mentioned more general ways notebook computers enhance students' experiences.

Quality of work

Eighty-seven percent of the teachers we surveyed claimed that laptop access has resulted in an increase in the quality of students' work. Teachers noted, for example, that students are willing to do the editing and reworking that they would otherwise avoid. The laptops also allow students to produce more professional looking work. Several teachers stated that their expectations for student work are now higher.

Interest in school

Most of the teachers we surveyed (71%) felt that their students' use of laptops has led them to be more interested in school. Teachers claim that students are highly motivated and they are willing to focus more on their work. They believe that students are spending more time on their work and completing larger projects.

Learning/understanding content

Sixty-five percent of the teachers we surveyed claimed that laptop access has increased students' learning and understanding of instructional content. Computers help, for example, by allowing students to turn to the Internet to explore new ideas when their curiosity has been piqued. The laptops also help students by allowing them to better see and understand the results of experiments. Teachers stated that computers aid in organization; students know where to find their documents and they work more effectively and efficiently.

Teachers' and Students' Assessments of the Program***Teacher enthusiasm remains high***

In their second year of the Laptop program, teachers remain highly enthusiastic about the laptops, their effects on students, and their impact on teaching. On a seven-point scale measuring enthusiasm, Teachers averaged a rating of 5.6.

Teachers believe laptops benefit all types of students

Teachers feel that the laptops benefit both average and special needs students, and are even more helpful for advanced students. Laptops allow teachers to design a more individualized learning approach for each student. Students can work at their own pace and in ways that interest them. Some teachers added that the laptops serve visual learners much better than traditional auditory teaching methods.

Teachers name advantages of laptops over desktops or labs

Again and again, teachers stress the advantages of laptops over classroom desktops or school computer labs. Greater access was the major benefit mentioned—laptops can be used anytime, anywhere, can move with the student, and provide students with one-to-one access. Teachers felt these advantages led to several benefits, including more immediate learning, greater efficiency, increased work time and quality, an extended school day, a sense of ownership and independence, and equity for all a classroom's students—benefits that desktops simply could not provide.

Students enjoy using the computers

In our surveys, Laptop students report that they prefer to use computers to do schoolwork, and that computers make their schoolwork more fun and/or interesting. Laptop students expressed agreement with these statements at higher levels than Non-Laptop students; these differences were statistically significant.

Students' favorite projects reflect laptops' positive impact

Over 400 students, both Laptop and Non-Laptop, reported to us about their favorite project of the year (projects did not have to involve a computer, and could be in any subject). These data reflect students' most memorable or meaningful school experiences, those perhaps most likely to stay with them over time. Significant differences appeared between Laptop and Non-laptop students. Laptop students found their most meaningful projects more often in core academic areas and research/report projects. Their favorite projects employed computers and the Internet more often, employed a greater variety of software tools, and called for a greater number of academic skills. These findings seem to indicate that laptops support and enhance students' academic work, and perhaps make that work more memorable and compelling.

In addition, we examined a small matched sample of 11th graders, half in their second year of the Laptop Program, and half Non-Laptop students. Since the students attend the same school, and share the same teachers, the same curriculum, and the same non-computer resources, differences between the two groups are startling. In each of the cases outlined above, Laptop students register greater frequencies than Non-Laptop students, and differences are much more pronounced than in our larger sample. These differences may reflect the ways in which the benefits of fulltime access to notebook computers only increase as time goes on.

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POWERFUL TOOLS FOR SCHOOLING: SECOND YEAR STUDY OF THE LAPTOP PROGRAM

INTRODUCTION

PROJECT BACKGROUND

In the Fall of 1996, Microsoft Corporation and Toshiba America Information Systems jointly kicked off a Laptop Pilot Program at 29 “pioneer” school sites across the United States. Students and teachers in both public and private schools participated. Participants acquired and regularly used Toshiba notebook computers loaded with Microsoft Windows and Microsoft Office software. 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.

ROCKMAN *ET AL*, an independent research organization in San Francisco, CA, was contracted to explore and assess the pioneer schools’ first and second year laptop program implementations. The early experiences of the participating schools are detailed in the June, 1997 “Report of a Laptop Program Pilot,” available on the web sites of Microsoft, Toshiba and ROCKMAN *ET AL*.

During the second year of the Laptop Program, the 1997-1998 school year, ROCKMAN *ET AL* continued to track the experiences of teachers and students at the pioneer schools. The second year study focuses on schools with concentrated laptop implementation models. Participating students at these schools have full-time access to notebook computers both in school and at home. In all, or most, of these students’ classes, every classmate has round-the-clock access to a notebook computer. By focusing on students, teachers and instructional activities in concentrated laptop classrooms, the second year study portrays how laptops are used, and when and why notebooks are considered the tool of choice for facilitating learning when this option is available to all students.

RESEARCH APPROACH AND METHODOLOGY

Research Approach

ROCKMAN *ET AL*'s second year evaluation of the laptop program is based on information gathered through a series of processes and instruments that were designed to support and validate each other. Where we find consistency in the outcomes using multiple approaches to gathering data, we have greater confidence in the findings.

Data reported here were gathered between January and June of 1998. Our study documents student laptop use and outcomes and examines applications of technology for teaching and learning. Data collection efforts included:

- Teacher survey on classroom implementation,
- Student surveys on technology skills and learning strategies,
- Shadow studies of and interviews with students and teachers over the course of several days,
- Comprehensive student data from simulated problem-solving tasks, and
- Students' detailed descriptions of their favorite projects and activities.

Collectively, this is a complex and rich set of data that helps to describe what happens in classrooms in which every student has access to a Toshiba notebook computer and Microsoft Office software. The findings point to significant learning and student and teacher accomplishments in skill development, applications of technology for schoolwork, and indicators of improved critical thinking.

Methodology

Teacher Survey

Our teacher questionnaire was administered in January, 1998. Teachers were asked about frequency of laptop use for class work and homework, purposes of laptop use, effects of laptop use on students and instructional processes, and their current level of enthusiasm for the laptop program. They were also asked to describe a lesson or project for which use of notebooks was particularly effective in accomplishing instructional goals.

All teachers who were in their second year of using laptops for instruction and who were currently teaching in classrooms in which every student had access to a notebook computer were asked to complete the questionnaire. A total of 144 teachers from 12 public and 8 private schools completed the survey. Sixty-four respondents were middle school teachers and 80 taught at the high school level. Thirty-two respondents taught in public schools and 112 respondents taught in private schools. This bias toward private school respondents is not surprising given that private schools tend to implement their laptop programs across entire grade levels or throughout an entire school, whereas public school

implementations tend to take place within a few selected classrooms at just one or a few grade levels.

Student Surveys

More than 450 students completed our student surveys between May and June of 1998. All of the 7th and 10th grade Laptop students at four of the pioneer laptop schools were asked to fill out both student surveys. The schools included: one private coed school in which all 5th through 12th grade students have notebooks, one all-girls private school in which all 5th through 10th grade students have notebooks, one public middle school in which 7th and 8th graders can choose to participate in the laptop program, and one public high school in which 10th and 11th graders can choose to participate in the laptop program. Several 11th grade Laptop students at the public high school also completed our surveys. Within each school, most or all of the classes that the laptop students are enrolled in include only students with full-time laptop access.

Table 1. Number and Distribution of Student Survey Respondents

School/Grade	Technology Skills Survey A	Technology Skills Survey B	Learning Skills Survey
<i>LAPTOP</i>			
<i>Grade 7</i>			
Private School 1	35	34	72
Private School 2	21	19	20
Public School	38	46	85
<i>TOTAL Grade 7</i>	94	99	177
<i>Grade 10</i>			
Private School 1	31	34	65
Private School 2	19	22	40
Public School	29	34	66
<i>TOTAL Grade 10</i>	79	90	171
<i>Grade 11</i>			
Public High School	10	12	22
<i>TOTAL LAPTOP</i>	183	201	370
<i>NON-LAPTOP</i>			
<i>Grade 7</i>			
Public School	17	17	65
<i>Grade 11</i>			
Public School	19	21	39
<i>TOTAL NON-LAPTOP</i>	36	38	104

At the public schools, a number of 7th and 11th grade students who have not joined the laptop program (Non-Laptop students) were also asked to complete our surveys. We

planned to collect surveys from 10th grade Non-Laptop students, but 10th grade teachers were unable to find the time to have their students complete surveys. Data were gathered from the Non-Laptop students so that we could compare the responses of students who do and do not have full-time access to their own notebook computer. Differences found between the responses of the students in these groups point to areas that have likely been impacted by the laptop program.

Technology Skills Survey. Approximately half of the students at each site were asked to complete Technology Skills Survey A and the remaining students were asked to complete Technology Skills Survey B. Both surveys (A and B) included the same set of questions about: the frequency with which students use the software programs included with Microsoft Office, the Internet and CD-ROMs; students' competence with each of these tools; and students' opinions about computer use for a variety of purposes. In addition, Survey A asked about students' use of computers to accomplish complex school tasks such as finding, organizing and analyzing information. Survey B asked students to rate their competence at performing specific tasks, ranging from simple to complex, when using Microsoft Office software programs and the Internet.

Learning Skills Survey. The Learning Skills 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.

Shadow Studies

A shadow study is a strategy for collecting information by following a person through a series of activities. By following individual students and teachers from class to class throughout the school day, we were able to collect information about the day-to-day use of notebook computers and software applications. Before- and after-school interviews allowed us to capture information about computer use outside of school. The combination of shadow studies and interviews provides rich detail about the use of technology in schools and the nature of the laptop program implementation.

A total of 60 shadow study days were conducted between April and June of 1998 at the same four schools at which students completed our surveys. Two 7th grade and two 10th grade students were shadowed at each of the private schools. Two middle school and two high school level teachers were also shadowed at each of these schools. At the public middle school, two 7th grade Laptop students and two 7th grade Non-Laptop students were shadowed as well as two Laptop teachers. At the public high school, two 10th grade Laptop students, two 10th grade Non-Laptop students and two Laptop teachers were shadowed.

Each participating student was shadowed for 3 days; each teacher was shadowed for one day. Students' shadow days were distributed over a period of at least two weeks.

Shadow days were chosen so that students could be observed while attending all of the courses they were currently enrolled in at least once during the observation period.

Table 2. Number and Distribution of Shadow Days

School/Grade	# Laptop Students (3 days each)	# Laptop Teachers (1 day each)	# Non-Laptop Students (3 days each)
GRADE 7			
Private School 1	2	2	0
Private School 2	2	2	0
Public School	2	2	2
GRADE 7 TOTAL	6 (18 days)	6 (6 days)	2 (6 days)
GRADE 10			
Private School 1	2	2	0
Private School 2	2	2	0
Public School	2	2	2
GRADE 10 TOTAL	6 (18 days)	6 (6 days)	2 (6 days)

Shadowing. Researchers met with their “shadowee” before the start of each shadow day and then accompanied their designated student or teacher to each class. Shadowees engaged in their normal activities while a researcher observed unobtrusively from the back of the classroom.

Prior to the start of shadowing, researchers were trained on observation procedures and coding methods. Researchers recorded information on three types of observation forms during the course of the shadow days: the Class Period form, the Lesson Segment form, and the Informal Computer Use form.

The Class Period form was filled out once for each class period. This form was used to collect basic information about each class period including subject area, length of the period, number of students in class and classroom facilities.

The Lesson Segment form was used to capture detailed information about instructional activities, lesson objectives, teachers’ roles, student grouping, and tools and materials used, including use of computers and particular software applications. In addition to recording which activities took place and which materials were used, researchers recorded the length of students’ engagement with activities and materials. Because the number of instructional activities and lesson objectives varied from class to class, the number of Lesson Segment forms completed for each class period also varied. Each time the focus of a lesson changed, researchers began completing a new Lesson Segment form. Between one and eight Lesson Segment forms were filled out for each class period.

The third observation form, the Informal Computer Use form, was completed only when shadowees used computers between classes, during lunch and before or immediately after school. In some cases, at the public middle school for example, students were prohibited from using their notebook computers between classes or during lunch due to concerns about

security. The Informal Computer Use form captured information about when, with whom and for what purpose computers were used outside of regularly scheduled class time.

Interviews. Each teacher and student who was shadowed participated in a Preliminary Interview prior to his or her first shadow day. Teachers and students also participated in a Before School Interview and an After School Interview each day that they were shadowed.

The students' Preliminary Interview asked about the subject areas, assignments and activities for which they use computers both in and out of school; the software programs they use; which software applications they most (and least) enjoy using; how they decide whether to use a computer or another tool; access to other computers at home and amount of computer experience. Students' Before School Interviews captured retrospective information about their use of computers during the previous afternoon and evening. During their After School Interviews, students reflected on their use of computers during their day at school and shared their expectations for using computers that afternoon and evening.

The teachers' Preliminary Interview captured information about their use of computers for preparing and teaching lessons and their perceptions of the ways in which the laptop program has impacted their instructional practices and their students' work. Teachers' Before School Interviews were used to alert the researchers to expected uses of notebooks during the upcoming day, including any activities the teachers considered particularly noteworthy. During their After School Interviews, teachers commented on the day's lessons and considered what might have been different about their lessons if students did not have access to notebook computers.

Problem-Solving Simulations

Students' problem-solving skills were assessed by engaging groups of students during a single class period in simulations of multi-day classroom projects. We designed two problem-solving tasks with topics selected to appeal to 7th and 10th grade students. Seventh grade students were asked to explore the challenges created by reintroducing wolves to national parks, and 10th grade students considered alternative points of view on the problem of global warming.

Each group of students worked with a single researcher in a quiet setting away from students who were not participating in the study. Students were asked to begin by reading a few pages of background information about their issue. They were then asked to work as a group to choose among three perspectives on their problem and discuss how they would collect, organize and present information to support their group's position. Instructions for students who discussed the wolf problem read as follows:

The students in your class have been invited to represent one of three organizations that have strong opinions about the wolves at next week's Congressional meeting. You and the other students in your group will work together to decide which organization you will represent and how you will go

about developing a presentation that will persuade Congress to adopt your point of view. You will need to consider how you would do research to find evidence to support your point of view and how you would organize your findings to convince Congress that you are right. As a group, you will report on the steps you would take to create a persuasive presentation.

Students spent a few minutes deciding which perspective their group would represent. The researcher then guided the group through a series of scripted questions, such as what kinds of information they would look for, and where they would go to find it. Multiple students responded to each question and group members were encouraged to offer all of their ideas and suggestions for gathering, analyzing and presenting information about their issue. Each of the problem-solving sessions was tape recorded and later transcribed.

In most cases we worked with groups of four to six students. On several occasions, however, up to ten students worked together as a group because having us work with larger groups was more convenient for the teacher who volunteered to have his or her students participate in our study. Two of our 7th grade groups had more than six students; one had seven students and one had eight. Eight of our thirteen high school groups were larger than planned; we worked with one group of seven students, three groups of nine students and four groups of ten students.

We designed the simulation tasks to be completed within a class period; however, sessions at one school were often cut short due to other instructional priorities. As a result, the average number of responses to each of our questions tended to be lower for the groups of students from this school.

Problem-solving sessions were administered in May and June of 1998 at the same schools at which students completed our surveys and participated in our shadow studies. We planned to work only with 7th and 10th grade students; however, due to timing issues, we were not able to gain the cooperation of as many 10th grade teachers as we needed at the public high school. We therefore took advantage of the opportunity to work with a few groups of 11th graders at this school. Our final tallies of participating Laptop and Non-Laptop groups at each school are presented on the following page in Table 3.

While the seventh graders approached their task in earnest, and provided us with interesting insights and discussion, the 10th and 11th graders seemed much less engaged. The researchers who conducted the upper grade groups noted that the students in their groups did not appear to be taking their task very seriously. Many of these groups were conducted close to the last day of school, and this timing may have had a negative effect. The upper grade groups were also larger, allowing less time for in-depth discussion and reflection. Also, we were able to work with only two Non-Laptop groups in the high schools, allowing little basis for comparison.

Not surprisingly, the results from the upper grade groups were inconsistent. Because we were concerned about the reliability and validity of the data, we decided not to include

the upper grade problem solving sessions in this report. We hope to conduct more fruitful problem-solving exercises at the high school level in our future research.

Table 3. Number of Problem-Solving Groups at Each Site

School/Grade	# of Laptop Groups	# of Non-Laptop Groups
GRADE 7		
<i>Private School 1</i>	4	0
<i>Private School 2</i>	4	0
Public School	4	4
GRADE 7 TOTAL	12	4
GRADE 10		
<i>Private School 1</i>	4	0
<i>Private School 2</i>	3	0
Public School	2	2
GRADE 11		
Public School	2	0
GRADE 10, 11 TOTAL	11	2

Descriptions of Students' Favorite Activities

More than 400 students provided descriptions of their favorite assignment or project completed during the 1997-1998 school year. Students responded to several questions about their chosen activity. These questions addressed the steps students followed to complete their assignments; use of tools and materials, including computers; amount of time spent working on their projects; and what was learned, what students liked best, and what they found most challenging about their assignments. Students also described their final products.

All of the 7th and 10th grade Laptop students at the same schools that participated in our other student evaluations were asked to describe their favorite activity. We also sought the participation of a sample of 7th and 10th grade Non-Laptop students at the public schools. However, again, we were not successful in securing the participation of the 10th graders. Instead, we were offered, and we accepted, data from smaller groups of 11th grade Laptop and Non-Laptop students. Students were asked to write their descriptions of their favorite activities during May and June of 1998.

Table 4. Number and Distribution of Favorite Activity Respondents

School/Grade	# of Laptop Groups	# of Non-Laptop Groups
GRADE 7		
<i>Private School 1</i>	70	0
<i>Private School 2</i>	33	0
Public School	67	65
GRADE 7 TOTAL	170	65
GRADE 10		
<i>Private School 1</i>	60	0
<i>Private School 2</i>	40	0
Public School	58	0
GRADE 11		
Public School	19	16
GRADE 10, 11 TOTAL	177	16

STUDENTS' USE OF TECHNOLOGY

A primary goal of the Laptop Pilot Program is to demonstrate that full-time access to "real world" business tools produces substantial educational benefits by supporting and facilitating learning. To understand how and why these benefits may be realized, it is important to know what students are doing with their notebook computers both in and out of school. We thus begin by portraying the frequency, context and purposes of students' computer use. Our descriptions are supported by data gathered from our shadow studies and our teacher and student surveys.

ACCESS TO TECHNOLOGY

Participation in the Laptop Program provides students with round-the-clock access to Toshiba notebook computers loaded with Microsoft Windows and Microsoft Office software. Full-time access to a personal computer is what differentiates the Laptop Program from other efforts to provide students with computer access at school and at home.

To better understand how access to personal notebook computers affects students' use of technology, we employed comparison (or Non-Laptop) groups that do not have access to laptops. Although the students in our comparison groups clearly have less access to computers than the Laptop students, they have higher than average access to computers at home and in school. Of the Non-Laptop students who completed our Technology Skills Surveys, 85% of 7th graders and 76% of 11th graders say they have *and use* computers at home. Sixty-five percent of the 7th graders and 62% of the 11th graders also used computers regularly in school.

HOW MUCH TIME DO STUDENTS SPEND USING COMPUTERS?

Data from our shadow studies clearly indicate that Laptop students use computers more than Non-Laptop students both in and out of school. Differences in frequency and amount of computer use were found for both middle school and high school students.

Seventh grade Laptop students who participated in our shadow studies used computers as much in a day as Non-Laptop students used them in a week. Laptop students spent 66 minutes per day, on average, using their notebooks during school. Non-Laptop students used computers for an average of only 13 minutes during each day at school. At home, the 7th grade Laptop students used computers almost six times as much as Non-Laptop students. Laptop students reported that they used their notebooks for an average of 59 minutes per day outside of school. In contrast, the Non-Laptop students used computers outside of school for an average of only 10 minutes per day.

In-school differences in computer use were even greater for the 10th grade students in our shadow studies. Tenth grade Laptop students used computers in school more than two hours per day, over nine times as much as the Non-Laptop students (122 minutes per day on average in contrast to 13 minutes). Outside of school, the 10th grade laptop owners used

computers 25% more than their Non-Laptop counterparts (101 minutes per day on average in contrast to 81 minutes). Overall, 10th grade Laptop students used computers more than twice as much as Non-Laptop students.

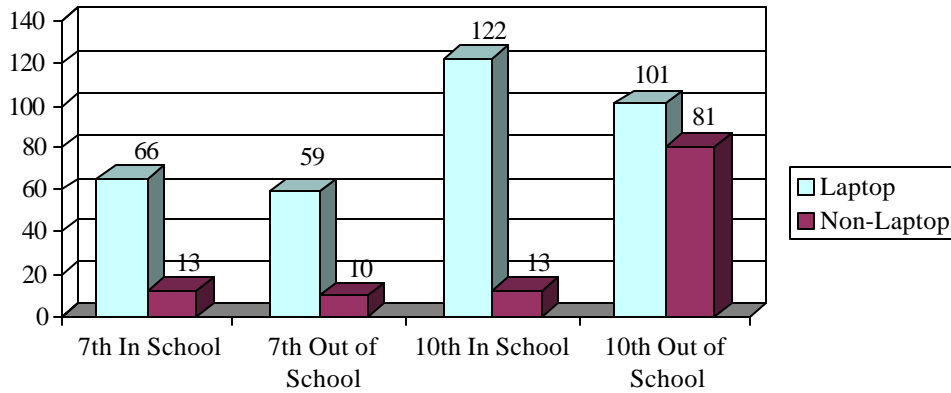


Figure 1. Average Daily Computer Use, in Minutes

Student use varied across sites and within classes. Individual students varied greatly in the amount of use they made of their notebook computers. Table 5 provides the range as well as the amount of time that students used their computers.

Table 5. Average Daily Computer Use by Shadow Study Participants

	GRADE 7		GRADE 10	
	<i>Laptop</i>	<i>Non-Laptop</i>	<i>Laptop</i>	<i>Non-Laptop</i>
<i>IN SCHOOL</i>				
Average (minutes)	66	13	122	13
Range (minutes)	15 – 132	0 – 26	19 – 181	0 - 26
<i>OUT OF SCHOOL</i>				
Average (minutes)	59	10	101	81
Range (minutes)	7 – 140	---	22 – 223	67 - 95
% Schoolwork	83%	50%	85%	71%

Data are from 6 Laptop and 2 Non-Laptop students at each grade level. Students were shadowed for 3 days each.

HOW ARE COMPUTERS USED OUTSIDE OF SCHOOL?

Laptops Appear to Extend the School Day

For both the 7th and 10th grade Laptop students in our shadow studies, laptops appear to have extended the school day. Laptop students spent substantial amounts of out-of-school time completing schoolwork on their notebook computers.

In both the 7th and 10th grades, students with notebook computers dedicated more of their out-of-school computer time to completing school-related work than the Non-Laptop students. Seventh grade Laptop students spent ten times as much out-of-school computer time on schoolwork as 7th grade Non-Laptop students (49 minutes per day on average compared to 5 minutes). Tenth grade Laptop students spent 48% more out-of-school computer time on schoolwork than 10th grade Non-Laptop students (86 minutes per day on average compared to 58 minutes).

When 7th graders used their notebook computers for homework, they typically spent 30 minutes to an hour on each subject. Tenth graders typically spent more than 30 minutes on a subject and it was not unusual for them to spend over an hour-and-a-half working on homework for a particular subject area.

Differences between the patterns of out-of-school computer use found for students with and without laptops cannot be attributed to a simple lack of computer access for the latter group of students. Each of the Non-Laptop students who participated in our shadow studies had access to more than one computer at home.

Purposes of Out-of-School Computer Use

When the Laptop students we shadowed used their notebook computers outside of school, they rarely used them for nonacademic pursuits. Instead, they completed assignments from a variety of subject areas. Figures 2 and 3 present the percentage of out-of-school laptop use time that Laptop students reported using their notebook computers for each subject area or activity. Both 7th and 10th grade Laptop students most frequently used their laptops to work on English and social studies assignments.

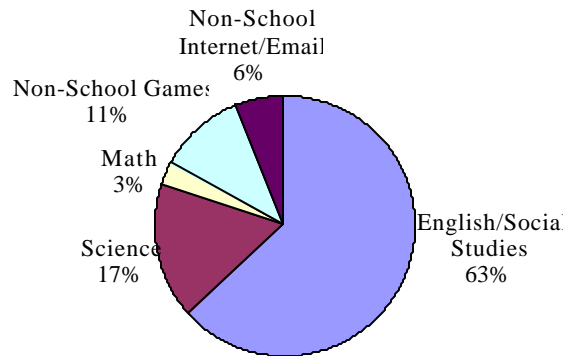


Figure 2. Percentage of 7th Grade Out-of-School Laptop Time Dedicated to Each Subject or Activity

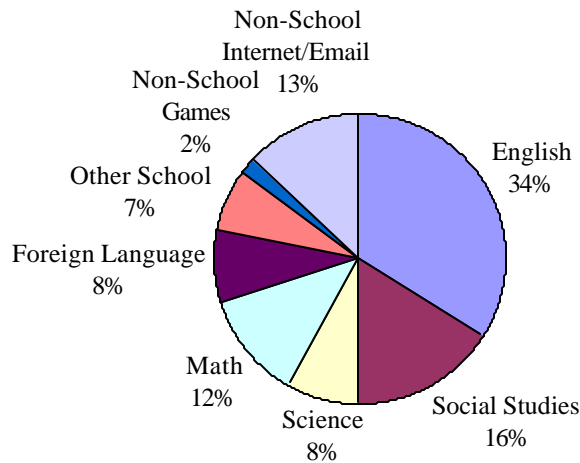


Figure 3. Percentage of 10th Grade Out-of-School Laptop Time Dedicated to Each Subject or Activity

The frequency with which we found Laptop students to be using their notebook computers for homework is not surprising given the results of our Teacher Survey. Teachers across five core subject areas claimed that they assign homework requiring laptop use on a regular basis.

For each of their classes, teachers were asked to indicate the percentage of homework assignments they give per week that involve laptop use. Responses from middle and high school teachers were similar: English and social studies homework assignments were most likely to require laptop use; students were least likely to need their notebook computers to complete math homework. These results mirror the trends found in the shadow data reported above. Differences between the percentages reported for individual subject areas in the two data sets can be accounted for by recalling that the shadow study results are based on observations and interviews from a limited number of students on a limited number of days, while the teacher survey data reflect teachers' perceptions of how they generally use laptops for instruction. Only teachers who assign homework requiring laptops at least occasionally were included in our analysis.

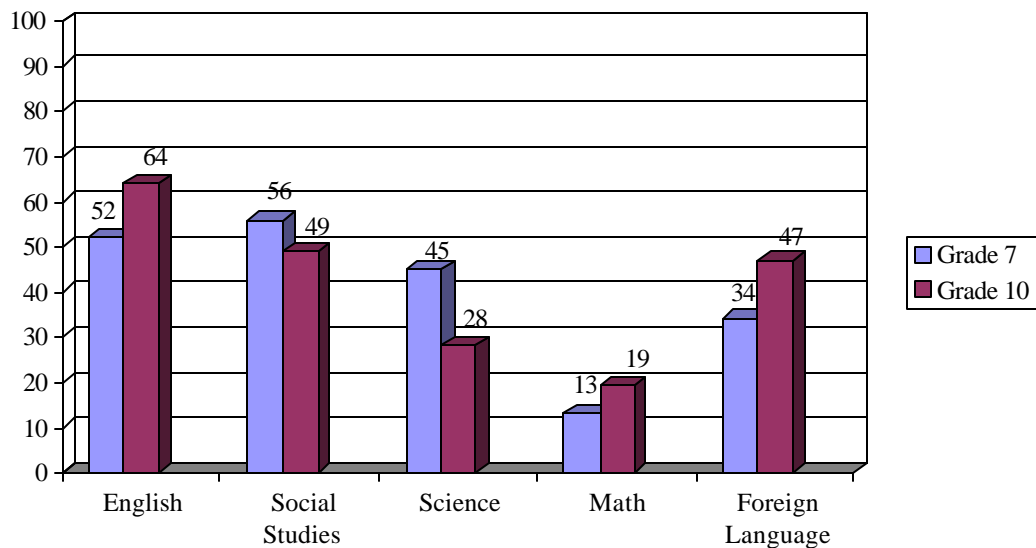


Figure 4. Percentage of Homework Assignments Per Week that Involve Laptop Use (Results from the Teacher Survey)

Note: Numbers reflect number of teachers who reported assigning homework at least occasionally in each subject area.

When we examined the data for the Non-Laptop students in our shadow study, we found that when these students use computers, they engage in some of the same activities as the Laptop students but with different frequencies. For the 7th grade Non-Laptop students, we noted only two instances of out-of-school computer use. One student spent 30 minutes working on a school-related science assignment. The other computer use occurred when a student spent 30 minutes using the Internet for purposes unrelated to school. The 10th grade Non-Laptop students made more frequent use of computers outside of school, but 29% of their time was spent using email and the Internet just for fun. Non-Laptop 10th graders spent 34% of their computer time working on a social studies assignment and 37% of their time working on a math assignment. (The math assignment was a research report that involved use of the Internet and Microsoft Word.)

When we combine school-related use of the notebook computers in and out of school, we find that Laptop middle school students spend almost two hours per day, and Laptop high school students spend more than three-and-one-half hours per day using computers for academic work. It appears that the computer and applications software have become indispensable tools for accomplishing the work of schooling.

HOW ARE COMPUTERS USED IN SCHOOL?

Laptops are Frequently Used in Core Subject Area Classes

Seventh and tenth grade Laptop students who participated in our shadow study made frequent use of their notebook computers during their core subject area classes; in addition, when the notebook computers were used, they were used for substantial amounts of time. These findings are supported by data from our teacher survey.

During our shadow study, we observed 163 core subject area classes that were attended by Laptop students. Core subject areas include English, social studies, science, math and foreign language. At two of the three schools at which we conducted our 7th grade shadow studies, English and social studies were taught together as an interdisciplinary class; at the third school, the content of English and social studies classes also overlapped. We therefore consider English/social studies as a single subject area for the 7th graders.

Observations from our 7th grade shadow studies revealed notebook computer use in almost half of the students' core subject area class periods. Use of the laptops varied, however, across subject areas. Laptops were used during 84% of the 7th graders' interdisciplinary English/social studies classes and 67% of science classes. Within these subject areas, laptops were used more than 40% of total class time. During the 24 days that we spent shadowing 7th grade Laptop students, we did not observe any laptop use in math or foreign language classes. The lack of laptop use in foreign language classes is likely due in part to the relatively small number (9) of class periods observed, but this finding may also be attributed to pedagogical beliefs. One Spanish teacher explained that she uses laptops in 8th grade classes but not 7th because her first year Spanish classes focus on oral communication; 8th graders focus on Spanish culture and literature and use laptops for research and writing.

Our observations of 10th grade Laptop classes revealed notebook computer use in over half of all core subject area class periods. Laptop use was common in English, social studies, science and foreign language classes but was never observed in math. Students used their laptops during almost half of their core subject class time.

Many students and teachers remarked in interviews that they had undertaken math activities and projects that used their notebook computers. Our finding of no math use during our observation period is a result of our sample and timing, not the absence of computer use in math class. Math projects are also noted among students' favorite activities.

Both 7th and 10th grade Laptop students used their notebook computers for about half an hour each time their work called for use of this tool. In many cases, students used their laptops for substantial amounts of time more than once within a given class period.

Table 6. Laptop Students' Computer Use in Core Subject Areas

	# of classes observed	% of classes w/ laptop use	% of class time w/ laptop use	Average duration of laptop use
GRADE 7				
English/Social Studies	25	84%	48%	30 minutes
Science	15	67%	42%	29 minutes
Math	16	0%	0%	---
Foreign Language	9	0%	0%	---
GRADE 7 TOTAL (*range)	65 (16 - 28)	48% (33 - 69)	33% (20 - 44)	30 minutes (17 - 39)
GRADE 10				
English	31	71%	52%	26 minutes
Social Studies	10	50%	44%	38 minutes
Science	27	70%	61%	26 minutes
Math	11	0%	0%	---
Foreign Language	19	47%	39%	26 minutes
GRADE 10 TOTAL (*range)	98 (24 - 39)	56% (37 - 92)	47% (25 - 66)	27 minutes (20 - 37)

Data are from 6 Laptop students and 6 Laptop teachers at each grade level. Students were shadowed for 3 days each. Teachers were shadowed for 1 day each.

*Note: Ranges under TOTAL show the variation in amount of laptop use among the 3 participating schools. Similar degrees of variation were also observed within the individual subject areas.

The results of our teacher survey show similar trends in the frequency with which notebook computers are used in core subject area classes. For each of their classes, teachers were asked to indicate the percentage of class time that students use laptops. Only teachers who use laptops at least *sometimes* for classroom instruction were included in our analysis. Both middle and high school teachers reported that they use laptops most frequently in English and social studies classes and least frequently for math. In all subject areas except science, high school teachers claim to use laptops more frequently than middle school teachers.

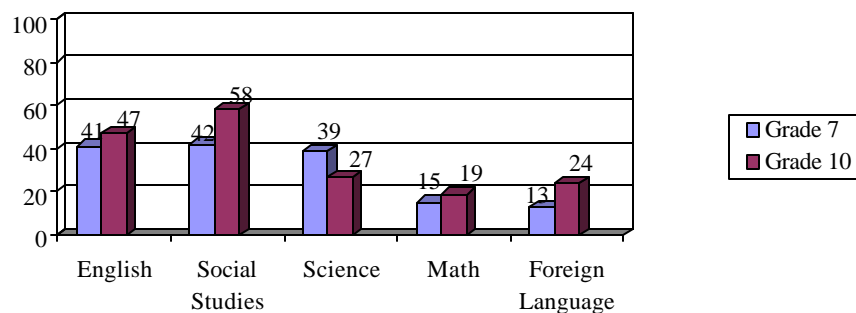


Figure 5. Percentage of Class Time that Students Use Laptops (Results from the Teacher Survey)

Non-Laptop Students Rarely Use Computers in Core Subject Area Classes

Although all of the Non-Laptop students we shadowed told us that they use computers at school, computer use was only observed in one out of the 27 core subject area classes that we attended with these students. No computer use was observed during the 12 core subject area classes shadowed for the two 7th grade Non-Laptop students. Tenth grade Non-Laptop students used computers during one of 15 core subject classes. Students in the social studies class in which computers were used spent 55 minutes using library desktops to conduct research on the Internet and Infotrac.

Computer Use in Non-Core Subject Area Classes

The Laptop students we shadowed were frequently observed using their notebook computers during non-core subject area classes. For example, 7th grade Laptop students used their notebook computers during all three Commercial Advertising classes that we observed. Students worked in groups on projects requiring research, writing, problem-solving and art work. Work was accomplished using Word, PowerPoint and the Internet.

Tenth grade Laptop students used their notebook computers during all six Religion classes that we observed. Students worked in groups or individually on designing brochures with the use of Word, PowerPoint and a CD-ROM. Tenth grade Laptop students were also observed using desktop computers during two Computer Applications classes. Students used the desktops to work on a DOS tutorial and to present PowerPoint projects that involved use of the Internet.

Computer use was never observed during Laptop students' Drama, Art or Music classes. Nor was computer use observed during any non-core subject area classes attended by Non-Laptop students. The Non-Laptop students' classes included Drama and Teen Living.

Laptop Use in Public versus Private Schools

Observations from our shadow studies indicated that Laptop students who attended public schools used their notebook computers more frequently and for more of the class time than the Laptop students who attended private schools. Public school students in both the 7th and 10th grades used their notebook computers in a higher proportion of core subject area classes and during a greater proportion of class time than the private school students. Furthermore, when laptops were used in public school classes, they were used for longer periods of time. This latter difference is likely due to the longer average class period length in the public schools.

Differences between the frequency of laptop use in the public and private schools may be related to levels of teacher commitment or to the need to satisfy parents. Public school teachers generally volunteer to participate in the laptop program and they often are

selected from a pool of qualified candidates. Because private schools tend to adopt the laptop program across entire grade levels, some teachers may participate in the program because they have to rather than because they choose to. Parents' satisfaction may come into play because public school parents are not used to paying outright for their children's education; if they are going to pay for their children to have access to a special tool, they want to be sure their children use that tool. For private school parents, notebook computers are just one part of the educational experience they are paying for their children to have.

Table 7. Use of Laptops in Public and Private Schools

	Typical class length (minutes)	# of classes observed	% of classes w/ laptop use	% of class time w/ laptop use	Average duration of laptop use
GRADE 7					
Private School 1	40/90	28	46%	27%	26 minutes
Private School 2	40/80/95	21	33%	18%	17 minutes
Public School	120	16	69%	44%	39 minutes
GRADE 7 TOTAL	---	65	48%	32%	30 minutes
GRADE 10					
Private School 1	42	35	37%	25%	22 minutes
Private School 2	40	39	51%	45%	20 minutes
Public School	80	24	92%	66%	37 minutes
GRADE 10 TOTAL	---	98	56%	47%	27 minutes

Data are from 2 Laptop students and 2 Laptop teachers per grade level at each school. Students were shadowed for 3 days each. Teachers were shadowed for 1 day each. The table includes data from core subject area classes only.

Purposes of In-School Laptop Use

One of the primary benefits of participation in the Laptop Program is full-time access to a computer, the same tool found to be so effective outside of school, out in the "real world." As a tool, computers are valuable for accomplishing particular tasks; computers do not meet our every need, nor are they expected to. The same is true for computer use in school. To understand how notebook computers serve as a tool that supports learning in school, we examined the purposes for which they were used within the context of students' core subject areas. Our findings are supported by data from the shadow studies and the teacher surveys.

During the shadow studies, classroom observers used four categories to record the purpose of students' laptop use. Students were recorded as using notebook computers when at least a third of the class were actively engaged in hands-on computer use. All of the instances of laptop use that we observed fit into one of our four categories. The categories are defined as follows:

<i>Writing</i>	Writing includes work towards completion of any extensive writing assignment such as a paper, essay or responses to open-ended questions.
<i>Note Taking</i>	Note taking includes all recording of information for later reference as well as completion of templates that require brief responses to “fill-in-the-blank” types of questions.
<i>Research/ Data Analysis</i>	Research/Data analysis includes using the Internet or other computer-based information sources, assembling research-based projects such as web sites and PowerPoint presentations, gathering data during hands-on labs and analyzing data. Research/Data analysis includes only laptop uses that could not be coded primarily as writing or note taking. Therefore, completing templates based on observations made during science labs is included under note taking. Writing extensive observations during labs is included under writing.
<i>Assessment</i>	Assessment includes taking tests, scoring tests and evaluating one’s own or others’ work.

Based on our observations of 65 7th grade and 98 10th grade core subject area class periods, Laptop students primarily use their notebook computers for writing, research and note taking. Laptops are rarely used for assessment.

During our shadow studies, 7th grade Laptop students used their notebook computers most frequently for research and writing. Research accounted for 60% of all laptop use during science classes. Writing and research occurred almost equally often (43% and 41% of laptop use, respectively) in interdisciplinary English/social studies classes.

Tenth graders used their notebook computers most frequently for writing and note taking. Writing accounted for over 40% of laptop use in English, foreign language and science classes. Note taking accounted for 42% of laptop use in science and over 30% of laptop use in English and foreign language classes. In social studies, students most often used laptops to conduct research.

Table 8. Purposes of In-School Laptop Use Observed during Shadow Studies
(% calculated across rows)

	Writing	Note Taking	Research/ Data Analysis	Assessment	TOTAL
GRADE 7					
English/Social Studies	16 (43%)	6 (16%)	15 (41%)	0	37
Science	3 (15%)	5 (25%)	12 (60%)	0	20
Math	0	0	0	0	0
Foreign Language	0	0	0	0	0
GRADE 7 TOTAL	19 (33%)	11 (19%)	27 (47%)	0 (0%)	57
GRADE 10					
English	17 (47%)	11 (31%)	4 (11%)	4 (11%)	36
Social Studies	2 (22%)	1 (11%)	6 (67%)	0	9
Science	17 (40%)	18 (42%)	8 (19%)	0	43
Math	0	0	0	0	0
Foreign Language	7 (47%)	5 (33%)	3 (20%)	0	15
GRADE 10 TOTAL	43 (42%)	35 (34%)	21 (20%)	4 (4%)	103

Note: The numbers recorded for writing, note taking, research/data analysis, and assessment refer to the number of instances during which laptops were used for each purpose.

Findings from our teacher survey mirror the trends found in our shadow studies. In our survey, teachers were asked to list the tasks that their students accomplish using their notebook computers for each of the classes they teach. Each teacher could list multiple purposes for which students use laptops.

Due to differences between the questions asked and the methods used for the teacher survey and the shadow studies, comparisons between the studies must be limited to looking at trends rather than exact percentages. The percentages presented in Table 8 reflect the relative frequencies of laptop use observed for each of four purposes during 24 shadow days at each grade level. Together, the tallies for writing, note taking, research/data analysis and assessment account for 100% of our observations. Percentages from the teacher survey reflect the proportion of teachers who listed each of several purposes for using notebook computers in their classrooms. The teachers' responses do not reflect frequency of use; students may use laptops for each of the listed purposes once during the school year or on a daily basis.

The trends identified in both the shadow studies and the teacher survey support the conclusion that middle school Laptop students predominantly use their notebook computers for writing and research. Middle school teachers who participated in our survey also reported frequent use of notebook computers for presentations. Only three student presentations were observed during the shadow study (only one in a core subject area class). These were not recorded in Table 8 because the table only reflects instances when at least a third of the students in a class were engaged in hands-on laptop use; during presentations, only a single student is actively using a computer. One third of the middle school teachers reported use of laptops for note taking, but only one teacher reported using laptops for assessment. Several other laptop uses were mentioned by just a few middle school teachers. These include: graphic organizers, email, mind maps, simulations, diagrams, CD-ROM use, art, calendars, a web meeting and dictionaries.

Our shadow study observations and teacher survey results are also mutually supportive at the high school level. Both sets of data indicate that high school students most frequently use notebook computers for writing and note taking. Like the middle school teachers, high school teachers reported frequent laptop use for presentations. Over 40% of high school teachers indicated that notebook computers are used for research, but only three teachers noted that laptops are used for assessment. Other purposes for which high school students use laptops include: vocabulary, text searches, email, simulations, labs, math applications, art, CD-ROM use, dictionaries and translations. Each of these “other” purposes was mentioned by just a few teachers.

Figure 6 presents the percentage of teachers across all subject areas reporting laptop use for writing, note taking, research, assessment, presentation and other purposes. Table 9 presents the percentage of teachers from each core subject area reporting laptop use for each purpose. The figures in this table suggest that the ways in which notebook computers are commonly used varies between subject areas; however, the limited number of teachers representing each subject area requires these differences to be interpreted with caution.

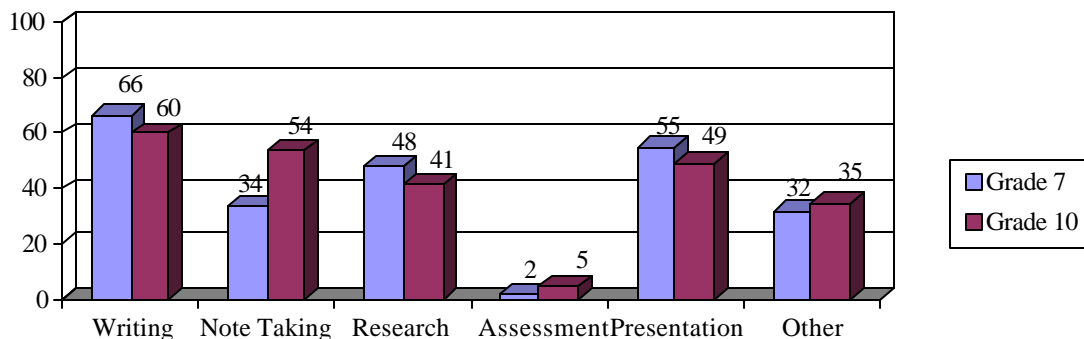


Figure 6. Percentage of Teachers from All Subject Areas Reporting Laptop Use for Each Purpose

Table 9. Percentage of Subject Area Teachers Reporting Laptop Use for Each Purpose

	#	Writing	Note Taking	Research / Data Analysis	Assessment	Presentations	Other
MIDDLE SCHOOL							
English	22	91%	36%	45%	5%	73%	18%
Social Studies	15	60%	47%	47%	0%	67%	13%
Science	15	80%	13%	73%	0%	53%	33%
Math	18	50%	17%	56%	0%	28%	28%
Foreign Language	9	33%	44%	11%	0%	56%	67%
HIGH SCHOOL							
English	18	89%	61%	50%	6%	50%	17%
Social Studies	10	70%	90%	50%	20%	30%	0%
Science	12	67%	50%	50%	0%	67%	50%
Math	12	8%	25%	33%	0%	42%	42%
Foreign Language	12	50%	50%	25%	0%	50%	67%

Note: # refers to the number of teachers responding to the survey within each subject area and grade level.

Choosing Appropriate Tools

In a separate analysis of our shadow data, we looked at the types of tasks Laptop students performed in school using either their notebook computers or paper and pen/pencil, and which tool was chosen when either one could be used to complete a task. Our results indicate that Laptop students almost always used their notebook computers for writing assignments. Notebook computers, however, were not frequently used for other tasks that could be completed using either a computer or paper and pen/pencil. Students were much more likely to use paper and pen/pencil for taking notes, assessment and solving math problems.

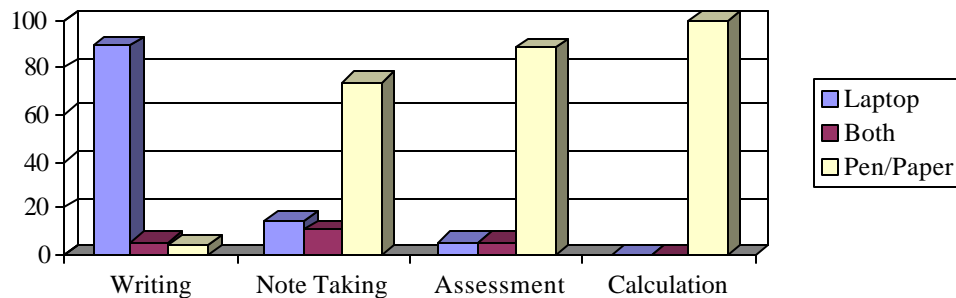


Figure 7. Laptop Students' Tool Choice for In-School Tasks

Students' responses to a question asked during the Preliminary Interviews for the shadow study provide explanations for the pattern that emerged from our observations.

Students were asked, “How do you decide when to use your laptop and when to use another tool such as paper and pencil?” Decisions about when to use each tool were based primarily on issues of efficiency and the desired quality of students’ final product. Paper and pencil were chosen when students needed to do something fast such as jot something down or draw a diagram in their notes. Using paper and pencil in these cases was faster than booting up a computer. Most students also said they took notes faster with paper and pencil, although some did use their laptops for note taking.

Students chose to use their notebook computers for larger writing projects so they could use editing tools and so they would not have to rewrite by hand. Laptops were chosen so that the final product would look neater, and some claimed that neater work resulted in a better grade. Several students also noted that they typed faster than they wrote and typing did not hurt their hand as much.

Use of Software Applications

Findings from the Shadow Studies

The results presented above indicate that Laptop students spend a large proportion of their computer use time writing and taking notes. Given these findings, we were not surprised to learn that Microsoft Word was the tool that was predominantly used when we observed students working on their notebook computers. Both 7th and 10th grade Laptop students were more likely to be using Word than any other software program during the shadow study. For the 7th graders, the Internet was a close second.

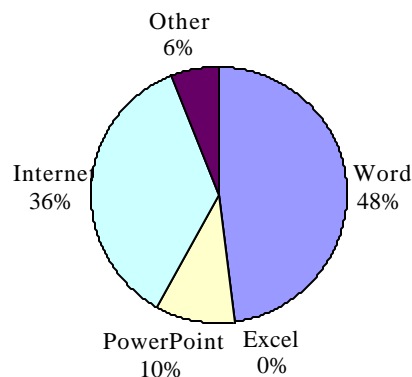


Figure 8. Seventh Grade Laptop Students' Software use in School

Note: Other software includes Print Shop Publisher and email

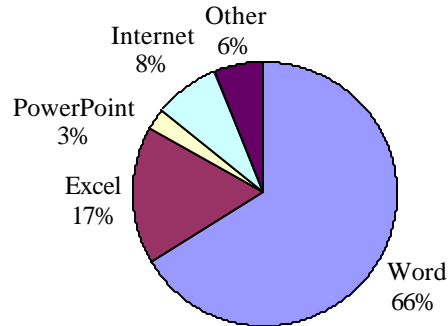


Figure 9. Tenth Grade Laptop Students' Software use in School

Note: Other software includes Vaneer Probeware, Logger pro graphing software, Infotrac, Paint, a CD-ROM, Homepage, and DOS

Software use outside of school was distributed similarly to in-school use. Seventh grade Laptop students reported in their shadow study interviews that they mostly used Word (6 instances) and the Internet (6). Use of Print Shop Publisher (4), PowerPoint (2) and Excel (1) were also reported. Tenth graders predominantly used Word (20 instances). They also reported use of Excel (2), PowerPoint (1), Access (1), the Internet (1), a CD-ROM (1) and Geometer's Sketchpad (1).

Supporting Evidence from the Teacher Survey

Our shadow study data provide us with information about software use in a limited set of Laptop classrooms and by a limited number of students during several days close to the end of the school year. We get a broader perspective on software use in Laptop classrooms from our Teacher Survey, which addressed the frequency with which Word, Excel, PowerPoint, Access, the Internet and email are typically used for instructional purposes.

Table 10 presents the percentage of teachers in our survey who said they use each software tool, and the average number of times per week each software application is used for each instructional purpose. It is important to note that only teachers who claimed to at least occasionally use a particular tool for a particular instructional purpose are included in the average for that purpose.

Table 10. Teachers' Use of Software for a Variety of Instructional Purposes

TOOL	% of teachers who use each tool	Average # of teacher uses per week to prepare lessons	Average # of teacher uses per week to teach lessons	Average # of student uses per week in class	Average # of student uses per week for homework
Word	98%	6.7	3.6	3.8	3.4
Excel	67%	2.9	1.7	2.2	1.6
PowerPoint	69%	1.5	1.6	1.4	1.3
Access	22%	1.3	1.3	1.9	1.6
Internet	84%	4.3	2.3	2.6	2.3
Email	68%	7.6	4.3	2.5	1.8

Almost all teachers use Word, and they frequently use this tool for a variety of instructional purposes. Teachers noted that they use Word to create assignments, tests, worksheets, study guides, scoring guides, project outlines, tables, schedules, newsletters, and web pages. They use Word for their own writing, such as for writing evaluations, and to edit students' work. Teachers indicated that their students use Word to write essays, lab reports, and notes, and to create graphic organizers, brochures and web pages.

The second most commonly used tool is the Internet. Teachers find the Internet to be particularly useful to their students and they frequently use it to prepare lessons. Both students and teachers use the Internet for research and presentations. Teachers also use the Internet to access background information for their lessons, to gather collections of web sites for their students and to listen to radio broadcasts in different languages.

Email, PowerPoint and Excel are each used by about two thirds of the teachers. Email is used for correspondence and information exchange with colleagues, parents and students as well as to collect students' homework assignments. Administrative use of email includes maintaining internship programs, receiving departmental updates, keeping track of attendance and receiving information from listserves. Teachers noted that students use email for communication, both with teachers and with other students, to turn in homework, and to gather and share information.

Excel is also used for both administrative and instructional tasks. Teachers use Excel for administrative purposes such as keeping track of attendance and grades and for budgeting and scheduling. Instructional uses include creating verb charts for foreign language classes and designing problem-solving and analysis exercises. Teachers listed several tasks that students accomplish using Excel. These include creating spreadsheets, graphs and charts, analyzing population projections and the results of science experiments, and keeping records. Students in the shadow study were also observed using Excel for note taking.

Teachers noted that they commonly use PowerPoint for creating presentations, outlines and graphs. Teachers in the shadow study were observed delivering PowerPoint

presentations on 5 occasions. Students use PowerPoint for presentations as well as for storytelling, demonstrations, and web page design.

Access is the Microsoft Office application that is used least frequently overall, but those teachers who do use the program use it for multiple purposes at least once a week. Many uses of Access are administrative. These uses include student scheduling, grade reports, writing comments, organizing sports teams, and inventory control. Teachers use Access as an instructional tool by designing databases for vocabulary, and for science and social studies content. Students make use of these databases, and they also use Access for journal writing, note taking and for writing lists.

In addition, teachers seem to be combining different software tools as they create projects for their students. In response to our survey question which asked teachers to choose a software tool they use often and describe a typical project, one-third of all the teachers described projects which used more than one software application. These lessons provide examples of how some teachers are successfully combining the best aspects of many software tools. Microsoft Word, the Internet, Excel, and PowerPoint were the programs most often combined with other software, in that order.

The following sample of teachers' lesson descriptions highlight the variety of ways teachers are employing different software tools in different subjects at various grade levels.

A sample of teachers' lesson descriptions

Word: Student-generated grammar books

English, 7/8th grade

I composed my own grammar diskette listing 15 major concepts and examples. Students use inductive methods to generate rules and add them to the program. When a student makes an error in writing, she adds the correction to the appropriate place on the diskette. In this way, students have generated their own tailor-made grammar books.

Excel: Spreadsheets for comparing/contrasting

History, 9/10th grade

I use Excel spreadsheets to organize items in order to compare and contrast, for example, different countries in Europe and how, when and why they formed nations. [Spreadsheets are] organized by country according to the following characteristics: type of rule, type of people's involvement, religion, trade, geography, capital city, and type of government. Students first had to decide how to organize the spreadsheet to their benefit—then had to decide which details were meaty and which were trivial.

Excel: Analysis of acceleration and Newton's Law
Science and Math, 9th and 12th grade

I teach Newton's Law using Excel. Students take data on the motion of a cart with different forces and masses on it, then use Excel to analyze the resulting acceleration. The graphs generated in Excel quickly and clearly demonstrate the mathematical relationship between force, mass, and acceleration. ...[Using the laptops,] students got past the details of the experiment to think about the meanings of the graph and proportionality.

PowerPoint: Creating templates for an ongoing research display***5/6th grade***

I recently brainstormed[what kinds of] data students would need to pull from research they were reading. We then created a template together on a PowerPoint slide. The students then got a copy of this PowerPoint slide; they duplicated it for each piece of research they read. They now have a running presentation of their research in an organized manner. They can share this research with their group members and use it to refer to for other projects.

Internet: Current Events presentations***History, 11th grade***

We spend most of Fridays doing current events. We now use (mostly) the Internet to accomplish this task. Each week one student is in charge of current events, but the rest of the class also bring their laptops, and it becomes a group process once the student in charge presents the topic or issue. The level of participation and enthusiasm is very high, and the students learn a lot about the topic since they are all involved and not just sitting there listening to someone else talk!

Multiple tools: Creating a planet database***5/6th grade—Access, Encarta, Word, Excel***

Students created their own database of the planets with instruction from me. They designed fields, selected data types, and were encouraged to use Encarta to embed pictures and utilize "any resource" to collect data. (We had no Internet access.) Students processed information about planets and learned how to use a simple database to take notes and retrieve information. In the second phase, students wrote a paper about three planets using the graphics in the document. Advanced students made comparison charts on Excel and embedded them in their documents.

Multiple tools: State history/geography project***History 7/9th grade-- Internet, Word, Excel, Publisher, PowerPoint***

In Ohio history, the students are using a combination of software applications for a Destination Ohio project. They are using the Internet for research on sites to see in Ohio. Then, using Word, they are planning an itinerary of their trip. They use Excel to keep track of the cost, and Publisher to make a brochure for one of the places they intend to visit. And finally they create a PowerPoint presentation selling this trip to other students.

Multiple tools: Creating data models***Math, 9th grade-- Excel, Internet, PowerPoint***

The [math] unit dealt with taking data and analyzing the pattern through a mathematical model, a linear model. Students learned to use spreadsheets and Chart Wizard to look at data graphically and fit a trend line to find an equation to the data. Using this line of best fit, students could predict future outcomes based on the data model, and evaluate the accuracy of their predictions using a scatter plot of residuals. Students were given a project to find data examples from the Internet and to analyze [them], developing the line of best fit, then checking the accuracy of their results.... The ability to change variables in the spreadsheet allowed for all the "what if's" to be developed. The spreadsheets gave students the ability to analyze easily, clearly and graphically the results of changing the variables in the model.

Students Views are Consistent with Their Teachers

Results from the Technology Skills Surveys that were completed by both Laptop and Non-Laptop students directly support the findings discussed above. Laptop students claim that Word is the software program that they use most frequently. The Internet is the second most commonly used tool, followed by email, Excel and PowerPoint. Laptop students also often use CD-ROMs, but teachers were not asked about this tool. Of the tools students were asked to rate, Access was used least frequently.

Non-Laptop students most frequently use the Internet, Word and CD-ROMs. Use of email, Excel, PowerPoint and Access occur relatively infrequently. Comparisons between the frequencies with which Laptop and Non-Laptop students use each of the software tools they were asked to rate indicate that the Laptop students have more experience with every tool, with the possible exception of Access. Differences between the two groups of students are statistically reliable for all tools except Access; the difference between the frequency with which the two groups use Access is marginally significant.

Differences between the frequencies with which Laptop and Non-Laptop students' use Word and the Internet are especially notable. On average, Laptop students use Word on a daily basis in contrast to the Non-Laptop students who use Word once a week. Laptop students use the Internet more than once a week while Non-Laptop students use the Internet about once a week. Average ratings for each group of Laptop and Non-Laptop students appear in Table 11.

Table 11. Frequency of Software Application Use by Laptop and Non-Laptop Students

School/ Grade	Word	Excel	Power Point	Access	Interne t	Email	CD- ROM
LAPTOP							
Grade 7							
Private School 1	4.5	2.3	2.8	1.6	4.7	4.4	3.2
Private School 2	4.9	2.1	2.2	1.2	3.3	2.5	3.9
Public School	4.8	3.1	2.6	1.7	3.4	2.6	4.1
Grade 10							
Private School 1	4.4	2.1	2.1	1.3	4.1	4.4	2.4
Private School 2	4.9	3.5	2.1	1.3	3.3	3.2	3.1
Public School	4.9	2.5	2.6	1.8	4.5	3.7	4.0
Grade 11							
Public School	4.8	2.4	3.1	1.4	4.6	3.2	4.0
TOTAL LAPTOP	4.7	2.6	2.5	1.5	4.0	3.5	3.5
NON-LAPTOP							
Grade 7							
Public School	2.8	1.7	2.2	1.4	3.0	2.0	3.0
Grade 11							
Public School	2.7	1.5	1.5	1.2	3.2	2.1	2.8
TOTAL NON- LAPTOP	2.8	1.6	1.8	1.3	3.1	2.1	2.9

Students rated each item on a 5 point scale. 1 = never; 2 = less than once a week; 3 = once a week; 4 = more than once a week; 5 = almost daily.

MORE COMPUTER USE RESULTS IN MORE PROFICIENT STUDENTS

Results from our Technology Skills Survey indicate that Laptop students' experience with multiple software applications results in greater proficiency with each of these tools. Laptop students have more confidence in their knowledge of these tools than Non-Laptop students, and most of them believe they are knowledgeable enough to teach skills to others.

In our surveys, students with and without notebook computers were asked to rate their ability to use Word, Excel, PowerPoint, Access, the Internet and email. Laptop students rated themselves as more proficient at using all of these applications except for Access. All of the differences between the Laptop and Non-Laptop groups are statistically reliable. Average ratings for each group of Laptop and Non-Laptop students appear in Table 12.

Table 12. General Proficiency Ratings of Laptop and Non-Laptop Students

School/ Grade	Word	Excel	Power Point	Access	Interne t	Email	CD- ROM
LAPTOP							
Grade 7							
Private School 1	4.1	3.1	3.8	2.0	4.1	4.2	3.8
Private School 2	3.9	2.7	3.1	1.4	3.4	3.1	4.0
Public School	3.9	3.1	3.7	2.3	3.8	3.4	4.2
Grade 10							
Private School 1	4.0	3.6	3.3	2.3	3.9	4.2	3.5
Private School 2	4.2	3.1	3.3	1.6	3.4	3.5	3.7
Public School	4.0	3.4	3.9	2.7	4.2	4.0	4.2
Grade 11							
Public School	4.2	3.5	4.1	2.1	4.3	4.1	4.3
TOTAL LAPTOP	4.0	3.2	3.6	2.1	3.9	3.8	4.0
NON-LAPTOP							
Grade 7							
Public School	3.4	2.0	3.4	1.7	3.3	2.5	3.1
Grade 11							
Public School	3.5	2.6	2.6	2.2	3.3	3.1	3.4
TOTAL NON- LAPTOP	3.4	2.3	3.0	1.9	3.3	2.8	3.3

Students rated each item on a 5 point scale. 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.

We also asked students to rate their ability to perform a variety of general computer-use tasks and a selection of specific tasks within Word, Excel, PowerPoint, Access, the Internet and Email. Our survey covered 29 specific skills ranging from simple to complex. Examples include using formulas in Excel, adding sound to a PowerPoint presentation, or creating headers in Word. Proficiency with these skills demonstrates students' mastery of the "basic operations and concepts" standards described in ISTE's *National Educational Technology Standards for Students*.

Differences between the ratings provided by Laptop and Non-Laptop students favored the Laptop groups for each of the skills in our survey. These differences were statistically reliable with two exceptions; differences between the groups on two out of three specific Access skills did not reach significance. Average ratings for each group of Laptop and Non-Laptop students for each skill category appear in Table 13.

For all categories except Access, comparisons between the averages presented in Tables 12 and 13 show larger differences between the two groups of students when they are asked about specific skills than when they are asked about their general proficiency levels.

Table 13. Specific Skill Ratings of Laptop and Non-Laptop Students

School/ Grade	Word	Excel	Power Point	Access	Interne t	Email	Genera l
LAPTOP							
Grade 7							
Private School 1	4.2	3.6	4.3	1.7	4.4	4.8	4.5
Private School 2	4.2	3.3	4.1	1.8	3.5	3.5	4.2
Public School	4.2	4.4	4.4	2.5	4.2	3.3	4.5
Grade 10							
Private School 1	4.2	4.0	3.7	2.5	3.9	4.4	4.3
Private School 2	4.6	4.3	4.3	1.9	3.6	3.9	4.5
Public School	4.6	4.2	4.5	3.6	4.4	4.5	4.6
Grade 11							
Public School	4.6	4.3	4.6	3.2	4.4	4.7	4.9
TOTAL LAPTOP	4.3	4.0	4.3	2.5	4.1	4.1	4.5
NON- LAPTOP							
Grade 7							
Public School	3.0	2.1	3.9	1.8	2.6	2.4	3.0
Grade 11							
Public School	3.3	2.6	2.7	2.3	3.4	3.3	3.4
TOTAL NON- LAPTOP	3.2	2.4	3.2	2.1	3.1	2.9	3.2

Students rated each item on a 5 point scale. 1 = I don't know what this means.; 2 = I don't know how to do this.; 3 = I can do this.; 4 = I can do this well.; 5 = I can teach someone how to do this. I am an expert.

IMPACTS ON TEACHING AND LEARNING

The results presented in the previous section of this report indicate that students who participate in the Laptop Program use computers more frequently than students without access to notebook computers, both during school and outside of school. Laptop students use computers to complete schoolwork from a variety of subject areas. They gain substantial expertise in using multiple software programs for a broad range of purposes, most notably writing, research, data analysis, note taking and presentations.

This section expands on these findings by closely examining the impacts of laptop access and use on teaching and learning. The impacts that we describe are consistent with the changes called for in educational reform documents such as the U.S. Department of Labor's SCANS report and ISTE's *National Educational Technology Standards for Students*. They are also consistent with constructivist approaches to learning encouraged by many of the school reform programs.

In many ways, the Laptop Program appears to serve as a catalyst for producing the types of educational change called for in these documents and instructional approaches. For example, Laptop students engage in more collaborative work. Their assignments provide them with frequent opportunities to locate, analyze, interpret and communicate information. They apply active learning strategies and critical thinking skills when completing school tasks and when considering real-world problems. Teachers engage in less lecturing and spend more time consulting with students to facilitate independent learning.

The findings that we report provide evidence that laptops may be particularly well-suited to supporting technology's promise of radically changing teaching and learning. The changes that we document with evidence from our shadow studies, teacher and student interviews and surveys, and students' problem-solving simulations fit well with the expectations for technology's role in education outlined in the SCANS (1992) report:

Even more promising [than CD-ROM and CD-I technologies] are instructional tools that allow students to use the same technology that adults use at work. For example, word processing makes it easier for students to submit multiple drafts of a paper. In short, technology offers the opportunity to change the roles that teachers and students have traditionally played. With technology dispensing information, teachers are free to coach and facilitate student learning. With technology monitoring learning, students can become active learners, working to effectively acquire new skills as they solve problems. If the goal of creating high-performance learning organizations is to be realized, the reinvention of American education has to incorporate these new tools. (p. 45, 1992)

CHANGES IN TEACHING

Students Collaborate More When Using Laptops

Students spend most of the class time in active involvement with the subject matter and with each other. We are quickly becoming co-learners and co-teachers.
(9th grade foreign language teacher)

I rely more on my students to teach one another about laptop skills. The atmosphere of peers teaching peers is very positive. (6th grade teacher)

Data from our shadow studies and our teacher and student surveys consistently indicate that Laptop students spend more time working collaboratively in groups than students without access to notebook computers. Teachers also report that Laptop students learn to rely on each other for assistance.

During the shadow studies, observers noted the amount of time students spent working together as a whole class, working in groups of two or more and working individually. Overall, 7th graders spent the majority of class time working individually; 10th graders spent most of their class time working as a whole class. The smallest proportion of class time for both grade levels was spent working in groups. However, Laptop students in both the 7th and 10th grades spent more time engaged in group work than Non-Laptop students. Seventh grade Laptop students spent 18% of class time engaged in group work, in contrast to 4% of class time for Non-Laptop students. Tenth grade Laptop students spent over twice as much time engaged in group work as 10th grade Non-Laptop students (22% of class time in contrast to 10%).

To determine whether Laptop students' class work was generally organized differently than Non-Laptop students' class work, or if group work typically occurred only when Laptop students were actively using their notebook computers, we compared the proportion of time Laptop students spent engaged in group work when they were using laptops versus when they were not. Tenth graders were found to spend more time working in groups when using laptops (30% of class time versus 11% of class time). The trend was the same for 7th graders; however, the difference between the percentages of time when students were and were not using laptops was smaller (21% versus 16% of class time). Laptops as a tool, then, may be increasing opportunities for collaboration.

Further comparisons between the percentages of time that Laptop students did and did not use their notebook computers indicated that 7th and 10th grade students were most likely to be working individually when working on their laptops. Students at both grade levels were most likely to be engaged in whole class activities when their laptops were not in use. Tenth graders, however, used laptops more frequently than 7th graders during whole class activities. This difference reflects the 10th graders' more frequent use of laptops for note taking during lectures, presentations and discussions.

Table 14. Percentage of Time Spent Engaged in Whole Class, Group and Individual Activities

Students	LAPTOP USE			NO LAPTOP USE			OVERALL		
	Whole	Group	Indiv.	Whole	Group	Indiv.	Whole	Group	Indiv.
<i>LAPTOP</i>									
Grade 7	3%	21%	76%	55%	16%	29%	30%	18%	52%
Grade 10	26%	30%	43%	71%	11%	17%	46%	22%	32%
<i>NON-LAPTOP</i>									
Grade 7	0%	0%	0%	39%	4%	57%	39%	4%	57%
Grade 10	0%	0%	100%	57%	11%	33%	52%	10%	38%

Note: The table only includes data from classes in subject areas in which laptops were at least sometimes used. 7th grade data includes only English/social studies and science classes. 10th grade data includes English, social studies, science and foreign language classes. No English or science class data was available for 10th grade Non-Laptop students.

Data from our student and teacher surveys support the finding that Laptop students spend more time engaged in group work than Non-Laptop students. Laptop students who completed our Learning Skills survey reported a higher frequency of writing reports and papers in collaboration with other students than Non-Laptop students. This difference is statistically reliable. Sixty-eight percent of the Laptop teachers we surveyed stated that the amount of cooperative learning and group work in their classrooms has increased since the start of the Laptop Program.

Teachers who participated in our surveys and interviews also told us that students' ability to do collaborative work in groups has increased since they began using laptops in their classrooms. All 12 of the shadowed teachers (100%) stated that laptops impacted student collaboration. Teachers see students asking each other questions and depending on their peers for information, ideas and editing as well as technical help. One teacher explained that when students use the Internet, they share their favorite sites and sources; in contrast, book research tends to be very independent.

Several teachers noted that their Laptop students interact more as peer teachers by giving more presentations in class and by sharing their expertise with technology. According to one teacher, this type of interaction helps poorer students gain confidence as they "teach the A students about technology" and creates a feeling of equality in the classroom.

Laptop Students Participate in More Project-Based Instruction

My instruction and assessment have become more project-oriented and the role of the students has changed as they themselves become producers and teachers.

(7th grade English teacher)

Several lines of evidence indicate that the Laptop Program encourages teachers to increase their reliance on project-based instruction. Seventy-eight percent of the teachers who participated in our survey claimed that project-based instruction has increased since the introduction of the laptops in their classrooms. A few teachers who were interviewed as part of our shadow studies told us that they relied primarily on project-based instruction even before the Laptop Program began, but other teachers mentioned that they now assigned more projects, including research and multimedia projects.

Teachers who responded to our survey explained that project-based instruction allows students to inquire into questions that they pose for themselves; teachers provide assistance as needed. These projects provide opportunities for students to direct and manage their own learning process rather than rely on their teachers to decide what is to be learned, and when that learning will take place. One eleventh grade Laptop student, who completed a large project on the Civil War, commented,

On this assignment, I learned how to completely dedicate myself to a huge project for an extended amount of time. This has not been the first time I have had to do extended projects, but each time is an entirely different experience, working with different people under different circumstances.

The results of our shadow study observations indicate that Laptop students participated in twice as much project-based instruction as Non-Laptop students. In addition, 7th grade Laptops students were found to participate in twice as much project-based instruction as 10th grade Laptop students. The amount of project-based instruction varied by subject-area.

Table 15. Percentage of Project-Based Instruction by Subject Area

	GRADE 7		GRADE 10	
	<i>Laptop</i>	<i>Non-Laptop</i>	<i>Laptop</i>	<i>Non-Laptop</i>
English	47%	29%	33%	No data.
Social Studies			27%	13%
Science	29%	12%	5%	No data.
Foreign Language	No laptop use.	No data.	24%	8%
TOTAL	41%	21%	21% for all subjects; 25% for English & science only	10%

Laptops Lead to More Student Writing and to Writing of Higher Quality

To me, the greatest outcome is improvement in writing skills. They write more, use the thesaurus more, practice spelling, can identify grammatical errors, etc. Final drafts are easier to read with the computer. (7th grade language arts/history teacher)

[There is] greater depth in writing for most users; better revisions, and more initial rough drafts. (11th grade English teacher)

Reports from both students and teachers indicate that laptop access leads students to do more writing. Ninety-two percent of the teachers who completed our survey claimed that students' use of laptops for writing papers and reports has increased. When asked to name the academic outcome or skill that has been most directly affected by use of the laptops, 37% of the surveyed teachers named writing. In fact, writing was the most common response to this question. Some teachers said simply that writing had generally improved. Others said that students were writing more and more often. Several teachers talked about the ease of editing, improved spelling and grammar, greater numbers of revisions and quicker production of drafts and final products. One teacher added that greater efficiency allowed more time for research, so that students' research also improved.

Teachers we interviewed as part of the shadow studies emphasized that students write more when they have laptops and their writing is of higher quality. They noted that students are willing to do more editing due to the ease of editing on a computer. One teacher mentioned that students were more open to feedback provided through the Track Changes tool in Word. She noted that with Track Changes, students can see exactly where each suggestion or comment comes from and they can accept or reject each change without rewriting.

Students in the Laptop Program also indicated that they were writing more. The Laptop students who completed our Learning Skills Survey claimed to write reports and papers more frequently than Non-Laptop students did. Seventh grade Laptop students were also more likely to write original stories than 7th grade Non-Laptop students from the same school. These differences between the Laptop and Non-Laptop groups are statistically reliable.

Within our samples of 7th grade Laptop and Non-Laptop students from the same school, both groups were equally likely to have used a computer to write a paper or report (81% and 80%, respectively). When writing stories, more 7th grade Laptop than Non-Laptop students relied on computers (69% versus 58%, respectively). Eleventh grade Laptop students were more likely to have used a computer to write papers and to write stories than 11th grade Non-Laptop students from the same school (77% versus 51% for papers; 68% versus 31% for stories).

***Laptops Increase Access to Information and Improve
Research and Analysis Skills***

I see a higher level of analytical thinking since students use more sources and discuss sources with peers and the teacher more often. Due to teacher instruction they have also become more aware of the importance of being critical of sources and not just accepting anything printed as true. (11th/12th grade history and math teacher)

[The impact on student academics has been on] the depth of information, ease of manipulating this information and analysis of huge amounts of information. The tedious repetition necessitated by other methods has been eliminated. (9th/10th grade math teacher)

*Access to information via the Internet has revolutionized education.
(10th/11th grade social studies teacher)*

Teachers claim that laptops benefit students both by providing them with access to a much broader range of research materials and by enhancing their ability to analyze information. Eighty-seven percent of the teachers who completed our survey and 92% of teachers who participated in our shadow study interviews claimed that students' use of their laptops for Internet research has increased since the project began. Several teachers also commented that laptops allow students to use CD-ROMs which provide quick and easy access to a world of information. Teachers who responded to our survey felt that access to both the Internet and CD-ROMs affects the quality of students' research projects and allows for a greater variety of assignments.

Teachers who participated in the shadow study noted that the Internet provided access to more information and more authentic materials. One teacher explained that the school library had only 52 books related to medieval times but the Internet offered much more. She also noted that for lessons on current events, the Internet provides access to a wide range of newspapers; students did not have to rely solely on their local newspaper, which she felt was not objective enough.

Many teachers also noted that greater access to information requires students to be more thoughtful about which sources they use and why. Students have to make more decisions, especially pertaining to research, because of the vast amount of information now available to them. One teacher claimed, for example, that the large amount of information available on the Internet requires that students have a "driving question." Students need to be more critical and discriminating researchers as they decide which sources to trust and which to discard.

Teachers maintain that the laptops not only increase access to information, but also provide a means for compiling and organizing information in compelling ways. For example, one teacher described how graph analysis software helped his students to obtain

results more quickly and explained that the ability to efficiently analyze data helped students' learning. Another teacher noted that using laptops to analyze data enables students to get past the details of science experiments so they can think about the meaning behind their results.

Laptop Students Prepare More Presentations than Non-Laptop Students

[Students] are learning to do research earlier and are also gaining skills in presenting before a group with PowerPoint projects. (7th/8th grade religion teacher)

After a PowerPoint presentation, I see other students revising, editing and improving their assignments. Positive peer response is important to them. (2nd through 8th grade computer teacher)

I like that fact that we can do presentations any way we want. Teachers usually don't tell us to do it a specific way, and I'm thankful because everyone has a different personality, so everyone's project should be different. (10th grade Laptop student)

According to both students and teachers, students with notebook computers gain more experience with preparing and delivering presentations than Non-Laptop students. Eighty-four percent of the teachers who responded to our survey stated that students' use of their laptops for preparing presentations has increased. When asked which academic outcome or skill has been most directly affected by use of the laptops, several of these teachers mentioned communication skills, including making presentations and speeches. Teachers interviewed as part of our shadow studies believe that doing more presentations helps students feel more comfortable with presenting. They also claim that Laptop students' presentations are better organized.

Students' responses to our Learning Skills Survey substantiate their teachers' claim that Laptop students are preparing more presentations than Non-Laptop students. On average, Laptop students prepare 9.8 presentations per year in contrast to the 6.0 presentations prepared by Non-Laptop students. The difference between the number of presentations prepared by Laptop and Non-Laptop groups during the school year is statistically reliable.

Within the public school comparison groups, Laptop students were more likely than Non-Laptop students to use computers to develop their presentations. This difference was greater for 11th grade students than for 7th grade students (91% in contrast to 18% computer use for 11th graders; 86% in contrast to 77% computer use for 7th graders). The seventh grade Non-Laptop students in our sample attend a school with much greater than average computer access for all students; each of the classrooms at their school is equipped with at least six notebook computers. It is interesting to note that the Non-Laptop students from this school used computers to develop presentations more often than the Laptop students from one of the private schools (77% in contrast to 71% computer use).

Table 16. Average Number of Presentations Prepared During School Year

SCHOOL	GRADE 7		GRADE 10		GRADE 11	
	<i>Laptop</i>	<i>Non-Laptop</i>	<i>Laptop</i>	<i>Non-Laptop</i>	<i>Laptop</i>	<i>Non-Laptop</i>
Private School 1	9.4	---	7.2	---	---	---
Private School 2	9.5	---	7.4	---	---	---
Public School	9.7	5.8	12.8	---	16.8	6.5
TOTAL	9.5	5.8	9.4	---	16.8	6.5

***Teachers and Students Take on Different Roles
When Students Have Laptops***

In our Teacher Survey, we asked teachers to tell us how the instructional process in their classrooms has been most directly affected by the use of laptops. The most common response to this question, given by one third of the teachers who responded, indicated that the laptops had the greatest impact on teachers' and students' roles. The 39 teachers who noted this type of change named one or more of the impacts described below.

Teachers Become Facilitators

Instruction has become more student-generated and my role has evolved into one of a facilitator of the instructional process. (7th grade English teacher)

Students are actively involved in the learning process. Students' PowerPoint presentations and reports are all generated by the students- their ideas, their work. I act as a guide and help them along the way. (7th/8th grade social studies teacher)

Twenty-three percent of the teachers who felt that the laptops most directly affected their own and their students' roles in the classroom stated that they had become more like facilitators and less like directors of learning. They noted that their classrooms are now more student-centered. Students lead their own inquiries and direct their own learning; teachers assist students as needed.

These teachers' statements are supported by our shadow study findings. Teachers in Laptop classes spent more time consulting and conferencing with individuals and groups than teachers in Non-Laptop classes. In the 10th grade classes we observed, teachers of Laptop students spent 29% of class time consulting in contrast to teachers of Non-Laptop students who spent 16% of class time consulting. This difference is larger when the Non-Laptop classes are compared only to the Laptop classes within the same school. Within this school, Laptop teachers consulted with students during 41% of class time in contrast to 16% of the Non-Laptop students' class time. Teachers at each of the other two schools spent 22% of class time consulting with students.

The same pattern was observed in our 7th grade shadow studies. Overall, teachers in 7th grade Laptop classes spent 42% of class time consulting with students in contrast to teachers in Non-Laptop classes who spent 36% of class time consulting with students. Comparisons between students within the same school show more drastic differences. Within this school, Laptop teachers consulted with students during 64% of class time in contrast to the 36% of Non-Laptop students' class time. Teachers at the other two schools spent 31% and 17% of class time consulting with students.

A closer examination of the shadow data provides further evidence of a relationship between teachers' consulting and students' laptop use. Eighty-one percent of the consulting time in 10th grade laptop classes and 74% of the consulting time in 7th grade laptop classes occurred while students were using their notebook computers.

Teachers Spend Less Time Lecturing

[With laptops] I trust the students more to learn through vehicles other than my lectures. (10th/12th grade English teacher)

One fifth of the teachers who believed that the laptops had their greatest impact on students' and teachers' classroom roles specified that they have decreased the amount of lecturing they do as a result of the laptop program. Instead, many of these teachers maintained, they act as facilitators as they work with small groups or individual students. Teachers' responses to a separate survey question that specifically asked about the effects of laptop use on lecturing indicate that many other teachers have also changed the frequency with which they lecture. Forty-one percent of the 144 teachers we surveyed claimed that the amount of lecturing in their classrooms has decreased since the inception of the Laptop Program.

Here again, the shadow study observations support the teachers' claims. In the shadow studies, lecturing occurred during 34% of 10th grade Non-Laptop students' class time but only during 21% of Laptop students' class time. The difference between Laptop and Non-Laptop classes within the same school is larger. Within this school, lecturing occurred during 15% of Laptop students' class time in contrast to 34% of Non-Laptop students' class time. Lecturing took place during 24% and 27% of class time at the other two schools.

Within 7th grade classrooms, lecturing took place during 11% of Non-Laptop students' class time and 15% of Laptop students' class time. Percentages of lecturing within the individual Laptop schools were 14% (at the same school attended by Non-Laptop students), 10% and 24%. Although there is no apparent difference between the amount of lecturing in 7th grade Laptop and Non-Laptop classes, a closer look at the shadow data reveals a negative correlation between laptop use and lecturing within the Laptop students' classes. At two of the three laptop schools, lecturing only occurred when laptops were not in

use. At the third school, only 21% of lecture time occurred when students were using their laptops.

Students Become Collaborators

As discussed earlier, Laptop students spend more time collaborating with their peers than Non-Laptop students. Forty-one percent of teachers who felt that laptop use most significantly affected teachers' and students' roles noted this trend. They elaborated by stating that students engage in more group projects and peer-editing, and they more frequently share ideas. Students teach each other, assist each other with technical problems, suggest research sites and offer other feedback.

Students Direct Their Own Learning

The fact that students have access to the use of laptops whenever they're needed allows them to take ownership of their own learning and as a result they are more independent. (9th grade math teacher)

Their work is of far better quality than before the program. [Students] want to find information out for themselves without me assigning or prompting them to do so. (10th to 12th grade English teacher)

I liked having the freedom and responsibility to do the project. We had a deadline as well as having to do the project whenever we wanted within the due date. (10th grade Laptop student)

Twenty-three percent of the teachers who believed that the laptops' most direct impact was on their own and their students' roles stated that the laptops have enabled students to take charge of their own learning process and to express what they have learned in highly individual ways. Teachers felt that the laptops allow students to express themselves more creatively and to work more independently.

IMPACTS ON STUDENTS' LEARNING

Laptop Students Report a Greater Reliance on Active Learning Strategies

Results from our Learning Skills Survey indicate that Laptop students more frequently rely on active learning and study strategies when reading and writing for school than Non-Laptop students. The findings presented in this section support teachers' claims that Laptop students are becoming more responsible for their own learning.

Laptop students report that they more frequently employ active learning strategies when they read material for school. Instead of just reading and rereading to learn and remember content, Laptop students claim that they often take notes on and underline or highlight information that they read. The Laptop students who responded to our survey indicated that they employ these learning methods more frequently than Non-Laptop students. Differences between the frequencies with which students in the two groups apply these active strategies are statistically reliable.

Statistically reliable differences were also found between the frequencies with which Laptop and Non-Laptop students employ active learning strategies when writing for school. Laptop students indicated that they engage in the following activities more frequently than Non-Laptop students:

- rewriting/rephrasing passages from published documents
- revising reports/papers before turning them in for a final grade
- writing an outline for a paper

Each of these activities requires students' active involvement and thoughtful reflection, qualities that teachers often struggle to elicit from students.

Not surprisingly, Laptop students are more likely to have used a computer when rewriting, revising and writing outlines than Non-Laptop students. Forty-two percent of Laptop students have used a computer to rewrite passages, in contrast to 15% of Non-Laptop students. Laptop students are twice as likely as Non-Laptop students to have used a computer to revise their work (67% versus 33%, respectively). Finally, Laptop Students are almost six times more likely than Non-Laptop students to have used a computer to write an outline for a paper (55% versus 9% respectively).

Differences between the percentages of students who have used computers to accomplish each type of task may be attributable to differences in the amount of computer access available to Laptop and Non-Laptop students. However, when we recall that over three-quarters of the Non-Laptop students in our comparison groups have access to home computers and over 60% have access to computers in school, it is tempting to conclude that laptops make active engagement in learning more appealing to students.

Laptop Students Use Computers to Accomplish Complex School Tasks

Laptop students who responded to our Technology Skills Survey indicated that they use computers more frequently than Non-Laptop students to find, organize, analyze and communicate information as well as when they brainstorm to generate ideas and collaborate with other students. According to the U.S. Department of Labor's SCANS report and ISTE's *National Educational Standards for Students*, these complex tasks require skills that are highly valued in both academic and business contexts. The differences between the frequencies with which Laptop and Non-Laptop groups reported using computers to perform each of these tasks were all statistically reliable.

Table 17. Frequency of Computer Use for Selected School Tasks by Site

	Brainstorm	Find	Organize	Analyze	Communicate	Collaborate
LAPTOP						
Grade 7						
Private School 1	2.7	4.3	3.5	3.2	4.0	3.7
Private School 2	2.4	4.0	3.7	3.2	4.5	3.8
Public School	2.6	4.3	3.6	3.4	4.0	3.5
Grade 10						
Private School 1	2.2	4.2	3.6	3.2	3.7	3.5
Private School 2	2.4	3.7	3.8	3.2	4.0	3.1
Public School	2.9	4.4	4.1	3.6	4.2	3.8
Grade 11						
Public School	3.3	4.4	4.0	4.1	4.3	3.9
TOTAL LAPTOP	2.6	4.2	3.7	3.4	4.0	3.6
NON-LAPTOP						
Grade 7						
Public School	2.0	3.8	2.6	2.6	3.2	3.1
Grade 11						
Public School	1.6	3.4	2.6	2.5	2.6	2.3
TOTAL NON-LAPTOP	1.8	3.6	2.6	2.5	2.9	2.6

Students rated each item on a 5 point scale. 1 = never; 2 = rarely; 3 = sometimes; 4 = frequently; 5 = always.

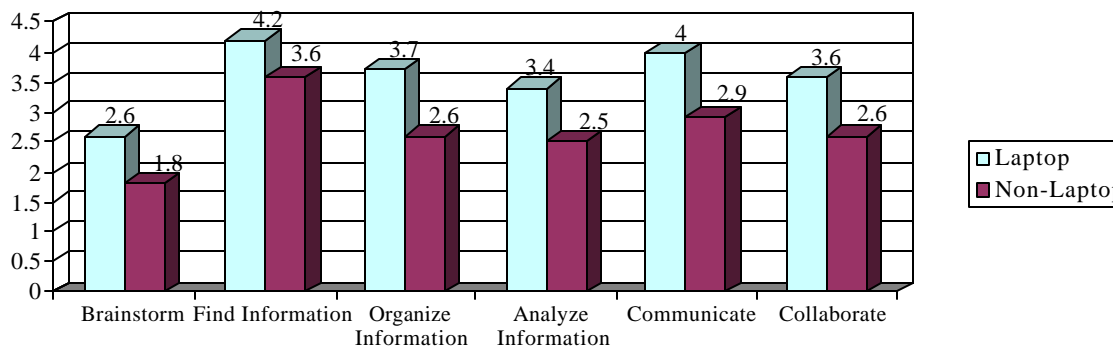


Figure 10. Overall Frequency of Computer Use for Selected School Tasks

In addition to asking students to rate the frequency with which they use computers to accomplish this set of tasks, we asked them to specify which tools they use for each purpose. Both Laptop and Non-Laptop students indicated that they use Word and the Internet in the service of several of these tasks. Laptop students also use PowerPoint for multiple purposes.

When students were asked to explain why they chose particular tools to accomplish these complex tasks, one out of four Laptop students noted at least one advanced feature of the computer that offered a strategic advantage in accomplishing schoolwork. In contrast, only one in twelve Non-Laptop students commented on how any advanced feature of Word, Excel, PowerPoint or the Internet could substantially help them. The types of advanced features that students mentioned include tables, outlines, bullets and bookmarks- features that would help them access or organize information more effectively.

***Problem Solving Simulations:
Laptop Students Readily Engage In Problem Solving and Critical Thinking***

Students should be judged well educated on the basis not of their capacities to respond to a large collection of trivia, but on their capacity to make important decisions and to think in new ways.

-- Deborah Meier

The 7th grade students who participated in our Problem-Solving Simulations explored the problems that occur when wolves are reintroduced to national parks. Groups of four to seven students were asked to choose and defend one of three positions in preparation for a public debate about their issue.

Our overall findings from the 7th grade problem-solving sessions indicate that Laptop students apply critical thinking skills more readily than Non-Laptop students. Laptop students immediately became engaged in addressing the controversial nature of their problem, gathering and evaluating evidence related to the alternative perspectives on the issue, and developing a strategy for supporting their own position on the matter. In contrast, Non-Laptop students tended to ignore the real-life controversial aspects of their problem. They seemed to view their task as a request to write a descriptive report rather than to take and defend a position on the matter in a public forum. Several lines of evidence support these interpretations of our findings.

Identifying Information Needs

Seventh grade Laptop students sought *more* information—and *more varied* information—about the situation they were asked to consider than 7th grade Non-Laptop students. These differences, which we substantiate below, support the idea that Laptop students are thinking creatively about various aspects of the real-life controversial wolf issue, whereas Non-Laptop students are perhaps following established procedures typically used when gathering information for school reports.

Differences in the amount of information sought by Laptop and Non-Laptop students were evident within three of the five information categories we examined.

- The first category in which we found differences between the groups includes references to information about wolf attacks on livestock and children, the types of attacks of concern to farmers who want the wolves removed from the parks.

I would look at some of these attacks and if the people prompted the attacks, like hit the wolves.

- The second category captures references to the opinions of the various parties affected by the reintroduction of wolves to the parks and information that would support a particular argument.

I'd probably go and look at the issue from everyone's point of view and write down why they want to do it that way. And then put answers to why they shouldn't do it that way.

- The third category includes a relatively small number of references to the various sites involved in the issue.

[I'd look up] Yellowstone Park, and maybe you could research back to when the wolves first came and see how that worked out.

The Laptop and Non-Laptop students showed equal levels of interest in obtaining information about:

- the Endangered Species Act (ESA) and other endangered animals,

I would probably look at an endangered species list and wolves would be in it... and it would show information on why they were endangered and where they were endangered and where the highest population is.

- and general information about wolves.

I would first look up background about the wolves and their natural habitat.

The types of information included in these latter categories might be of interest for any descriptive report about wolves; they do not reflect any particular involvement with the problem students were asked to consider.

Differences between the number of suggestions offered by Laptop and Non-Laptop groups for gathering information of the five types we examined were evident within just those categories that reflect students' engagement with evidence and opinions directly related to the controversial issue they were asked to consider. Laptop students sought more information of these types, and they thus appear to be more deeply engaged in critically analyzing their problem. The differences found between the two groups for these categories

are even more pronounced when the Non-Laptop students are compared only to the Laptop students from their own school (see Figure 11 on the next page).

Table 18. Average Number of Information Items Produced Per Category During the Four Problem-Solving Sessions at Each Site

	Attacks	Opinions	Sites	ESA	Wolves	TOTAL
LAPTOP						
Private 1	4.3	2.5	2.5	1.0	5.8	16.0
Private 2	6.3	3.8	1.8	1.5	8.0	21.3
Public	10.5	4.8	1.8	2.0	13.0	32.0
AVERAGE	7.0	3.7	2.0	1.5	8.9	23.1
NON-LAPTOP						
Public	3.3	2.0	0.5	1.5	8.3	15.5

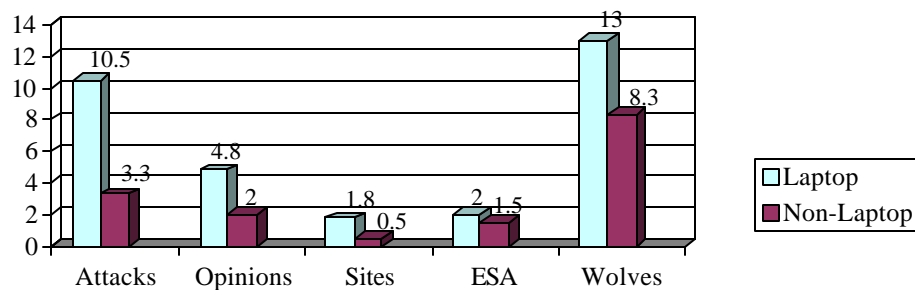


Figure 11. Average Number of Information Items Produced by Student Groups Within the Same School

Locating Information

When we asked the 7th grade students about the sources they would rely on and the steps they would take to find information about the issue they were asked to consider, Laptop students suggested a greater variety of methods for finding information relevant to their problem. Students in the Laptop groups offered a wide range of suggestions for investigating the wolf issue. Their ideas included site visits, interviews with scientists and park rangers, petitions, and wolf tracking devices. In contrast, Non-Laptop students offered fewer methods and showed a greater reliance on standard print and media sources such as encyclopedias, books and the Internet. Again, differences between the Laptop students and their Non-Laptop counterparts are more pronounced when the comparison is limited to students within the same school (see Figure 12, below).

Two additional differences between Laptop and Non-Laptop students emerge when only the groups from the same public school are considered. The Laptop students from this

school generated longer lists of potential on-site research locations that might prove useful in investigating the wolf problem. These students also named more specific media sources (e.g., specific web sites and search engines) than the Non-Laptop students at their school (11 items on average compared to 4.5 items). This latter difference is likely attributable to the Laptop students' more extensive experience with the Internet.

The differences that we found between the Laptop and Non-Laptop students' ideas for locating information would not surprise the Laptop students' teachers. Eighty-five percent of the teachers who completed our Teacher Survey believe that laptop access has resulted in students' use of a greater *variety* of sources in research projects. Eighty percent of these teachers claim that laptop use has increased the *number* of sources used in research projects.

Table 19. Average Number of Methods, Sources and Places Suggested During the Four Problem-Solving Sessions at Each Site

	Methods	Sources	Places	TOTAL
LAPTOP				
Private School 1	5.0	10.0	3.0	18.0
Private School 2	7.3	16.5	4.5	28.3
Public School	13.5	18.5	7.8	39.8
AVERAGE	8.6	15.0	5.1	28.7
NON-LAPTOP				
Public School	5.0	16.0	4.8	25.8

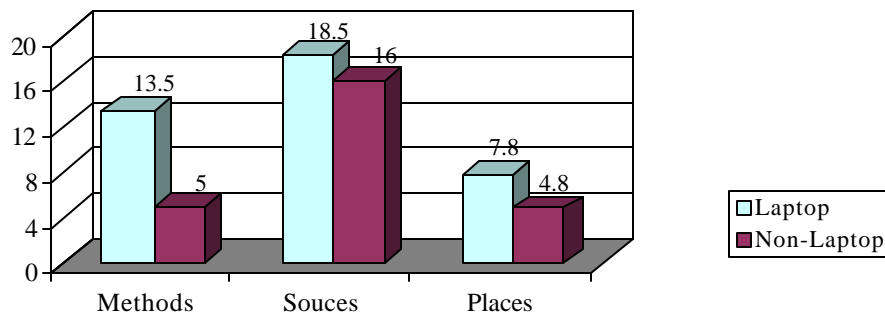


Figure 12. Average Number of Location Items Produced by Student Groups Within the Same School

Applying Higher Order Thinking Skills

Both Laptop and Non-Laptop students sometimes offered a rationale for how or why they would gather information related to the wolf problem. Such explanations were coded as applications of higher-order-thinking skills (HOTS) when they explicitly illustrated students' causal reasoning, and when that reasoning was considered both complex and meaningful in relation to the wolf problem. Seventh grade Laptop students showed greater evidence of applying higher-order-thinking skills to big-picture, strategic issues rather than to information gathering and procedural issues.

Three categories of higher-order thinking were identified. Informational HOTS provide a rationale for seeking a particular piece of information; they explain why information is relevant. For example, one student suggested:

Maybe you could follow the wolves around and see how many farm animals they actually do kill and maybe they're over-exaggerating how many the wolves kill. Some farm animals might die from other causes or they're just missing or something.

There were minimal differences between the two groups on this kind of HOTS.

Sources/steps HOTS provide a rationale for obtaining information in a particular order or in a particular way; they explain procedures. Examples of this type of HOTS include:

I would set up a camera first so you could see if it was actually the wolves killing the animals.

I'd probably go to the park newspaper because it took place in the park and maybe there's people who witnessed it so you'd have better details on what happened.

Non-Laptop students applied higher-order-thinking skills more frequently in the sources/steps category than Laptop students, but this difference is minimized when only students within the same school are compared.

Argument HOTS provide a rationale for using a particular argument or strategy in order to gain support for one of the positions on the wolf issue; they relate to "the big picture." For example, one student recommended:

You should probably think of what the argument might be and then think up things that might come up on the other side and then find ways that you could support that. And also that you could go against that side. And also you might want to have some questions prepared about what you would say to the other side.

Laptop students showed greater evidence of argument-related higher-order-thinking skills than Non-Laptop students. Across the four Non-Laptop groups that participated in the problem-solving sessions, only two instances of this type of HOTS were identified. This difference between the two groups adds further support to the claim that Laptop students are

thinking critically about how to defend their position on a real-life controversial issue while Non-Laptop students view their task as a request to write a descriptive school report that is detached from real-world controversy.

Table 20. Average Number of Applications of Higher-Order-Thinking Skills of Each Type Produced by the Four Groups at Each Site

	Informational HOTS	Sources/Steps HOTS	Argument HOTS	TOTAL
LAPTOP				
Private School 1	1.3	1.3	1.3	3.8
Private School 2	1.8	2.8	2.3	6.8
Public School	1.0	2.8	2.8	6.5
AVERAGE	1.3	2.3	2.1	5.7
NON-LAPTOP				
Public School	1.0	3.3	0.5	4.8

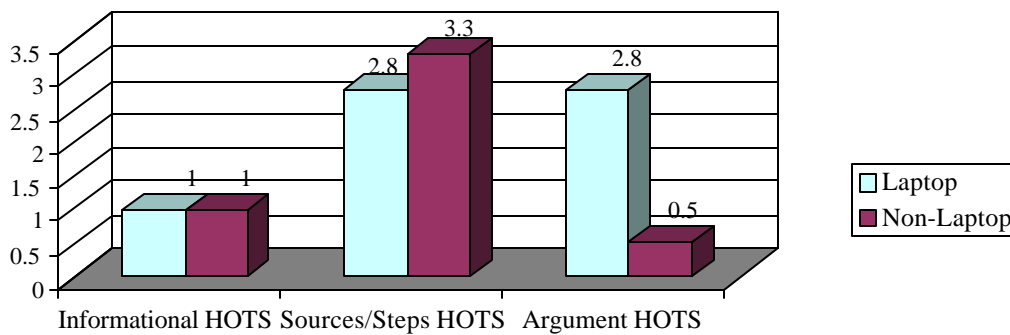


Figure 13: Average Number of Higher-Order Thinking Skills Produced by Student Groups Within the Same School

Teachers Attribute Students' Critical Thinking Skills and Problem-Solving Proficiency to Their Use of Laptops

I believe that critical thinking/problem solving skills are most enhanced by the presence of the laptops. Both the multitude of choices the machine delivers and the handful of problems that it presents create constant opportunities for decision making. (6th grade teacher)

When asked to name the academic outcome or skill that has been most directly affected by use of the laptops, 24% of the teachers who completed our Teacher Survey stated that the primary effect of the laptops was to encourage students to think in more complex ways. Writing was the only academic outcome that was mentioned by a larger proportion of

the teachers who responded to this question. Teachers' responses to a separate survey question that specifically asked about the effects of laptop use on higher-order thinking indicate that the majority of teachers believe laptop use has had a positive impact on students' thinking processes. Sixty-six percent of the 144 teachers we surveyed claimed that laptop access has resulted in an increase in the amount of higher-order thinking demonstrated by students in their classrooms.

In their responses to our open-ended question about the impact of the laptops on students' academic skills, teachers noted that laptop use stimulates analytical thinking, including synthesizing material and manipulating information. Teachers feel that the laptops encourage more problem-solving and critical thinking by students, in part because laptops provide students with a large number of choices that, in turn, demand advanced decision making skills. Several teachers stated that laptops improve students' ability to organize data, especially in their reports and presentations. A few teachers also noted increases in students' creativity and independent thought.

Clearly, teachers' perceptions of what is transpiring in their classrooms are consistent with the conclusions from our problem-solving simulations and our student surveys. Again and again, our findings suggest that full-time access to notebook computers motivates students to more willingly apply active learning strategies and critical thinking to their schoolwork.

Teachers Believe Laptops Benefit Students' Learning in General, but Significant, Ways

The results discussed above point to many specific ways in which round-the-clock access to laptop computers appears to have a positive impact on students' learning environment and learning strategies. Results from our Teacher Survey and our Shadow Study Interviews indicate that teachers believe that laptop access offers general learning benefits as well. Most of the teachers we surveyed believe that students' use of notebook computers leads them to produce higher-quality work, to show greater interest in school and to better understand instructional content.

Quality of work

[The laptop] has "raised the bar" on the standard, level and quality of work expected and delivered. (11th /12th grade science teacher)

I've had the students for two years. The quality of work and their "thinking process" have grown far more than any other class in the past. (6th grade teacher)

Eighty-seven percent of the teachers we surveyed claimed that laptop access has resulted in an increase in the quality of students' work. Teachers noted, for example, that

students are willing to do the editing and reworking that they would otherwise avoid. The laptops also allow students to produce more professional looking work. Several teachers stated that their expectations for student work are now higher.

Interest in school

[With the Internet, students are] using Spanish to access real information, intended for native speakers. Through projects, students are motivated and WANT to find the information needed for their project. They choose to access Spanish sites on the Internet and to use the information gained even if they read for the “gist” or to gather main points. (9th grade foreign language teacher)

Most of the teachers we surveyed (71%) felt that their students' use of laptops has led them to be more interested in school. Teachers claim that students are highly motivated and they are willing to focus more on their work. They believe that students are spending more time on their work and completing larger projects. One teacher stated that this increased interest allowed students to cover more content in the same amount of time.

Learning/Understanding Content

Students have a greater understanding of the subject because of their ability to manipulate data. (8th to 10th grade math teacher)

When students are learning something and express special interest in a topic, you can alter the class in process and go to the Internet for more exploration and research... [with laptops] you can take advantage of “the current” interest. (6th/7th grade health teacher)

Sixty-five percent of the teachers we surveyed claimed that laptop access has increased students' learning and understanding of instructional content. Computers help, for example, by allowing students to turn to the Internet to explore new ideas when their curiosity has been piqued. The laptops also help students by allowing them to better see and understand the results of experiments. One teacher mentioned that use of a graph analysis software tool allowed his students to get quicker results than if they had to take their data home and plot it there, and this was very helpful for learning. Other teachers stated that computers aid in organization; students know where to find their documents and they work more effectively and efficiently.

TEACHERS' AND STUDENTS' ASSESSMENTS OF THE LAPTOP PROGRAM

The results of our studies have shown that students who have full-time access to a notebook computer use technology frequently, for a wide variety of purposes, and within contexts that appear to promote learning. Given these outcomes, we are not surprised to report that both teachers and students are responding very favorably to the Laptop Program.

TEACHERS' ENTHUSIASM REMAINS HIGH

Teachers who responded to our survey, all of whom were in their second year of teaching with laptops, gave the Laptop Program an average rating of 5.6 on a 7-point scale. On this scale, one was defined as "unenthusiastic" and seven was defined as "very enthusiastic".

Throughout interviews and various survey responses, teachers consistently express these high levels of enthusiasm. Teachers' enthusiasm remains at the same high level as during the first year of the laptop program.

TEACHERS BELIEVE LAPTOPS BENEFIT ALL TYPES OF STUDENTS

Laptops help the struggling student as much as they help the gifted student. (10th/11th grade social studies teacher)

Findings from our Teacher Survey indicate that teachers believe the Laptop Program benefits students of all types. Teachers' average ratings on a 7-point scale on which zero was defined as "no benefit", three was defined as "moderate benefit" and six was defined as "great benefit" were:

Average students	4.1
Advanced students	4.5
Special needs students	4.1

Teachers noted that the one-to-one ratio of computers to students provided by the Laptop Program benefits students by allowing them to work at their own pace and in ways that interest them. In addition, laptops can help students understand information better because students' individual needs and learning styles can be targeted. One teacher wrote that with laptops, more individual work can be assigned and class time can be used to help students with the problems they encounter as they explore. A teacher who participated in our shadow studies told us that she is able to reach her more visual and kinesthetic learners because she can now show students exactly what she means through the laptops. Other shadow study teachers felt that PowerPoint is particularly helpful to students because it allows them to give and receive information in ways that are visual as well as auditory.

LAPTOPS ARE FAVORABLY COMPARED TO DESKTOPS AND COMPUTER LABS

[The laptop's] impact is dramatic. The only equivalent I can imagine is having desktops in every room, plus corridors, libraries, etc. Plus have one at home. Even then, students wouldn't have the flexibility they have with laptops. They don't have to be ANY special place to use laptops. The difference is night and day! (11th/12th grade computer teacher)

When the teachers who responded to our survey were asked to tell us about any ways in which the Laptop Program's impact is different from the impact of desktop computers or computer labs, their comments about the Laptop Program were overwhelmingly positive. Ninety percent of the teachers who responded to this question noted differences between laptops and other forms of computer access. Only 8% of the teachers identified any negative aspects of the program.

Seventy-eight percent of the respondents named "greater access" as a major difference between laptops and desktops. Teachers talked about several aspects of computer access. They noted that laptops are more portable; they can be moved with students from class to class. Several teachers mentioned that students now have round-the-clock access to a computer and that work can be accomplished anywhere—at school, at home, in the car, etc. Others were most impressed by the one-to-one ratio of students to computers that the Laptop Program provides.

Teachers made several other interesting observations about how individual access to notebook computers differs from the use of desktops or computer labs. Many of the benefits that teachers noted are possible because of the greater access to computers that the Laptop Program provides.

Immediate Learning

The freedom of the laptop allowed us to introduce new ideas right away, even things that you realize are pertinent [only] at the time you are in class. If we had to go to the lab, half of these things wouldn't happen. (7th through 12th grade foreign language teacher)

[There are] many more teachable moments. In class, the library, at home—I mentor via email. (9th/10th grade history teacher)

With the laptops, teachers feel they can explore new ideas immediately. When students show interest in a particular subject during a class discussion, for example, they can turn to the Internet for further exploration; students who are studying a particular historical era can immediately hear music from that era on their CD player. There is no need to wait for learning to take place.

Efficiency

Students have immediate access to computers at all times and don't have to share. I use this technology as a matter of course now rather than having to plan far in advance, booking the computer lab, moving the class to the lab, etc., which was always discouraging, disruptive, and time consuming. (9th/10th grade math teacher)

Students with laptops are, of course, more comfortable and competent, and the use of laptops for all work has been easily facilitated. Few desktop computers and scheduling problems have always impeded this process [before]. (7th grade English teacher)

Teachers state that the laptops allow students to complete their work more quickly than desktop computers did. Because students are very familiar with their own laptop's setup, they know exactly where their stored documents are and can even create ready formats for their note-taking and papers; they are able to get down to work much more efficiently. The laptops become an integral part of everyday work and are easily incorporated into students' days.

Increased Work Time and Quality

They use it all the time—anywhere. One kid was using it in the bathroom. You can't take the desktop with you and you have to wait to learn at the lab. (6th grade teacher)

[Students] are comfortable with the computer as part of their book bag; therefore, they spend TIME with it far more than a stationary one. The result is that they have the time to correct, edit, reread, etc. (11th grade English teacher)

Teachers note that because students have their laptops with them all the time, they spend more time on their computers and more time on their schoolwork. Some teachers report that more editing and rewriting occurs simply because of this increased time with the computer. In addition, students grow more comfortable with their laptops through this increased use; they have more time to explore the computer and what the computer provides access to. According to teachers, students' level of comfort with the laptop results in higher quality work than that produced with desktop computers.

Extended School Day

I have had to revise my [teaching] plans because laptop students have computers 100% of the time, which allows them to continue with a project and explore outside of class. (2nd through 8th grade computer teacher)

With the laptops, teachers can assume that all students have access to the same hardware and software, both in school and out. Many teachers report that creating assignments has become easier for this reason. Additionally, there is more of a link between

class work and homework; students can take their assignments back and forth and work with the same tools and the same formats anywhere they go. The increased access to the computer, the continuity between school and home, and the increased time students spend working on their laptops all contribute to extending learning beyond the boundaries of the school day.

Ownership

Students seem to develop a personal connection with their laptops in a way that is not seen with desktops/computer labs. (6th grade teacher)

Many teachers report that students feel a sense of ownership, pride and responsibility for their laptops that they would not have if they were working on desktops. In addition, some teachers note that students are more in charge of their learning because they can work with their notebook computers whenever they choose. Teachers feel that students become more responsible for what they learn and when they learn it, and, therefore, they become more independent.

Equity

[There are] no have/have not issues—all students are on the same footing as far as available equipment. Students are able to do computer homework at home. [There is] universal access to the Internet. (9th through 12th grade computer teacher)

We could never equip the school with a computer for everyone. (10th through 12th grade history teacher)

Several teachers point out that the one-to-one access to common tools that the laptops provide means increased equity for their classes. They feel that this equity would not be possible with desktops because it would be difficult to provide one-to-one access for students at school, and, even if they could, the same tools would not be available to all students after school.

Negative Differences

A few of the teachers we surveyed noted a handful of negative aspects of having laptops instead of desktops. Two teachers mentioned the increased weight of students' backpacks. Another mentioned logistical problems such as finding places to plug in, recharging batteries and finding ways to discourage students from playing games during school time. Three teachers noted that there are more malfunctions with the laptops (perhaps in part because there are simply more computers used more often), and one wrote that getting technical support is more difficult because the tech support person operates throughout the school now instead of being available at a central location. One teacher told us that time was wasted because students have to restart their computers between classes; the "suspend"

function does not work in conjunction with their school's central network. Finally, one teacher wrote that there are not enough laptops at her school for the poorer students.

In their responses to other questions in our Teacher Survey, teachers noted just a few additional difficulties that the laptops have presented. One teacher felt that there is now more emphasis on product over process. Another said that students' focus on their laptops resulted in fewer class discussions. A few teachers wrote that they had to spend some class time teaching students to use software applications. One teacher said that students were not proofreading, but instead were relying on the tools provided by the computer. Finally, another teacher felt she was being pressured to use the laptop as much as possible, even when it might not be the most suitable tool.

STUDENTS DESCRIBE BENEFITS OF THE LAPTOPS

Students Enjoy Using Computers

All of the students who completed our Technology Skills Surveys were asked to describe their level of agreement with each of the following statements:

1. I enjoy playing games on computers.
2. I prefer to use computers to do school work.
3. Computers make schoolwork more fun/interesting.
4. Computers make schoolwork easier to do.
5. Computers help me to improve the quality of my schoolwork.
6. Computers help me understand my classes better.

Students rated these statements on a five-point scale on which one was defined as "strongly disagree" and five was defined as "strongly agree".

In comparison with their Non-Laptop counterparts, Laptop students averaged a higher level of agreement for each of the six statements except for the first, "I enjoy playing games on computers." For statements two and three, "I prefer to use computers to do school work" and "Computers make schoolwork more fun/interesting," the differences between Laptop and Non-Laptop groups were statistically reliable (an average of 3.8 vs. 3.4 for the preference to use computers, and 3.9 vs. 3.6 for computers making work more interesting.)

Overall, for the first five statements, the means for Laptop students are all high, averaging 4.0 ("I agree."). Non-laptop students' average for the same questions was slightly lower, at 3.8. For statement six, "Computers help me understand my classes better," on average both groups neither agreed nor disagreed, with Laptop students' mean slightly higher (3.1 vs. 3.0).

Students Comment on the Laptops' Impact

In response to our questionnaires, students commented directly on how computers made their school work more enjoyable, interesting, and productive. An eleventh grader who had explored the Internet and prepared a PowerPoint presentation on the Titanic commented on the impact of doing her research in this manner:

By doing this assignment I learned probably more than I ever could have reading from a text book about the early 1900's and the whole era.

A 10th grade student who conducted research on Kenya described how his laptop facilitated his work:

What I liked most about this assignment was that finding information on Kenya was not a problem and that, thanks to the computer, I was able to organize the information, write my report, and design my presentation so easily.

A seventh grader concurred:

I like going on the computer, because it's easier, it's faster. You can get what you want fast.

Students also appreciated that many of the projects they did on their laptops allowed them to be very creative, and to explore in the directions they chose. A tenth grader who conducted research on the International Space Station wrote,

First I researched my topic at NASA, then I began to organize my topic into subtopics. Then, I started to develop PowerPoint, then added video and practiced the presentation, then presented. The topic was creative and I could go where the research led me.

A seventh grader, who used Word to create a book from Internet research on Genghis Khan, voiced her enthusiasm:

I liked most that I got a chance to have fun and use creativity to do it. I loved my final product.

An eleventh grader commented on how the freedom to be creative impacted her learning in a history research project:

I liked the creative aspect of my project. In working and having fun on the project, it made a deeper impression in my memory than normal methods would have.

Students' Favorite Projects Reflect Laptops' Positive Impact

In our Favorite Activity Survey, we asked over 400 Laptop and Non-Laptop students to describe their favorite project of the year, and to tell us what they had enjoyed most and what they had found most challenging about this assignment. The data reflect very positive impacts of the Laptop Program.

Students were asked to write about their favorite activity, rather than a typical activity. While these data, then, do not necessarily reflect students' most common experiences, they do represent those activities that captured the most student enthusiasm, and perhaps received the most effort from the students. Since the favorite projects were chosen from all activities completed during the entire school year, we can also assume that they are memorable for the students, and that what the students experienced and learned stays with them over time. Findings from these data are important as indications of those projects and class experiences which leave the greatest impression on students and their learning, those in which students are willing to expend effort and energy.

Laptop Students Choose Core Academic Subject Areas and Activities

When asked to name their single most favorite project of the year, Laptop students chose projects in their core academic subjects (English, history/social studies, math, science, and foreign language) more often than Non-Laptop students. Ninety-three percent of the Laptop students chose projects from core academic areas, versus 75% of the Non-Laptop students. While a quarter of the Non-Laptop students are naming, for example, a cooking project in a Teen Living class as their favorite project of the year, Laptop students are favoring projects such as a PowerPoint presentation in history. This finding may suggest that laptops are making assignments in core academic areas more memorable and enjoyable than they otherwise would have been.

Additionally, the favorite activities that students selected were classified as either research/reports, teaching/learning tools, or creative products (such as art or cooking projects). Laptop students chose research/report projects more often (75%) than Non-Laptop students (58%). This difference between the two groups of students may suggest that Laptop students are demonstrating greater interest in traditional assignments and research, or that the laptops are enhancing these projects for students.

Rather than shifting focus away from traditional academics, laptop use appears to enhance more traditional academic subjects and activities for students.

Laptop Students Favor Computer Projects

In this survey, students could choose any project from any subject area, not just projects that involved laptop or computer use. Laptop students chose projects that involved a computer at consistently high rates. Ninety-one percent of all Laptop students chose

computer projects as their favorite activity for the year. In contrast, 60% of the Non-Laptop students chose computer projects.

Given that students could choose any project from the entire school year, including such traditional favorites as cooking projects, art projects, and field trips, the number of students who chose computer-related activities is surprisingly high. When we examine subsets of our survey, we find, not surprisingly, that the groups with the most computer access were also the groups most likely to favor a computer project. In our group of Non-Laptop students who have only home or lab access to desktops, about a third chose computer projects. For Non-Laptop students who have high classroom-based access to laptops and some access to desktops at home, computer projects were chosen by over half. And Laptop students, the group with the most computer access, chose projects involving a computer in almost every case.

The higher number of computer projects chosen by Laptop students may reflect that a larger percentage of their schoolwork involves computers, or that the laptops themselves are generating enthusiasm as students spend more time with them. In either case, it is clear that Laptop students are enjoying and remembering computer projects at very high rates.

Internet Use

Laptop students used the Internet for more of their favorite computer projects (55%) than Non-Laptop students (40%). This difference may be evidence that Internet access is more widely available for students with notebook computers, or that Laptop students' greater facility with computers enhances their time on the Internet.

When examined by grade level, tenth and eleventh graders named Internet projects as their favorite projects of the year more often than seventh graders did. Upper grade students used the Internet for 61% of their favorite computer-related projects. Seventh graders used the Internet for only 46% of their computer projects. Although our shadow data showed little Internet use by 10th graders, the Favorite Activity results suggest that high school students do use the Internet, and that these uses are highly engaging and meaningful.

Additionally, when students were asked what they had learned the most about while doing their favorite projects, 11% named research skills. However, 82% of those who named research skills were working with the Internet. Therefore, Internet projects make up the majority of the projects in which students felt they were gaining new research skills.

Software Use

As is reflected elsewhere in our study, a small set of software tools proved the most popular with students. Many students used more than one software tool on their projects. Students most frequently used the Internet (53% of projects), PowerPoint (36%), and Word (36%). Students chose Excel projects (9%) and Encarta projects (8%) less often as their

favorites. However, 36% of the students named a wide variety of other software, including Adobe PhotoShop, Visual Basic, Paint, HTML programs, clip art, and Microsoft Bookshelf.

More Skills Are Applied in Computer Projects

Students were asked to name all of the skills they had needed to complete their favorite projects. There was no checklist, so students did not necessarily remember to name everything they did. Most of the skills students named fell into seven categories: research, software knowledge, writing, creating/building, analysis, presentation, and revision.

Students who chose projects involving computers mentioned almost all of these skills more frequently than students whose projects did not make use of computers. According to the students, computer projects required more frequent use of research, writing, presentation, and, of course, software skills. Revision and analysis were mentioned equally often by students who did and did not use computers for their projects. Non-computer users mentioned only type of skill—creating/building— more frequently than computer users; use of this skill by the former group reflects their more frequent choice of creative projects over research or reports. On average, students who used computers to complete their projects mentioned more skills (2.2 per student) than students who preferred non-computer projects (1.3 per student).

These findings may indicate that computer use promotes the application of a greater variety of skills. Alternatively, students may choose to use computers for projects that require more skills. Either way, students who choose computer projects as their favorite activities for the school year appear to gain experience in applying complex skills that are valued in both academic and business contexts.

Table 21. Percentage of Students Naming Each Skill

	Computer Projects (N=366)	Non- Computer Projects (N=62)
Research	64%	27%
Software knowledge	45%	N/A
Writing	40%	15%
Creating/building	19%	56%
Analysis	19%	21%
Presentation skills	26%	8%
Revision	8%	6%

Laptop Students Keep Better Track of Their Work

Students were asked if they still had these projects—their most favorite projects of the year. Laptop students who completed computer projects were most likely to still have their final product (74%), even more so than Non-Laptop students who completed computer projects (66%). Students who did not use a computer were least likely to still have their final product (42%). From other data sources, we have learned that teachers feel the laptops help students become more organized, both by organizing files on the laptop, and by the added responsibility of caring for the laptop itself. These numbers appear to reflect that finding.

A Matched Sample Case: 11th Graders

Our large sample of students and their favorite projects included an interesting subset of 11th graders who attend the same high school. Half of these students have used laptops in school for two years, and the other half have computer access only at home and/or at the school's computer lab. Although the numbers are small (the groups contain 19 and 16 students respectively, for a total of 35 students), the case is interesting because the students share the same teachers, the same curriculum, and the same non-computer resources.

Large differences emerged between the two groups. First, all of the Laptop students chose projects completed for their core academic subject areas, but only 56% of the Non-Laptop students chose projects from these subject areas. All of the Laptop students chose computer projects as their favorite activities; in contrast, only 38% of the Non-laptop 11th graders chose computer projects. Eleven Laptop students (58%) in this sample used the Internet for their favorite projects; only two Non-Laptop students did (13%). Fifty-eight percent of the Laptop students chose research/reports as their favorite projects, compared to 44% of the Non-Laptop students.

In addition, the second year Laptop students' portrayals of their favorite projects tended to reflect a level of complexity and innovation which we did not see in the 11th grade Non-Laptop students' descriptions. On the following page is a sample of some of these projects.

The 11th grade Laptop students were also the group that named the greatest range and variety of software, including Homescape Designer, Shop Pro, Yahoo, Paint, "an interactive encyclopedia", Netscape, Microsoft Bookshelf, Encarta, and clip art. In contrast, only one of the six 11th grade Non-Laptop students who completed a computer project named any specific software (Encarta). The other students simply said they used "the computer," not identifying which software programs they were employing.

11th grade Laptop students describe their favorite project of the year

Of all the major assignments I have completed this year, my favorite would have to have been my Civil War project that I completed for my US history class, which I completed with [another student]. To complete this assignment, extensive research on the Internet, online encyclopedia and paperbound resources was required. Next, my friend and I organized and compiled our information and created an extremely large PowerPoint presentation, approximately 66 slides long. The final product for this project was an extensive look into many of the aspects of the Civil War, including several of the more famous generals, some of the battles, including statistics, maps, and other physical layouts, and many more of the different aspects, inside and outside of the war itself.

My favorite assignment of the year was constructing and animating a virtual bridge in the VRML modeling language. This was an assignment for my history class, which we used as a prop for a project entitled "Bridging the Gap" - a project focusing on a certain time in history. In order to complete the assignment, I had to find layouts for a bridge on the Internet, as I am not very good with graphic design. After this, I used modeling tools from Cosmo software to convert this bridge into a VRML object, animate certain areas of it and set up viewpoints and layouts. I then used Netscape Communicator software to create a web page in which to display the bridge on-line. The final bridge was fully navigable, and contained many preset positions from which to view certain angles of the bridge. During many demonstrations of the bridge to people, I was able to explain how to use Cosmo's VRML viewer to navigate the 3-dimensional bridge.

I think that one of my favorite assignments of this year was a final project in biology. We had to pick a topic and research it. I choose snowboarding and I had to explain how wax improves speed and reduces friction. So I decided to explain how boots and bindings give more stability and explained many of the accessories on the market today. To complete this assignment I had to research many different snowboards, bindings, accessories and boots on the Internet and then put together a visual using poster board and then make a Microsoft PowerPoint presentation and present it in front of the class.

When listing the skills they had needed to complete their favorite projects, the 11th grade Laptop students named almost every skill more often than the 11th grade Non-Laptop students. These skills include: research, software knowledge, writing, analysis, and presentation. The only exceptions were revision and creating/building; the relatively small differences between the Laptop and Non-Laptop groups for these categories may reflect the greater number of non-research projects completed by the Non-Laptop group.

Table 22. Percentage of 11th Grade Students Naming Each Skill

	11th Grade Laptop (N=19)	11th Grade Non-Laptop (N=16)
Research	84%	25%
Software knowledge	37%	N/A
Writing	42%	19%
Creating/building	47%	56%
Analysis	37%	19%
Presentation skills	58%	13%
Revision	11%	19%

In summary, sharp differences were found between the 11th grade Laptop and Non-Laptop students, differences which were bigger than those found for our larger sample. These second year Laptop students felt more enthusiasm for academic core projects, and for projects that involved a computer and the Internet; they described using a greater number of skills and a wide variety of software tools. Given that these students share the same teachers, the same curriculum, and the same non-computer resources, the variation between the two groups appears to be primarily attributable to the Laptop Program. While our 11th grade groups are small, our findings strongly suggest that further study of matched groups, with Laptop students beyond the beginning stages of computer use and Non-Laptop students in the same grade and school, may demonstrate that the benefits of full-time access to notebook computers only increase as time goes on.

About the Research Team

This research study was conducted by ROCKMAN *ET AL*, an independent research and consulting firm, specializing in technology and education. The company consults with corporations, state and federal agencies, and educational organizations on research, evaluation, and policy development that advance the application of technology to meet educational and business learning needs. Capabilities include print and media materials for learners, teachers, and corporations; research and evaluation; organizational development; long range planning; and projects involving technology, learning, and the change process. Saul Rockman established ROCKMAN *ET AL* in 1990 after leaving Apple Computer where he was Manager of Education Research.

Current and recent clients of ROCKMAN *ET AL* include: Ameritech, Apple Computer, California Department of Education, Children's Television Workshop, Claris, Indiana's Buddy Project, Indiana Department of Education, Microsoft, Pacific Bell, Scholastic, US West, Public Broadcasting Service, Warner*Active*, and numerous Department of Education and National Science Foundation projects ranging from Challenge Grants to NetDay to Bill Nye, the Science Guy.

The offices of ROCKMAN *ET AL* are located in San Francisco, California and Bloomington, Indiana; the company has working relationships with contractors, university faculty, and consulting groups in all regions of the country.

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