When Each One Has One: The Influences on Teaching Strategies and Student Achievement of Using Laptops in the Classroom

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In this study, we examined the educational effects of providing fifth-, sixth-, and seventh-grade students with 24-hour access to laptop computers. Specifically we examined the impact of laptops on classroom activities, and on student use of technology and their writing and problem-solving skills. Participating teachers received computer integration training using the iNtegrating Technology for inQuiry (NTeQ) model to develop problem-based lessons that engage students in critically examining authentic issues, and strengthen research and writing skills. A matched treatment-control group design was employed, in which classes taught at the same grade levels in five participating schools served as the laptop (1 computer per student) and control (5+ computers per class) contexts. Participants included students, teachers, and parents from the two groups. Although systematic observations revealed relatively few differences in teaching methods between laptop and control classrooms, laptop students used computers more frequently, extensively, and independently. Writing assessment results showed substantial and significant advantages for laptop over control students, with six of eight effect sizes exceeding +0.80. Results also showed significant advantages for the laptop group on five of the seven components of the problem-solving task.

☐ Almost 20 years ago, Alfred Bork presented the following vision of how computers would soon affect education:

> We stand at the beginning of a major revolution in the way people learn . . .. We are moving rapidly toward a future when computers will comprise the dominant delivery system in education for almost all age levels and in most subject areas. Not since the invention of the printing press has a technological device borne such implications for the learning process (1985, p. 3).

Judging by the recent developments in computer acquisitions, at least part of Bork's prophesy might appear close to becoming realized in today's schools. Not only are there many more computers in schools than there were a decade ago, the proportion in classrooms relative to computer laboratories is also increasing. For example, in 1995, 84% of 7,000 fourth-grade students reported that they had computers in their classroom, and 79% had computer labs at their schools (Jerald & Orlofsky, 1999). The ratio of students to computers is also declining every year (Meyer, 2001). In 1992, there were 19.2 students per instructional computer, whereas in 2000, the number decreased to 4.0.

Realization of Bork's "revolution," however, would appear to require developments beyond merely increasing the number of computers available to students. That is, whether there are many or few computers at a school, the key factor influencing teaching and learning is how computers are used. Accordingly, Windschitl and Sahl (2002) concluded from their study of classrooms in a laptop computer school, "the availability of technology was neither a necessary nor a sufficient condition to affect pedagogy" (p. 201). Although all of the students in that study had their own computers, two out of the three teachers observed failed to use the technology in ways that substantially changed their former, teacher-centered approaches. In a study of a middle-school context, Orrill (2001) found that even with extensive professional development and student access to technology, teachers struggled to use computers in promoting student-centered learning.

From their review of events over the past several decades, Morrison and Lowther (2002) concluded that society is increasingly recognizing the need for developing computer skills that are applicable to solving real-life problems. In this regard, the constructivist theoretical orientations encourage student uses of the computer-as-a-tool for active inquiry and problem solving. Examples of constructivist environments in recent literature are numerous, for example, Jasper Woodbury (Cognition & Technology Group at Vanderbilt, 1992), education partnerships such as the Computer as a Learning Partner Curriculum (Linn, Shear, Bell, & Slotta, 1999), visualization tools for collaborative inquiry such as CoVis (Edelson, Pea, & Gomez, 1996), and Open-ended Learning Environments (e.g., Hannafin, Hall, Land, & Hill, 1994; Land & Hannafin, 1997; Oliver & Hannafin, 2001). Such orientations, unfortunately, still occur infrequently in typical classroom settings across the United States. (Hokanson & Hooper, 2000; Ross & Lowther, 2003). Notably, the most common computer uses in elementary schools were recently identified as word processing and skill games (Becker, Ravitz, & Wong, 1999).

The educational technology applications represented in many research studies and supported in the literature as optimal for fostering higher-level learning often are based on the assumption that the hardware and software needed to perform the tasks are readily available to students. Despite increased access to computers by today's K–12 students (National Center for Education Statistics, 2000), the challenges of designing effective instruction in general, let alone computer-based lessons that address state-mandated content and standards of technology practices (International Society for Technology in Education, 1998), remain as demanding on teachers as ever—perhaps even more so in the present high accountability era of the *No Child Left Behind* legislation (U.S. Department of Education, 2001).

Teachers at many schools may find that despite their interest in integrating computers with instruction, implementation of an effective lesson can be hindered when each computer has to be shared with five or more students (Hester, 2002). Further, while teacher skills in working with technology are increasing (Pianfetti, 2001), recent findings indicate that nearly two thirds of all teachers feel not at all or only somewhat prepared to use technology in their teaching (U.S. Department of Education, 2000). Further, in a different study, two thirds of the teachers reported never having used a computer prior to being introduced to one while working in a school setting (Moe & Blodgett, 2000).

Thus, the question is whether or not the design and delivery of technology-supported instruction would be more reasonable for teachers if every student had access to a computer. While it is common to try to resolve the access problem by having students work together in a group (Johnson, Johnson, Stanne, & Garibaldi, 1990), cooperative learning in itself can be quite demanding to design and deliver effectively (Nath & Ross, 2001). The teacher-designer is thus faced with trying to orchestrate students working cooperatively while trying to manipulate possibly unfamiliar technology applications to perform relatively complex learner-centered tasks. Similarly, computer laboratories, although possibly providing students high access to computers, bring the obvious inconvenience of scheduling class time and moving students from the reference material and other resources of their regular classrooms.

These considerations suggest advantages for "laptop classrooms" as potentially optimal contexts for integrating technology usage with curriculum. It was recently estimated that more than a thousand schools are employing some type of laptop program, and the number is increasing significantly (Windschitl & Sahl, 2002).

An obvious advantage of laptops is that when they are brought to class, a student-to-computer ratio of 1 : 1 can be achieved. Another advantage is increasing home-to-school linkages (Funkhauser, Steif, & Allen, 1998). However, despite these appealing features and the growing use of laptops in schools, there are relatively few controlled studies of their effectiveness for learning. In a recent comprehensive review of research on technology used to enhance home-to-school connections, Penuel et al. (2002) found only 12 studies dealing with classroom laptops. Of these, only one was published in a refereed journal. The studies in combination showed small positive effects of the laptop treatments on student achievement. Why such effects occurred, however, was unclear, because of inadequate descriptions of the applications as well as apparent research design limitations in the identified studies.

The present study was designed to provide further insight into the degree to which school laptop programs can influence students' educational experiences and learning. The decision by a school district (to be referred to by the pseudonym, Crossriver School District) to implement a structured laptop program and provide both laptop and control classrooms within each participating school created an opportunity to explore these basic questions. Research questions and methodology for the study evolved from the pilot investigation described below.

Pilot Study: First-Year Laptop Program

The purpose of the pilot study (Ross, Lowther, Plants, & Morrison, 2000) was to examine first-year outcomes of Crossriver School District's implementation in seven schools (four elementary and three middle) of the laptop program based on Anytime, Anywhere Learning (AAL, 2000). Through the program, laptop computers were made available to students for a monthly lease fee of fifty dollars. Because Crossriver predominantly serves suburban middle-class families, many students in the district were able to participate. Grants from local foundations provided support to a limited number of students whose families could not afford the lease fee. Still, because district capacity to support implementation of the program restricted the number of laptop classrooms to only one or two per grade, sampling was subject to whatever bias would occur from families' interest in and ability to have their child participate.

Study context. The Laptop Pilot Program began with 26 teachers who taught grades 5 and 6. These teachers received more than 70 hours of training based on the iNtegrating Technology for inQuiry (NTeQ) model (Morrison & Lowther, 2002). NTeQ provides teachers a framework to develop problem-based lessons that utilize real-world resources, student collaboration, and the use of computer tools to reach solutions. The lessons are typically structured around projects that engage students in critically examining community and global issues, while strengthening student research and computer skills.

Method. The research design for the pilot study was based on the collection of quantitative and qualitative data from students, teachers, and parents associated with the laptop and control (nonlaptop) classrooms in the seven schools. The data set included 50 one-hour systematic classroom observations of both basic pedagogy and technology usage, a district-administered writing sample, student surveys and focus groups, a teacher survey and interview, and a parent survey and interview.

Results. The pilot study findings showed that teaching was noticeably different in laptop compared to control classes. Statistically significant effects favored laptop classes (with effect sizes > +0.59) on using more student-centered instructional strategies. Examinations of specific technology use also favored the laptop students over the controls; for example, better computer skills, and more extensive use of computer applications for research, production, writing, and design. With regard to achievement differences, laptop students outperformed control students on a district writing test, with effect sizes ranging from +0.61 to +0.78.

The qualitative data overall painted a positive picture of experiences in the pilot program.

Both students and teachers viewed the laptops as increasing interest in learning and stimulating more meaningful classroom activities (as the observation data confirmed). Parents felt that the laptops had increased their children's interest in school. Drawbacks of the program were discussed in relation to the logistics of carrying the computers to and from school, equipment breakdowns, and demands for more teacher professional development.

Purposes of the Present Research

Aside from the positive qualitative results, of particular interest in the pilot study was the finding of higher writing performance by laptop students. If laptops stimulate more active teaching and learning, it would seem logical that students might achieve better than their counterparts in more passive learning contexts. Unfortunately, internal validity threats reduce the level of confidence with which these preliminary findings can be viewed. First, because the laptop program was voluntary, it might be assumed that more capable or motivated students relative to the control sample would participate. Because student identification was not collected, preprogram achievement data could not be accessed for purposes of comparing the equivalence of the laptop and control students and making statistical adjustments if needed in writing test scores.

Second, only laptop teachers had received the NTeQ training (Morrison & Lowther, 2002), which provided fairly extensive professional development not only on technology integration but also on associated student-centered teaching methods. Thus, the pilot study might have been reflecting the effects of positive pedagogical changes that could just as easily have occurred in the absence of the laptop program. Third, although raising student achievement is an essential criterion for identifying "proven practices" (U.S. Department of Education, 2002), the writing assessment employed in the pilot study might be viewed as a fairly limited indicator of laptop program effects.

Given these considerations, we refined the design of the pilot study to incorporate: (a) an analysis of preprogram achievement scores of laptop and control students, (b) participant samples of only those laptop and control teachers who had participated in the same NTeQ training, and (c) dependent measures of student performance in both problem-solving and writing skill. The two primary research questions were: (a) Is teaching and student behavior different in laptop compared to control classrooms; and (b) Do students achieve differently in laptop classrooms? Also of interest for explaining student classroom outcomes were the reactions and interests of key stakeholder groups (i.e., teachers, students, and parents).

METHOD

Participants and Design

Classroom selections for the study were made across the district under the criterion that a laptop class and one or more comparable control classes were taught at the same grade level in the same school. Control classes were defined as ones where teachers received computer integration (NTeQ) training and the classrooms were equipped with 5–6 desktop computers, more than the usual number for classrooms in the district. Five different schools, four middle and one elementary, met these criteria. In Grade 6, two laptop classes were linked to a single control class in the same school; thus, fewer control classes than laptop classes participated. The resultant sample consisted of 21 classrooms (12 laptop; 9 control) distributed across three grade levels: 6 in Grade 5 (3 laptop; 3 control), 9 in Grade 6 (6 laptop; 3 control), and 6 in Grade 7 (3 laptop; 3 control). From these grades, the participant sampling pools consisted of all teachers, students, and parents associated with the laptop program and comparable participant groups in control classrooms. Cross-treatment group contamination was not considered an issue because the only differing variable was access to computers. Varying numbers of participants were included for different types of data collection as described in Table 1 and in the sections below.

Importantly, for the purpose of establishing group equivalence, the district granted us permission to analyze the fifth-grade writing scores

Table 1 ☐ Data source sample sizes by participant group

Evaluation Measure	Total Number	Group	Number by Participant Group: Laptop classes	Control classes
School Observation Measure	55	5th Grade	08	10
		6th Grade	17	06
		7th Grade	07	07
Survey of Computer Use	55	5th Grade	08	10
		6th Grade	17	06
		7th Grade	07	07
Writing Test	118	6th Grade	29	29
		7th Grade	30	30
Problem-Solving Test	111	6th Grade	52	59
Student Survey	391	6th and 7th Grade	257	134
Student Focus Group	71	5th Grade	06	05
		6th Grade	05	06
		7th Grade	27	22
Teacher Interview	03	Laptop teachers	03 (1 @ 5th, 6th, & 7th)	
	03	Control teachers		03 (1 @ 5th, 6th, & 7th)
District Parent Survey	66	Laptop parents or caretakers		

on the district test, and science scores on the state-mandated test, for 41 laptop and 39 control seventh-graders. Fifth-grade scores were chosen because they reflect achievement prior to implementation of the laptop program. The results yielded an unanticipated mixed pattern. On the science test, the laptop group (M = 43.49) demonstrated a significant advantage over the control group (M = 37.18), $F(1,78) = 10.18$, $p < .01$, ES = +0.72. In contrast, on the writing test, the control group (M = 2.82) demonstrated a significant advantage over the laptop group (M = 2.53), $F(1,78) = 10.18$, $p < .01$, ES = –0.64. There is no clear explanation of this reversed pattern. However, these results still help to establish that the laptop sample, while superior to the control group on a multiple-choice science test, clearly did not enter the present study with an advantage (and perhaps was at a disadvantage) for the present achievement measures (writing sample and problem solving), both of which were open-ended writing-oriented tasks. In any case, results must be interpreted in view of the limitations of the ex post facto (subjects preselected for treatments) research design.

Data Sources and Instrumentation

School Observation Measure (SOM©). Classroom visits were conducted by trained observers from graduate education programs at Wayne State University. They collected data regarding observed instructional practices. While the observers should have noticed that some classes had more computers than others, they were unaware of the purposes of the study and had no special interest in the results. The observation instrument used, the SOM, was developed to determine the extent to which different common and alternative teaching practices are used throughout an entire school (Ross, Smith, & Alberg, 1999). The standard SOM procedure involves observers visiting 10–12 randomly selected classrooms, for 15 min each, during a 3-hr visitation period. The observer examines classroom events and activities descriptively, not judgmentally. Notes are taken relative to the use or nonuse of 24 target strategies. At the conclusion of the 3-hr visit, the observer summarizes the frequency with which each of the strategies was observed across all classes in general on a data summary form. The frequency is recorded via a 5-point rubric that ranges from 0 = *not observed* to 4 = *extensively observed.* Two global items use 3-point scales (*low, moderate, high*) to rate, respectively, the use of academically focused instructional time and degree of student attention and interest.

The target SOM strategies include both traditional practices (e.g., direct instruction and independent seatwork) and alternative, predominately student-centered methods associated with educational reforms (e.g., cooperative learning, project-based learning, inquiry, discussion, using technology as a learning tool). After receiving the manual and instruction in a group session, each observer participates in sufficient practice exercises to ensure that his or her data are comparable with those of experienced observers (i.e., the trainers). In a reliability study (Lewis, Ross, & Alberg, 1999), pairs of trained observers selected the identical overall response on the 5-category rubric on 67% of the items and were within one category on 95% of the items. Further results establishing the reliability and validity of SOM are provided in Ross, Smith, Alberg, & Lowther (in press).

For the present study, the focus was the program within the school (laptop vs. control) rather than the whole school. Accordingly, laptop and control teachers comprised the observation samples. One SOM was based on 60 continuous minutes of prescheduled observation in one classroom. This observation was divided into about 4 (rather than 10–12) 15-min segments that were then summarized on one SOM Data Summary form.

Survey of Computer Use (SCU©). A companion instrument to SOM in this study was the SCU (Lowther & Ross, 1999). The SCU was completed as part of the 1-hr observation. The SCU items were compiled through examination of research, existing instruments (e.g., Apple Classrooms of Tomorrow researched by Stuebing, Celsi, & Cousineau, 1994), focus groups of K–12 teachers and administrators, researchers, college faculty, and a series of formative evaluation strategies.

The SCU was designed to capture exclusively *student* access to, ability with, and use of computers rather than teacher use of technology. Therefore, four primary types of data are recorded: (a) computer capacity and currency, (b) configuration, (c) student computer ability, and (d) student activities while using computers. *Computer capacity and currency* is defined as the age and type of computers available for student use and whether or not Internet access is available. *Configuration* refers to the number of students working at each computer (e.g., alone, in pairs, in small groups). *Student computer ability* is assessed by recording the number of students who are computer literate (e.g., easily used software features and menus, saved or printed documents) and the number of students who easily use the keyboard to enter text or numerical information.

The next section of the SCU focuses on student use of computers with regard to the types of activities, subject areas of activities, and software being used. The computer activities are divided into three categories based on the type of software tools used: (a) production tools (word processing, databases, spreadsheets, draw-paint-graphics, presentation authoring, concept mapping, and planning), (b) Internet or research tools (Internet browser, CD reference materials, and communications), and (c) educational software (drill-practice-tutorial, problem solving, and process tools). This section ends by identifying the subject area of each computer activity (language arts, mathematics, science, social studies, and other). The computer activities and software being used are summarized and recorded using a 5-point rubric that ranges from (0) *not observed* to (4) *extensively observed.* The final section of the SCU is an "overall rubric" designed to assess the degree to which the activity reflects "meaningful use" of computers as a tool to enhance learning. The rubric has four levels: 1 = *low-level use of computers,* 2 = *somewhat meaningful,* 3 = *meaningful,* and 4 = *very meaningful.*

The reliability of SCU was determined in a study involving pairs of trained observers conducting SCU observations in 42 targeted visits to classrooms that were scheduled to have students using technology. Results from the study revealed that overall, the paired observers selected the identical SCU response on 86% of the items, with all other responses being only one rating apart. When looking at subcategories of the SCU, the percentage of times that paired observers selected the same response was as follows: computer capacity and currency—83%; configuration—95%; student computer ability—70%; student activities while using computers—92%; subject areas of computer activities—88%, and overall rubric rating meaningfulness of computer activities—88% (Lowther & Ross, 1999).

Because computer capacity and currency was an established condition of the study (laptop—1 new computer per student; control—5+ new computers per classroom) and configuration data were collected via the Student Survey, the present study used the last two SCU data sets, (a) computer ability and (b) student activities while using computers.

Writing assessment. As a means of determining the impact of the laptop program on student performance, the school district's Writing Scoring Guide was used to assess prompted writing samples from laptop and control students. The district assessment examines four dimensions of writing: (a) ideas and content, (b) organization, (c) style, and (d) conventions. The rubric employed categorizes the writing sample into one of four levels on each dimension: 4 = *mature,* 3 = *capable,* 2 = *developing,* and 1 = *emerging.* A copy of the rubric criteria for each Dimension × Level category is provided in Ross, Lowther, & Morrison, (2001).

All district students in Grades 3 through 8 complete the writing test at the end of the academic year. The assessment involves students being asked to write a letter of introduction to their "new" teacher for next year. For this study, the school district made available the sixth- and seventh grade writing scores. From these data sets, 59 laptop and 59 control (see Table 1) writing samples were randomly selected for analysis. Experienced reviewers used the district's 4-point rubric to conduct a blind assessment of the writing samples for each of the four dimensions, yielding four scores per student.

Problem-solving assessment. To assess the ability of students to comprehend problems and formulate solutions, a problem-solving task was devised for this study with the assistance of a group of sixth grade teachers. The task posed a situation dealing with the problem of used soda cans accumulating at city parks. The overall problem was to help the Parks Commission motivate visitors to recycle their used cans. Specifically, students were asked to describe:

- How they would solve the problem,
- What materials and resources they would use, and
- If they would work with others.

They were then asked to answer the following questions:

- Which park has the largest number of cans in the trash?
- How much money does the vending company keep from cans that are turned in for deposit?
- What are the benefits of recycling?
- What could be done to encourage people to recycle cans rather than put them in the trash?
- How would one would determine if increasing the deposit amount would act as an incentive to increased return of cans?
- How should the results be presented to the Parks Commission?

Laptop and control teachers received written instructions for administering the problem-solving task: Students had 45 min to complete the task and were to take the test via computer, given that all sixth grade students in the district had received computer literacy training; teachers were to read a statement instructing students not to include their name or any other identifying marks on their work.

Random samples of 52 laptop and 59 control students in the sixth grade were administered the task. Trained reviewers from the graduate education programs at Wayne State University judged the student responses on a rubric composed of 7 Components × 3 Performance Levels (see Figure 1). Components consisted of (a) understands problem, (b) identifies what is known about problem, (c) identifies what needs to be known to solve the problem, (d) determines how the data need to be manipulated to solve the

Figure 1 ☐ Problem-solving rubric.

Component or Rating	*Level 1*	*Level 2*	*Level 3*
Understands problem.	The overall problem-solving approach demonstrates a very limited understanding of the problem.	The overall problem-solving approach somewhat demonstrates a general understanding of the problem.	The overall problem-solving approach strongly demonstrates clear understanding of the problem.
Identifies what is known about the problem.	Provides a very limited or no description of what is known.	Provides an incomplete description of what is known.	Provides a complete and detailed list of what is known about problem.
Identifies what needs to be known to solve the problem.	Provides no or a very limited relationship between data and what needs to be known to solve problem.	Provides some reasoning as to how data and what needs to be known are related to problem-solving.	Provides developed rationale as to how data and what needs to be known are related to solving the problem.
Determines how the data needs to be manipulated to solve the problem.	Does not address data manipulation.	Provides indication that data must be manipulated.	Describes specific ways of manipulating data to solve problem.
Describes use of technology.	Description of technology use is not included or very limited, e.g., the computer will be used to get information.	Describes specific technology or software that will be used to solve problem, but only provides general tasks to be completed, e.g., the Internet will be used to find information.	Describes specific technology or software and specific tasks that will be used to solve problem, e.g., the Internet will be used to find information about recycling paper.
Describes how to present findings.	Provides no or very limited detail as to how results will be presented.	Provides a general description of how results will be presented.	Describes details of how and what results will be presented.
Collaborative learning.	No mention of collaboration or independent orientation.	Describes limited collaboration, mostly for sharing information or obtaining help.	Describes a collaborative orientation with assigned responsibilities and extensive interactions with partners.

problem, (e) describes use of technology, (f) describes how to present findings, and (g) collaborative learning. The reliability of ratings was assessed by having three raters independently evaluate 15 sets of randomly selected responses. Component means were computed for each rater. Differences between the highest and lowest means on each component ranged from only 0.05 (technology) to 0.33 (understands problem) with a median difference of 0.18. Interrater correlations across all components were moderately high: +0.73, +0.75, and +0.79. All reviews were done blindly, without knowing either student identities or treatment conditions.

Student survey. The 36-item Laptop Student Survey was developed and field-tested during the pilot study (Ross et al., 2000). The Control

Student Survey was designed to be identical in length and context to the laptop version, except that it referred to "school computers" or "home computers" rather than the "laptop computers." The content included multiple choice, Likert-type items and open-ended questions. Internal consistency reliability computed for the two sections of the Laptop Student Survey involving multiple item scales (Section 1 on personal effect and Section 4 on skills, see below), using Cronbach's alpha, was $r = .795$ and .854, respectively. For the control survey, the respective reliabilities were $r = .735$ and .806. The surveys were administered online during class time to 257 laptop students and 134 control students.

Section 1 of the survey began by asking students how having the laptop had affected them personally. These items ($n = 8$) addressed the student's writing ability, interest, and improvement in school, and if the laptop made schoolwork easier. A 3-point scale consisting of the response categories *none, somewhat,* and *a lot more* was employed. A sample item is, "My computer skills are better because I have a laptop." Section 2 ($n = 7$) explored if students worked with other students while using the laptop and asked students to identify the subject areas covered in laptop lessons. A 4-point scale consisting of *never, once a week, several times a week,* and *almost every day* was used. The students then were asked in Section 3 ($n = 3$) to rate on the same 4-point scale how often they used the laptop at home, what laptop activities they did at home, and if other family members used the computer. The last questions in this section inquired about Internet access in the home ($n = 1$, *yes* or *no*). If Internet access was available, students were asked to rate ($n = 2$), again using the 4-point scale, how frequently it was used for schoolwork and other activities. In Section 4, students were asked to rate ($n = 11$) how well they used 11 different types of computer software (e.g., database, drawing, e-mail, games, etc.). The rating scale ranged from *not at all* to *very well.* The final section asked open-ended questions regarding the best and worst aspects of having a laptop, how the laptop program should be changed, and any other comments.

Student focus group. The student-focus-group questions were targeted toward four major areas: (a) overall impressions of the laptop (or general computer) program, (b) classroom level changes, (c) student results, and (d) parental support. Questions concerning classroom effects asked students if they had more projects this year than previously, if the assignments were more involved, if their schoolwork required more research and writing, and if authentic assessment tools such as portfolios or rubrics were used. Six focus groups, consisting of 71 randomly selected students, were conducted by university researchers (see Table 1).

Teacher interview. Teacher-interview questions were grouped into the same four areas as the student focus group, while including a fifth area—impact on teachers. The latter section asked teachers how the program had affected them personally and in their relationship with other teachers. The teacher-interview participants were randomly selected from the pool of fifth-, sixth-, and seventh-grade laptop and control teachers, resulting in six teachers being interviewed (one teacher per grade level per group; see Table 1). The interviews were conducted by university researchers.

District parent survey. In addition to the above measures, we also informally examined results from a district parent survey. Survey items addressed the best and worst aspects of the laptop program and asked for general comments.

RESULTS

The results are described below by instrument. Quantitative results were analyzed via appropriate nonparametic tests, analysis of variance (ANOVA) and multivariate analysis of variance (MANOVA), for the dependent measures of concern. Qualitative analyses, guided by Miles and Huberman's (1994) analysis model, were performed on open-ended survey and interview responses. The procedure consisted of transcribing ideas and concepts, deriving patterns and concepts, identifying themes, and revising and refining results, based on member checking and inter-rater review. Once a final set of themes was established for each question, the data were examined to derive frequencies of occurrence for the respondent groups. Using this procedure, we were able to supplement the closed-ended responses by determining for each question the major themes, and the manner and frequency with which the themes were experienced by individuals.

SOM

As indicated in the description of SOM, the observation procedure focused on 24 instructional strategies using a 5-point rubric (0 = *not observed,* 1 = *rarely,* 2 = *occasionally,* 3 = *frequently,* and 4 = *extensively*). Two additional items use a 3-point scale (1 = *low,* 2 = *moderate,* 3 = *high*) to rate the degree to which academically focused class time and student engagement are evidenced. The total number of observations completed was 32 for the laptop teachers and 23 for the control teachers.

Tables 2 and 3 summarize the results for the laptop and control classrooms, respectively. For laptop, strategies viewed occasionally or more in at least 40% of the classrooms include direct instruction (44% total), teacher acting as coach or facilitator (44%), independent seatwork (41%), and technology as a learning tool (59%). For control classrooms, the parallel listing includes direct instruction (57%), higher-level questioning (52%), and independent seatwork (52%) (see Table 4). Generally, control classes reflected usage of more traditional, teacher-centered strategies than did laptop classes. It should also be noted that on the final two summary items, academically focused class time was rated as high in 72% of the laptop visits (Table 2), while level of student interest or engagement was rated as high in 62%. In control classes (Table 3), by comparison, these ratings were 70% and 44%, respectively. The higher level of student interest or engagement in the laptop classrooms could logically be attributed to students having continual computer access.

Because of unequal variances across items, the large number of items, and the somewhat small sample sizes, statistical assumptions for MANOVA were not met. Instead, we employed separate *t* tests for independent samples comparing the means for laptop and control classes on each SOM item in each grade. To determine the strength of any significant outcomes, we computed effect sizes by Cohen's *d* formula (Cohen, 1988) using the pooled standard deviation in the denominator. Significant results are summarized in Table 5. All showed effect sizes exceeding +0.80 in absolute value, indicating strong and educationally meaningful effects.

In Grade 5, results strongly favored the laptop classes on using technology as a learning tool (*ES* = +1.25) and on level of student attention or interest (*ES* = +0.89). The control group, however, was favored on use of higher-level questioning (*ES* = –1.08) and integration of subject areas (*ES* = –0.98). Only one significant difference occurred in Grade 6: Laptop classes made more extensive use of technology as a learning tool than did control classes (*ES* = +1.31). None of the comparisons was significant in Grade 7.

SCU

Findings on the SCU are summarized for all grades combined for both laptop and control students in Table 6. Comparisons between laptop and control classes were made using chi-square tests of independence. Due to insufficient cell frequencies, the three grades were combined for these analyses. With regard to computer abilities, laptop students were rated significantly higher than were control students on computer literacy ($p < .05$) and keyboarding skills ($p < .05$). The Production Tools section of Table 5 reflects use of word processing as the primary production activity in both laptop and control classes. At least *occasional* use of word processing was observed in 57% of the laptop classes and in 24% of the control classes, a significant contrast ($p < .05$). There were directional but nonsignificant tendencies for laptop students to make greater use of the Internet browser and CD-ROM referencing than did control students.

Scores on the overall rubric concerning meaningfulness of computer usage (1 = *low-level use,* 4 = *very meaningful use*) were analyzed via a *t* test for independent samples. Results showed the laptop classes (M = 2.12) to have a nonsignificant advantage (p < .10) over control classes (M = 1.78). Analyses conducted separately by grade showed comparable outcomes. However, in Grade 6 only, laptop students (M = 2.50) were rated significantly higher than control students (M = 1.00) on the overall rubric, $t(17) = 5.14$, p < .001, ES = +1.43.

Writing Achievement

Sixth grade. The performed MANOVA on the four writing dimensions yielded $F(4, 53) = 8.87$, $p < .001$, indicating a highly significant program effect favoring the laptop group (see means on Table 7). ANOVAs were highly significant (p < .001) on three of the four ratings: (a) Ideas and Content, (b) Organization, and (c) Style. The fourth (Conventions) approached significance (p = .053). Effect sizes ranged from +0.53 to +1.47, with those for the three significant components all exceeding +1.00. Effects of this magnitude represent strong and educationally important influences (Cohen, 1988).

Seventh grade. The MANOVA yielded $F(4, 55)$ = 4.133, p < .005, again indicating a highly significant program effect. Univariate analyses yielded significant differences favoring the laptop students on each of the four dimensions (see Table 6). Effect sizes were moderate to strong in magnitude, ranging from +0.59 on Conventions to +0.94 on Style.

Problem-Solving Achievement

A MANOVA comparing the means of laptop and control sixth-grade students on the seven problem-solving components yielded a highly significant difference, $F(7, 103) = 3.378$, $p = .003$. Follow-up analyses (see Table 8) showed significant advantages for the laptop group on five of the seven components. Effect sizes ranged from +0.38 to +0.76, the latter associated with "Understands Problem."

Student Survey

Laptop students. A total of 257 laptop students completed the student survey (see Table 1). Return rate approximated 100% of the students attending class on the day of administration. Given the many items and the extensiveness of the descriptive data, we will provide only a summary of major findings here. A more detailed reporting can be found in a comprehensive technical report (Ross et al., 2001).

With regard to possible program effects, the laptop students were highly positive that their computer skills had increased (75% responded, "a lot more"), and they could do Internet research to find information (74.%). A strong majority (80%) were glad that they had a laptop computer and wanted to use a laptop computer again the following year (78%). Students were less committal that having a laptop increased their interest in learning (34% responded, "a lot more"), in getting better grades (24%), or in working with other students (30%).

Other survey questions dealt with the conditions under which computers were used in school and at home. Almost one half (46.2%) of the students generally worked with the laptop by themselves in the classroom every day. However, nearly all (91%) worked with one other student at least once a week, while about 76% worked with a group or team at least once a week. The most common subjects involved in laptop uses were language arts (53% "almost every day") and social studies (32%). More than half of the students (64%) reported using the laptop at least several times a week for completing homework, while even more (71%) reported regular uses for "other things." About a third of the respondents (31%) reported use by other family members at least one time a week.

There was moderate use of the laptop for Internet access to complete homework (47% at least several times a week), but more frequent use of the Internet for "things other than schoolwork" (71% at least several times a week). The types of school-related activities included research for projects, checking class Web pages for assignments, meeting in chat rooms to discuss projects, or asking the teacher or other students school-related questions. When asked to assess

Table 2 ☐ SOM descriptive data for laptop classrooms: Frequency of observed strategies (all grades combined)

Strategies	*None (%)*	*Rarely (%)*	*Occasionally (%)*	*Frequently (%)*	*Extensively (%)*
Instructional Orientation					
Direct instruction (lecture)	31.3	25.0	18.8	15.6	9.4
Team teaching	100.0	0.0	0.0	0.0	0.0
Cooperative or collaborative learning	78.1	6.3	9.4	6.3	0.0
Individual tutoring (teacher, peer, aide, adult volunteer)	96.9	3.1	0.0	0.0	0.0
Classroom Organization					
Ability groups	100.0	0.0	0.0	0.0	0.0
Multiage grouping	100.0	0.0	0.0	0.0	0.0
Work centers (for individuals or groups)	100.0	0.0	0.0	0.0	0.0
Instructional Strategies					
Higher-level instructional feedback (written or verbal) to enhance student learning	59.4	15.6	12.5	6.3	6.3
Integration of subject areas (interdisciplinary-thematic units)	93.8	0.0	0.0	3.1	3.1
Project-based learning	77.4	0.0	3.2	3.2	16.1
Use of higher-level questioning strategies	50.0	12.5	9.4	21.9	6.3
Teacher acting as a coach or facilitator	43.8	12.5	12.5	18.8	12.5
Parent / community involvement in learning activities	100.0	0.0	0.0	0.0	0.0
Student Activities					
Independent seatwork (self-paced worksheets, individual assignments)	59.4	0.0	6.3	12.5	21.9
Experiential, hands-on learning	84.4	3.1	0.0	3.1	9.4
Systematic individual instruction (differential assignments geared to individual needs)	96.9	3.1	0.0	0.0	0.0
Sustained writing-composition (self-selected or teacher-generated topics)	65.6	3.1	6.3	15.6	9.4
Sustained reading	87.5	3.1	0.0	6.3	3.1
Independent inquiry-research on the part of students	62.5	9.4	6.3	9.4	12.5
Student discussion	78.1	0.0	3.1	6.3	12.5
Technology Use					
Computer for instructional delivery (e.g. CAI, drill & practice)	87.5	6.3	3.1	3.1	0.0
Technology as a learning tool or resource (e.g. Internet research, spreadsheet or database creation, multi-media, CD-ROM, laser disk)	34.4	6.3	6.3	15.6	37.5
Assessment					
Performance assessment strategies	90.6	0.0	0.0	3.1	6.3
Student self-assessment (portfolios, individual record books)	84.4	6.3	3.1	3.1	3.1

Summary Items	*Low*	*Moderate*	*High*
Academically focused class time	10.3	17.2	72.4
Level of student attention / interest / engagement	10.3	27.6	62.1

Note. SOM = School Observation Measure

Table 3 ☐ SOM descriptive data for control classrooms: Frequency of observed strategies (all grades combined)

Strategies	*None (%)*	*Rarely (%)*	*Occasionally (%)*	*Frequently (%)*	*Extensively (%)*
Instructional Orientation					
Direct instruction (lecture)	39.1	4.3	13.0	26.1	17.4
Team teaching	95.7	0.0	4.3	0.0	0.0
Cooperative or collaborative learning	82.6	0.0	8.7	4.3	4.3
Individual tutoring (teacher, peer, aide, adult volunteer)	91.3	4.3	0.0	4.3	0.0
Classroom Organization					
Ability groups	100.0	0.0	0.0	0.0	0.0
Multiage grouping	95.7	0.0	0.0	0.0	4.3
Work centers (for individuals or groups)	91.3	0.0	0.0	4.3	4.3
Instructional Strategies					
Higher-level instructional feedback (written or verbal) to enhance student learning	65.2	0.0	4.3	26.1	4.3
Integration of subject areas (interdisciplinary-thematic units)	52.2	13.0	13.0	13.0	8.7
Project-based learning	69.6	0.0	4.3	8.7	17.4
Use of higher-level questioning strategies	47.8	0.0	17.4	26.1	8.7
Teacher acting as a coach or facilitator	47.8	17.4	8.7	21.7	4.3
Parent / community involvement in learning activities	95.7	4.3	0.0	0.0	0.0
Student Activities					
Independent seatwork (self-paced worksheets, individual assignments)	39.1	8.7	17.4	21.7	13.0
Experiential, hands-on learning	82.6	0.0	4.3	8.7	4.3
Systematic individual instruction (differential assignments geared to individual needs)	91.3	0.0	4.3	4.3	0.0
Sustained writing-composition (self-selected or teacher-generated topics)	60.9	0.0	13.0	21.7	4.3
Sustained reading	73.9	4.3	8.7	4.3	8.7
Independent inquiry-research on the part of students	78.3	0.0	4.3	4.3	13.0
Student discussion	73.9	4.3	8.7	13.0	0.0
Technology Use					
Computer for instructional delivery (e.g. CAI, drill & practice)	95.7	0.0	0.0	0.0	4.3
Technology as a learning tool or resource (e.g. Internet research, spreadsheet or database creation, multimedia, CD-ROM, laser disk)	82.6	0.0	4.3	4.3	8.7
Assessment					
Performance assessment strategies	73.9	4.3	8.7	8.7	4.3
Student self-assessment (portfolios, individual record books)	87.0	4.3	4.3	0.0	4.3

Summary Items	*Low*	*Moderate*	*High*
Academically focused class time	8.7	21.7	69.6
Level of student attention / interest / engagement	17.4	39.1	43.5

Note. SOM = School Observation Measure

Table 4 ☐ SOM strategies viewed occasionally or more in 40% of the classrooms

Strategies	*Laptop* %	*Control* %
Technology as a Learning Tool	59	17
Direct Instruction	44	57
Teacher as Coach or Facilitator	44	35
Independent Seatwork	41	52
Higher-level Questioning	38	52

Note. Scale: 0 = not observed, 1 = rarely observed, 2 = occasionally observed, 3 = frequently observed, 4 = extensively observed
SOM = School Observation Measure

their skills in using different types of software, the laptop students rated themselves the highest in word processing (78% "very well"), followed by CD-ROM encyclopedias (67%), and PowerPoint® (66%).

The four final survey items were open ended. The first asked students what they felt were the best aspects of the laptop program. The majority of the responses (56% of 257) indicated that the laptop made schoolwork easier, faster, and more varied due to the use of the Internet and CD-ROM resources. The next most common response was playing games and visiting new Web sites (16%). The next question asked about the hardest part of the laptop program. Almost half (42%) of the students responded that the laptop computer was heavy and difficult to carry when combined with books and band instruments. Less frequent comments referred to computer breakage, slow or poor service, maintaining the laptop, and learning how to use it. When asked what they would change about the laptop program, students wanted fewer restrictions and rules regarding the use of games and the Internet 20%), more time to use the computers during class (19%), a different brand of laptop (19%), and computers that were lighter and easier to carry (16%). About one third (35%) of "additional comments" (f = 82) were positive affirmations that the students liked having a laptop. Many students (20%) also indicated that they wanted the program to continue but to include all students.

Control student survey. A total of 134 control students completed the student survey. Because the descriptive results for the control students are of limited interest in the present study, we will focus primarily below on items associated with significant relationships (in two-way chi-square tests of independence) between survey response and participant groups (see Ross et al., 2001, for a full reporting of control group responses).

Regarding program effects, most of the con-

Table 5 ☐ Summary of items showing significant program differences on the SOM by grade

Significant Items	*Laptop* *M*	*SD*	*Control* *M*	*SD*	*t*	*ES*
Grade 5						
Technology as a learning tool	1.88	1.89	0.20	0.63	2.41*	1.25
Use of higher-level questioning	0.38	0.52	1.60	1.43	–2.51*	–1.08
Integration of subject areas	0.00	0.00	0.70	0.95	–2.33*	–0.98
Level of student attention or interest	3.00	0.00	2.50	0.71	2.24*	0.89
Grade 6						
Technology as a learning tool	2.18	1.91	0.00	0.00	4.69**	1.31

Note. Scale: 0 = not observed, 1 = rarely observed, 2 = occasionally observed, 3 = frequently observed, 4 = extensively observed
*$p < .05$, **$p < .01$
SOM = School Observation Measure

Table 6 ☐ Survey of computer use data summary: Laptop vs. Control for all grades combined

Groups		Not observed %	Rarely %	Occasionally %	Frequently %	Extensivly %
Student Computer Ability						
Laptop	Students were computer literate*	25.0	0.0	0.0	7.1	67.9
	Students easily used keyboard*	25.0	0.0	3.6	7.1	64.3
Control	Students were computer literate	64.0	0.0	4.0	4.0	28.0
	Students easily used keyboard	64.0	0.0	4.0	8.0	24.0
Production Tools Used by Students						
Laptop	Word Processing	39.3	3.6	3.6	7.1	46.4
	Database	96.4	0.0	0.0	0.0	3.6
	Spreadsheet	96.4	0.0	0.0	0.0	3.6
	Draw, paint, or graphics	85.7	3.6	3.6	7.1	0.0
	Presentation (e.g., PowerPoint)	89.3	0.0	3.6	3.6	3.6
	Authoring (e.g., HyperStudio)	100.0	0.0	0.0	0.0	0.0
	Concept mapping (e.g., Inspiration)	100.0	0.0	0.0	0.0	0.0
	Planning (e.g., MS Project)	100.0	0.0	0.0	0.0	0.0
Control	Word Processing	76.0	0.0	8.0	0.0	16.0
	Database	100.0	0.0	0.0	0.0	0.0
	Spreadsheet	100.0	0.0	0.0	0.0	0.0
	Draw, paint, or graphics	92.0	0.0	4.0	0.0	4.0
	Presentation	100.0	0.0	0.0	0.0	0.0
	Authoring	100.0	0.0	0.0	0.0	0.0
	Concept mapping	100.0	0.0	0.0	0.0	0.0
	Planning	100.0	0.0	0.0	0.0	0.0
Internet or Research Tools Used by Students						
Laptop	Internet browser (e.g., Netscape)	60.7	3.6	10.7	7.1	17.9
	CD reference (encyclopedias, etc.)	82.1	3.6	3.6	3.6	7.1
	Communications	96.4	3.6	0.0	0.0	0.0
Control	Internet browser	76.0	4.0	12.0	0.0	8.0
	CD reference	100.0	0.0	0.0	0.0	0.0
	Communications	96.0	4.0	0.0	0.0	0.0
Educational Software Used by Students						
Laptop	Drill, practice, tutorial	100.0	0.0	0.0	0.0	0.0
	Problem solving (e.g., SimCity,)	100.0	0.0	0.0	0.0	0.0
	Process tools (Geo. Sketchpad)	100.0	0.0	0.0	0.0	0.0
Control	Drill, practice, tutorial	96.0	0.0	0.0	4.0	0.0
	Problem solving	100.0	0.0	0.0	0.0	0.0
	Process tools	100.0	0.0	0.0	0.0	0.0

Subject Areas of Computer Activities		Other %	Language Arts %	Mathematics %	Science %	Social Science %
Laptop	Production tools**	5.6	44.4	5.6	11.1	33.3
	Internet or research tools*	8.3	33.3	8.3	8.3	41.7
	Educational software	100.0	0.0	0.0	0.0	0.0
Control	Production tools	100.0	0.0	0.0	0.0	0.0
	Internet or research tools	66.7	8.3	0.0	0.0	25.0
	Educational software	88.9	0.0	11.1	0.0	0.0

*$p < .05$, ** $p < .001$

Table 7 ☐ Descriptive and inferential results from comparisons between laptop and control students' writing dimensions

	Laptop		Control				
Component or Rating	*M*	*SD*	*M*	*SD*	*F(1, 58)*	*p*	*ES*
Grade 6							
1. Ideas and content	3.45	0.73	2.17	1.04	23.60	.000	+1.43
2. Organization	3.55	0.78	2.34	0.86	21.12	.000	+1.47
3. Style	3.20	0.82	2.34	0.77	10.78	.000	+1.10
4. Conventions	3.52	0.74	3.21	0.41	1.40	.053	+0.53
Grade 7							
1. Ideas and content	2.73	0.91	2.00	0.69	12.36	.001	+0.90
2. Organization	2.60	1.00	1.87	0.73	10.47	.002	+0.83
3. Style	2.63	0.96	1.90	0.55	13.12	.001	+0.94
4. Conventions	3.43	0.50	3.13	0.51	5.28	.025	+0.59

Note. Scale: Mature (4), Capable (3), Developing (2), Emerging (1).

Table 8 ☐ Descriptive and inferential results for comparisons between laptop and control 6th grade students on the problem solving assessment

	Laptop		Control				
Component or rating	*M*	*SD*	*M*	*SD*	*F(7,103)*	*p*	*ES*
1. Understands problem	2.56	0.67	1.98	0.84	15.59	.000	+0.76
2. Identifies what is known about the problem	2.29	0.78	1.71	0.85	13.76	.000	+0.72
3. Identifies what needs to be known to solve the problem	1.88	0.73	1.56	0.70	5.70	.019	+0.45
4. Determines how data should be manipulated to solve problem	1.67	0.76	1.41	0.62	4.13	.044	+0.38
5. Describes the use of technology	1.33	0.71	1.08	0.38	5.19	.025	+0.44

trol students (54%), but significantly ($p < .001$) fewer than the laptop group (75%) felt that their computer skills had increased as a result of having access to classroom computers. The control students tended to feel less strongly that access to computers increased their interest in learning ($p < .001$) and in earning better grades ($p < .05$). About half (compared to three fourths of the laptop group) felt that using school computers improved their skills in writing to some degree ($p < .001$). Although 65% of the control group wanted to use computers again in class next year, this response was less positive ($p < .05$) than the 78% agreement by the laptop group.

Understandably, only 32% of the control students, as compared to 46% of the laptop students, worked with the computer by themselves every day ($p < .001$). In general, control students had relatively few opportunities compared to laptop students to complete computer work with another student ($p < .001$) or with a team ($p < .001$). For each school subject listed on the survey (e.g., language arts, mathematics, social studies, science), control students conveyed significantly less ($p < .001$) usage of computers than did laptop students.

Control students reported less use of the Internet to complete homework than did laptop students ($p < .001$), but more frequent use of the Internet for "things other than schoolwork" ($p < .05$). Control students tended to rate themselves significantly lower ($p < .05$) in skills than did laptop students on the majority of software types: database, drawing, Internet searches, Power-

Point®, Excel®, word processing, encyclopedia, and calendar or telephone book.

In summary, the survey results showed that the control students were acquiring regular computer experiences but in ways less diversified in scope and less connected to everyday classroom instruction than did laptop students. Control students felt positively about using computers and were fairly regular users of the Internet, albeit mostly for activities other than school work. They mostly worked with computers individually, and viewed themselves as skilled in more routine software applications such as e-mail, games, and word processing. Their perceived skill levels with more sophisticated tool software was consistently less than that of the laptop group.

Student Focus Groups

Results of the six student focus groups (3 laptop; 3 control) are synthesized below.

Laptop students. Students were very positive about having a laptop, and indicated that the best aspects were easy access to online resources, ease of creating and editing work, and ability to make assignments look much better. Students indicated that the worst aspects of having the laptop was dealing with technical difficulties and carrying it to and from school.

All of the students indicated that the laptop had influenced classroom-level changes in fostering more project work, research, higher-level thinking, writing, and cooperative learning. When asked if having the laptop had influenced their personal learning, student responses were positive, with some indicating that it had helped them to be more organized and that access to online resources had increased their knowledge. Responses were mixed with regard to the impact on student-to-student or student-to-teacher communication. Some stated that communications had increased from the use of e-mail and instant messenger, whereas some indicated no noticeable changes.

Students reported that their parents were generally very positive about the program but that some became frustrated when the laptop was not working or repairs took too long. The most common reply regarding reactions of other family members was "jealousy." Students felt that communication between parents and teachers had not really increased, but many indicated that the form had changed from face-to-face to e-mail correspondence.

Control students. In general, the control students liked having computers in their classroom, stating that the best parts were that it made writing assignments easier than with paper and pencil, that research is easier, and that they like the spell-checker. The worst parts were having to wait to use a computer, forgetting to save work, and experiencing technical difficulties.

In contrast to the laptop students, the control student responses were mixed with regard to whether or not having classroom computers had caused an increase in project work, required research, amount of writing, working with other students, or the use of portfolios and rubrics. Control students gave similar mixed responses when asked about the impact of the computers on student learning. In general, control students were positive about classroom computers but did not see the technology as substantively changing teaching and learning activities.

Teacher Interviews

A total of six teacher interviews were conducted with one randomly selected laptop and one control teacher from each grade level (fifth, sixth, and seventh).

Laptop teachers. The three laptop teachers were very positive about the overall laptop program. They identified the most effective aspects of the program as the improved ability of students to use the computer and to conduct Internet-based research. There was general agreement that the two most difficult aspects of the program were (a) monitoring use of the Internet and (b) technical difficulties, yet each teacher indicated that the positive aspects of having laptops outweighed the negatives. Detailed reporting of results are provided in Ross et al. (2001); a summary of primary themes are presented here.

According to the fifth-grade teacher, laptop students were more eager to engage in project-based activities, worked more cooperatively during projects because they could e-mail products to team members, and were better able to "find current information quicker." This teacher also indicated that students were better writers because they "are not afraid to write—they can delete and redo a paper much easier." The sixth-grade teacher reported that more science and social studies projects were assigned, more cooperative learning was used, and student writing skills had improved. That teacher also indicated that the degree of higher-level learning had increased because "I expect more out of my students." The seventh-grade teacher felt that the laptops enhanced student research skills, ability to work together, and interdisciplinary learning because content area information, such as in social studies, could be transferred into graphing software to reinforce math skills. This teacher was less certain that writing was positively affected because of student reliance on grammar and spell check tools.

Control teachers. The classrooms of the three control teachers each had five or more computers available for student use. Overall, the teachers were supportive about the computers, but indicated a desire for more computers to decrease the student-to-computer ratio. The most effective aspects of having computers were noted as access to the Internet, and assignments that were word processed and thus easier to read. Like the laptop teachers, the control teachers felt that the most difficult aspects were management of student Internet use, and equipment failures. However, unlike the laptop teachers, they also experienced difficulty due to student unfamiliarity with computer use.

The control teachers were mixed concerning positive effect of computer use on classroom activities, students, parental support, and the teachers themselves. For example, regarding influence of the computer on student writing, the sixth-grade teacher saw positive effects, while the seventh-grade teacher felt that students "think the grammar and spell check are sufficient, so they are not as willing to correct their papers." All three indicated little if any impact of computers on the use of cooperative learning.

Control teacher responses with regard to effect of classroom computers on students were again mixed. The sixth-grade teacher indicated that students "stayed on task, listened, focused, and worked harder when using computers." The seventh-grade teacher, on the other hand, reported that students, "become irritated when equipment does not work, fight over time constraints on the computer, and are disgruntled about lack of supplies (e.g., ink, paper)." They also indicated increased classroom management demands because of technical difficulties and student lack of interpersonal and technical skills.

Parent-Caretaker Reactions

Laptop parents were given the opportunity to react to their child's involvement as part of the school district's formative evaluation of the program. A total of 66 laptop parents or caretakers (out of approximately 300) returned open-ended comments in response to three general questions. Although these responses cannot be viewed as necessarily representative of perceptions by the total parent population, they are briefly reviewed as possible indicators of program strengths and weaknesses.

In commenting on the "best thing about the laptop program," more than one third of the respondents indicated that having the laptop had increased their child's level of computer skills, 31% thought the laptop had helped their child with school-related work such as research and writing skills, and 20% felt the laptop had helped increase other skills such as organization and ability to accept responsibility. For example, one respondent wrote, "Her ability to work with computers, all types, is unbelievable . . . this will do wonders for success in her future." Another indicated, "He has stopped complaining about writing and doing projects. He spends time creating his papers instead of rewriting them."

On the other hand, about one fourth of the parent responses indicated that the worst aspect of having the laptop was that it was hard for their child to carry, especially when other books and a band instrument also had to be carried. Approximately the same number (24%) thought that computer breakage and dealing with a repair service was the most difficult aspect (e.g., "My daughter's laptop was down for almost three weeks and they do not have loaners to use."). Other comments included concerns that the laptops were not used enough for educational purposes (13%) and that they decreased their child's practice with handwriting, spelling, and library use (11%).

In making additional comments, seven respondents expressed concerns about the equity of laptop distribution and use. Such sentiments are exemplified by the following comments:

> The school has made some major mistakes in their implementation of this program. There is a separation between the "laptop" kids and the "nonlaptop" kids, and our district makes this separation wider by such things as having the "laptop" students in one hall, and all "nonlaptop" students in another. Technology is not the "be all and the end all" in education. It is simply another tool. I wish as much effort was put into my son's fifth grade math book selection as was put into this program.

DISCUSSION

Results of this study suggest varied effects of the laptop program on students, teachers, and family members. These findings are discussed below in reference to the two primary research questions.

Is Teaching Different in a Laptop Classroom?

Research on schools indicates that classroom teaching methods are remarkably resistant to change (Cuban, 1993). From the 1890s to today, teacher-centered practices still dominate the class arrangement, communication dynamics, and instructional activities (Bellanca, 1998; Peterson, 1991; Ravitch, 1985). In the more confined context of technology usage, such tendencies have been mirrored by teacher reliance on computers for *delivering* instruction (e.g., "drill-and-practice") and entertainment rather than for facilitating student-centered activities such as inquiry and problem solving (Hokanson & Hooper, 2000; President's Committee of Advisors on Science and Technology, 1997).

In the Year 1 evaluation of the program, laptop classes were compared to control classes that did *not* have extraordinary access to computers (Ross et al., 2000). Results indicated greater uses in the laptop classes of student-centered teaching strategies, such as project-based learning, independent inquiry, teacher as coach, and cooperative learning. Overall, the laptop classes were busier and more active learning environments. Most revealing was the laptop students' superiority in using the computer as a learning tool.

The present descriptive results mirrored the trend for more extensive student-centered learning in laptop than in control classes, and also relative to national norms for the SOM instrument (Ross et al., 1999). However, in contrast to Year 1, few differences were statistically significant. Objectively, the most obvious explanation of the discrepancies is that the present sample of laptop classes tended to use student-centered teaching approaches less frequently than did the Year 1 group. A clear difference, for example, was in cooperative learning, which was observed in 65% of the Year 1 laptop visits as compared to only 22% of the Year 2 laptop visits. While the present (Year 2) laptop classes were busy and active places compared to typical classrooms that we have observed (Ross & Lowther, 2003) perhaps the teachers were less influenced by a "Hawthorne-type" effect than in Year 1, and thus were less likely to demonstrate "model" lessons when observers visited. Some teachers may have felt more confident about intermixing traditional practices to ensure that state content standards were being addressed. At the same time, because of their exposure to the NTeQ training, control teachers may have been oriented to use constructivist practices more than in the past (see Hokanson & Hooper, 2000; Reiber, 1992).

Consistent across both years of the study was the laptop students' more frequent usage of the computer as a learning tool rather than to deliver instruction. Specifically, such applications were observed in 66% of the visits to laptop classes compared to only 17% of the control classes—a highly significant and educationally important difference. The SCU findings further revealed greater use of word processing in the laptop classes and more meaningful overall usage of the computer in Grade 6. These results were not as striking as in the first year, but especially in view of control classes also having NTeQ-trained teachers and enhanced technology resources, they were still suggestive of positive impacts of the laptop program for infusing technology use into teaching practices.

Another positive effect is suggested from the significant finding in Grade 5 (and directional trend in Grades 6 and 7) for laptop students to be more attentive and interested in learning relative to control students. This finding may be partly attributable to the tendency of control teachers to rely more on teacher-centered delivery of instruction. For example, SOM results showed direct instruction to be frequently or extensively observed in 45% of the control classes compared to only 25% of the laptop classes.

Do Students Achieve Differently in a Laptop Classroom?

Two measures of achievement—a writing prompt and a problem-solving task—were administered in this study to assess achievement. The present results corroborated the pilot study findings for writing in both Grades 6 and 7. Six of the eight effect sizes (4 Components $\times$ 2 Grades) exceeded +0.80, while the mean differences in many cases approximated or exceeded a full rubric point. Clearly, the laptop students were demonstrating superior writing skills.

Although the SOM data were inconclusive about writing activity, SCU results did reveal significantly more involvement by laptop than control students in the use of word processing. Laptop students frequently or extensively used word processing in more than half (54%) of the classroom visits compared to only 16% of the control classes. In their survey responses, nearly 75% of the laptop students and 100% of the teachers felt that use of the laptop had improved student writing skills. Notably, open-ended comments on the Student Survey identified the facilitation of writing as the “best aspect” of having a computer.

Results on the problem-solving test were further suggestive of the laptop program’s positive impact on student achievement. These differences may have been influenced by laptop students’ engagement in research activities, as evidenced in teacher and student survey responses. Teachers explicitly conveyed that the availability of the laptops facilitated lesson design and activities that increased student research skills. They also indicated that they integrated computer tools, such as word processing, Internet, and presentation, into their coursework for the specific purpose of engendering research and inquiry.

Not surprisingly, student survey responses revealed significantly higher confidence by laptop students compared to control students for using all the basic software applications. Responses also indicated that 95% of the laptop students felt confident to conduct Internet searches. As revealed in the following student comments, engagement in research activities was often perceived as one of the most valuable aspects of the laptop program: “It opens up a whole variety of resources”; “I like Excel which is very useful for organizing and creating graphs for science and math”; “The best thing is being able to find information really fast and use it in class for projects”; “It helps you to be organized”; and “It makes it easier to do research projects and write essays.”

Research- and project-oriented tasks would seem likely to enhance student performance in the types of problem-solving skills assessed in this study (e.g., understanding a problem, identifying what is needed to solve it, using technology). In this respect, laptop students had two seemingly important advantages over their control counterparts. One was that their teachers placed greater emphasis on such tasks than did the control teachers. Second, laptop students had greater accessibility to and better skills at using application software geared to solving open-ended learning problems (i.e., arranging data, obtaining information, presenting results, etc.). This combination of factors conceivably increased their range for planning and conceptualizing how a new, complex problem could be approached and systematically solved.

In the current era of heightened educational accountability (Slavin, 2002), applications of technology in K–12 classrooms will be increasingly judged on the basis of demonstrating success in raising student achievement. While the debate regarding the appropriateness of high-stakes standardized testing continues (Linn, 2000), it seems reasonable to question the degree to which classroom uses of involving, technologically supported constructivist activities would be the most direct route to raising scores on group-administered multiple-choice tests (see Shepard, 2000). The dearth of studies showing the effect of laptop programs on student achievement, therefore, does not seem surprising (Penuel et al., 2002). On the other hand, the assumption that such programs might affect directly supported learning skills such as writing and problem solving, as evidenced in the present research, seems logical. Given the ex post facto design employed in this study, the present results can be considered only suggestive rather than conclusive about the benefits of the laptop program. Additional research, using experimental-type methodology (Shavelson & Towne, 2002) is needed to demonstrate similar findings, in diverse contexts and with other student groups (e.g., disadvantaged populations). Issues related to implementation, such as ensuring equitable access to laptop computers within a school, and dealing with problems of transport and equipment maintenance, also require further exploration to inform educational practice. □

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REFERENCES

Anytime, Anywhere Learning. (2000). *Introduction to getting started.* Retrieved September 22, 2002, from http://www.microsoft.com/education/aal/guideintro.asp

Becker, H., Ravitz, J.L., Wong, Y. (1999). *Teacher and teacher-directed student use of computers and software.* Teaching, Learning, and Computing: 1998 National Survey. Report #3. Center for Research on Information Technology and Organizations. University of California, Irvine and University of Minnesota. Retrieved September 17, 2002 from http://www.crito.uci.edu/tlc/findings/ComputerUse/html/startpage.htm.

Bellanca, J. (1998). Teaching for intelligence: In search of best practices. *Phi Delta Kappan, 79,* 658–660.

Bork, A. (1985). *Personal computers for education.* New York: Harper & Row.

Cognition & Technology Group at Vanderbilt. (1992). The Jasper experiment: An exploration of issues in learning and instructional design. *Educational Technology Research and Development, 40*(1), 65–80.

Cohen, J. (1988). *Statistical power analyses for the behavioral sciences.* Hillsdale, NJ: Lawrence Erlbaum Associates.

Cuban, L. (1993). Computers meet classroom: Classroom wins. *Teachers College Record, 95*(2), 185–210.

Edelson, D.C., Pea, R.D., & Gomez, L. (1996). Constructivism in the collaboratory. In B.G. Wilson (Ed.), *Constructivist learning environments* (pp. 151–164). Englewood Cliffs, NJ: Educational Technology Publications.

Funkhauser, J.E., Steif, E.A., & Allen, S.E. (1998). *Title I school-parent compacts: Supporting partnerships to improve learning.* Final report. Washington, DC: Policy Studies Associates.

Hannafin, M.J., Hall, C., Land, S.M., & Hill, J.R. (1994). Learning in open-ended environments: Assumptions, methods, and implications. *Educational Technology, 34*(8), 48–55.

Hester, J. (2002). *The influence of select variables on the instructional use of computers in Shelby County School District.* Unpublished doctoral dissertation. The University of Memphis.

Hokanson, B., & Hooper, S. (2000). Computers as cognitive media: Examining the potential of computers in education. *Computers in Human Behavior, 16*(5), 537–552.

International Society for Technology in Education. (1998). *National educational technology standards for students.* Eugene, OR: ISTE.

Jerald, C.D., & Orlofsky, G.F. (1999). Raising the bar on school technology. *Technology Counts '99, Education Week, 19*(4), 58–69.

Johnson, D.W., Johnson, R.T., Stanne, M.B., & Garibaldi, A. (1990). Impact of group processing on achievement in cooperative groups. *The Journal of Social Psychology, 130*(4), 507–516.

Land, S., & Hannafin, M.J. (1997). Patterns of understanding with open-ended learning environments: A qualitative study. *Educational Technology Research & Development, 45*(2), 47–73.

Lewis, E.M., Ross, S.M., & Alberg, M. (1999). *School Observation Measure: Reliability analysis.* Memphis, TN: Center for Research in Educational Policy, The University of Memphis.

Linn, M.C., Shear, L., Bell, P., & Slotta, J.D. (1999). Organizing principles for science education partnerships: Case studies of students' learning about "rats in space" and "deformed frogs." *Educational Technology Research and Development, 47*(2), 61–84.

Linn, R.L. (2000). Assessments and accountability. *Educational Researcher, 23*(9), 4–14.

Lowther, D.L., & Ross, S.M. (1999). *Survey of computer use: Reliability analysis.* Memphis, TN: Center for Research in Educational Policy, The University of Memphis.

Meyer, L. (2001). New challenges. *Education Week, 20*(35), 49–64.

Miles, M.B., & Huberman, A.M. (Eds.). (1994). *An expanded sourcebook: Qualitative data analysis* (2nd ed.). Thousand Oaks, CA: Sage Publications.

Moe, M., & Blodgett, H. (2000). *The knowledge web.* Washington, DC: Merrill Lynch, & Co., Global Securities Research & Economics Group.

Morrison, G.R., & Lowther, D.L. (2002). *Integrating computer technology into the classroom* (2nd ed.). NJ: Upper Saddle River, Merrill Prentice Hall.

Nath, L.R., & Ross, S.M. (2001). The influence of a peer-tutoring training model for implementing cooperative groupings with elementary students. *Educational Technology Research and Development, 49*(2), 41–56.

National Center for Education Statistics. (2000, September). *Teachers' tools for the 21st Century. A report on teachers' use of technology*. Washington, DC: Author. (ED 444 599) Retrieved October 2, 2002, from http://nces.ed.gov/spider/webspider/2000102.shtml.

Oliver, K., & Hannafin, M. (2001). Developing and refining mental models in open-ended learning environments: A case study. *Educational Technology Research and Development, 49*(4), 5–32.

Orrill, C.H. (2001). Building technology-based, learner-centered classrooms: The evolution of a professional development framework. *Educational Technology Research and Development, 49*(1), 15–34.

Penuel, W.R., Kim, D.Y., Michalchik, V., Lewis, S. Means, B., Murphy, R., Korbak, C., Whaley, A., & Allen, J.E. (2002). *Using technology to enhance connections between home and school: A research synthesis.* Washington, DC: Planning and Evaluation Service, U.S. Department of Education, DHHS Contract # 282-00-008-Task 1.

Peterson, P. (1991). *Profiles of practice: Elementary teachers' views of their mathematics teaching.* (Elementary Subjects Center Series, No. 39). East Lansing, MI: Institute for Research on Teaching. (ERIC Document Reproduction Service No. 341546.)

Pianfetti, E.S. (2001). Teachers and technology: Digital literacy through professional development. *Language Arts, 78*(3), 255–262.

President's Committee of Advisors on Science and Technology. (1997). *Report to the President on the use of technology to strengthen K–12 education in the United States.* Washington, D.C.

Ravitch, D. (1985). *The troubled crusade: American education 1945–1980.* New York: Basic Books.

Reiber, L.P. (1992). Computer-based microworlds: A bridge between constructivism and direct instruction. *Educational Technology Research and Development, 40*(1), 93–106.

Ross, S.M., & Lowther, D.L. (2003). Impacts of the Co-nect school reform design on classroom instruction, school climate, and student achievement in inner-city schools. *Journal for Educational Research on Students Placed At Risk, 8*(3), 215–246.

Ross, S.M., Lowther, D.L., & Morrison, G.R. (2001). *Anytime, anywhere learning: Final evaluation report.* Center for Research in Educational Policy, University of Memphis.

Ross, S.M., Lowther, D.L., Plants, R.T., & Morrison, G.R. (2000). *Anytime, anywhere learning: Final evaluation report.* Center for Research in Educational Policy, University of Memphis.

Ross, S.M., Smith, L.J., & Alberg, M. (1999). *The school observation measure (SOM).* Memphis, TN: Center for Research in Educational Policy, The University of Memphis.

Ross, S.M., Smith, L. Alberg, M., & Lowther, D. (in press) Using classroom observations as a research and formative evaluation tool in educational reform: The school observation measure. In S. Hilberg and H. Waxman (Eds.), *New directions for observational research in culturally and linguistically diverse classrooms.* Santa Cruz, CA: Center for Research on Education, Diversity & Excellence.

Shavelson, R.J., & Towne, L. (2002). *Scientific research in education*. Washington, DC: National Academy Press.

Shepard, L.A. (2000). The role of assessment in a learning culture. *Educational Researcher, 29*(7), 4–14.

Slavin, R.E. (2002). Evidence-based policies: Transforming educational practice and research. *Educational Researcher, 31*(7), 15–21.

Stuebing, S., Celsi, J., Cousineau, L. (1994). *Environments that support new modes of learning: The results of two interactive design workshops.* ACOT report #19. California: Apple Computer Inc.

U.S. Department of Education. (2000, April). *Teacher use of computers and the Internet in public schools.* (Publication No. 20000090). Retrieved October 9, 2002, from http://nces.ed.gov/pubsearch/pubsinfo.asp?pubid=2000090.

U.S. Department of Education. (2001). *No child left behind.* Washington, DC: The White House.

U.S. Department of Education. (2002, September). *Internet access in U.S. public schools and classrooms: 1994–2001.* (Publication No. 20020018). Retrieved October 9, 2002 from http://nces.ed.gov/pubsearch/pubsinfo.asp?pubid=2002018.

Windschitl, M., & Sahl, K. (2002). Tracing teachers' use of technology in a laptop computer school: The interplay of teacher beliefs, social dynamics, and institutional culture. *American Educational Research Journal, 39*(1), 165–205.