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STUDENT LAPTOP USE AND SCORES ON STANDARDIZED TESTS*

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ABSTRACT

Objectives: The primary objective of the study was to investigate the relationship between ubiquitous laptop use and academic achievement. It was hypothesized that students with ubiquitous laptops would score on average higher on standardized tests than those without such computers. *Methods:* Data were obtained from two sources. First, demographic and computer usage information was obtained through face-to-face interviews of 4th and 5th grade students enrolled in an ethnically diverse elementary school in Southern California. Student achievement and related data were obtained from existing school records. An unmatched case-control group design was implemented. Descriptive, bivariate, and multivariate techniques were performed on the data. *Results:* Overall English/Language Arts and Mathematics scores for the entire sample were 359 and 396 respectively in 2008. Students who were given 24/7 laptop computers, however, had higher scores in English/Language Arts (M = 392.7, SD = 34.98) than students without laptops (M = 338.54, SD = 39.69). In Mathematics, students with laptops had a mean of 448.1 (M = 448.1, SD = 56.83), whereas those without laptops

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had an average of 365.05 (M = 365.05, SD = 52.64). Independent sample t-tests showed that these differences between cases and controls were statistically significant. *Conclusions:* Results showed that, in general, ubiquitous laptop computers improve student performance in English Language/Arts, Mathematics, and Science. These findings contradict other studies that have shown that 24/7 laptops have no effect on student achievement. It is suggested that policy makers continue judicious use of technology in the education curriculum.

INTRODUCTION

In an increasingly globalized and interdependent world, competition among nations in economic and social development is likely to increase and intensify with time. For a modern state to survive and advance economically, it needs a highly educated workforce that is capable of adapting to advances in technology to meet job demands of the 21st century and beyond. Where work related skills of the labor force do not match the requirements of jobs, the result may well be wage and social inequality (Handel, 2003). There are indications that while the United States still maintains some degree of overall economic and military supremacy (International Institute for Strategic Studies, 2012; Nuxoll, 1994; Summers & Heston, 1991), it lags behind most countries in the Organization for Economic Cooperation and Development (OECD) in student academic achievement (National Center for Education Statistics [NCES], 2008). For instance, while the average (PISA) mathematics literacy score for 15-year-olds in all OECD countries was 496 in 2009, that of the United States was 487, a figure that was significantly below average (OECD, 2010). Countries such as Australia (514), Belgium (515), Canada (527), Finland (541), Germany (513), the United Kingdom (492), the Netherlands (526), Korea (546), and Japan (529) all had mathematics literacy scores that were much higher than that of the United States (OECD, 2010). American students also scored much lower (502) than students in many other OECD countries in Science literacy (OECD, 2010).

Concerns about an academic achievement gap have been raised not only with regard to the standing of U.S. students relative to those in other countries, but about racial/ethnic group disparities within the country (Balfanz & Byrnes, 2006; Flores, 2007; Geary, 1996). Debates have focused on three central issues. First, is there an achievement gap, and what is its nature? Second, how widespread is the gap? Third, what are the causes and consequences of the gap? In responding to the first question, analysts appear to be in general agreement that a gap exists between European American students and African American, and between European American and Hispanic students in Mathematics, Science, and Reading (Gregory, Skiba, & Noguera, 2010; Lee, 2002; Reardon & Galindo, 2009). In an analysis of National Assessment of Educational Progress (NAEP) data and SAT results, Lee (2002, p. 5) reported that between 1970 and 1980, academic improvement occurred among all lower performing students across all racial and ethnic groups, and the black-white gap in achievement in reading, mathematics, and science narrowed. Black and Hispanic students narrowed test gaps in verbal and mathematics skills substantially in the 1970s through the first half of the 1980s. The pace of improvement in closing the achievement gap for Black and Hispanic students (relative to non-Hispanic White students) slowed in the late 1980s, and there is evidence to suggest that by the late 1990s a reversal had begun to occur (Lee, 2002, p. 8).

Perhaps more controversial in the education literature is not the extent of the academic gap between racial/ethnic groups, but reasons for its existence and persistence. Earlier studies pointed to residential segregation (Flores, 2007; Gaskin, Dinwiddie, Chan, & McCleary, 2012; Kozol, 1967, 1991; Massey & Denton, 1993). Where racial segregation exists, opportunities and life chances for individuals in the racial/ ethnic groups involved tend to be fundamentally unequal (Kozol, 1991, 2006; Gaskin et al., 2012). The tradition of local control of public education in the United States entails that schools located in predominantly white and often affluent neighborhoods tend to have greater and higher quality resources than those located in predominantly minority neighborhoods (Kozol, 1991, 2006, 2012; Ryan, 1999). More white and affluent communities have a higher tax base, and this enables them to afford better funding for schools, which can be seen in up-to-date textbooks, better paid teachers, smaller class sizes, and an overall physical environment that fosters learning (Kozol, 2006, 2012; Ryan, 1999). Schools in less affluent neighborhoods, on the other hand, tend to have out-of-date textbooks, less paid teachers, beginning and less prepared teachers, larger class sizes, crumbling infrastructure, and low teacher expectations (Gregory et al., 2010; Hanushek & Rivkin, 2009; Kozol, 1991). Students may also come from families that experience high rates of joblessness, poverty, and income inequality (Duncan, Brooks-Gunn, & Klebanov, 1994; Wilson, 1987, 1996). The above position locates causal factors of the academic gap in socio-structural and socioeconomic attributes. Some analysts also propose that the racial/ethnic academic gap lies in the differentials between minority and white students in disciplinary sanctions given out in schools (Gregory et al., 2010; Wallace, Goodkind, Wallace, & Bachman, 2008). In this view, some school administrators tend to be biased, if not prejudiced, and that they disproportionately sanction Black, Hispanic, and Native American students in the form of suspensions, expulsions, and other away from classroom punishments compared to white students (Gregory et al., 2010; Gregory & Weinstein, 2008; Skiba, Simmons, Ritter, Gibb, Rausch, & Cuadrado, 2008). If students are forced to be out of class for infractions, they tend to miss out on lessons, and this could affect not only their attitudes toward learning itself, but eventually their test scores (Gregory &Wenstein, 2008; Noguera, 2007; Skiba et al., 2008; Wallace et al., 2008).

Regardless of the academic gap sources, attention has increasingly focused on information technology, primarily using computers as a means of increasing student academic achievement (Penuel, 2006), and also closing a perceived digital divide within the United States (Becker, 2000; Judge, Puckett, & Cabuk, 2004; Light, 2001; Swaine & Pearson, 2002).

In the past decade, there has been an increasing use of laptops in U.S. elementary, middle, and high schools. Lowther et al. (2003, p. 23) observe that there are over a thousand schools using some type of laptop program in the United States, and Windschitl and Sahl (2002) point out that the number of schools with such programs is growing. Many analysts note apparent advantages that laptops have over desktops in school settings, including reduced computer to student ratios, increased home-to-school connectedness, and increased accessibility (Funkhauser, Steif, & Allen, 1998; Penuel, Kim, Michalchik, Lewis, Means, Murphy, et al., 2002).

Despite this growing use of computers in schools, however, there is a paucity of research that examines their effectiveness, especially their impact on student academic achievement. Different investigators often working with the same set of variables have produced remarkably different results. A review of the extant literature by Penuel (2006) found only 12 studies on classroom laptops, and of these, only one appeared in a peer reviewed journal. In general, research findings on the impact of laptop computers on student academic achievement are mixed. Some investigators have found significant effects of laptop use on student achievement (Efaw, Hampton, Martinez, & Smith, 2004; Gulek & Demirtas, 2005; Light, McDermott, & Honey, 2002; Siegle & Foster, 2001). Other analysts report negligible or no statistically significant effects of laptop use on achievement (Dunleavy & Heinecke, 2007; Gardner, Morrison, & Jarman, 1993; Gardner, Morrison, Jarman, Reilly, & McNally, 1994; Rockman, 1999). As Lowther et al. (2003, p. 25) observe, however, it is unclear from the existing literature why any effects could be found because of serious limitations in study research designs.

In a further effort to eliminate some of the inconsistencies observed in past work and to fill existing gaps in knowledge about the link between laptop computers and student academic achievement, the present study was designed to systematically reassess the effects of laptops on student academic achievement using a combination of descriptive and multivariate statistics. The research questions asked are simple:

1. Do students with ubiquitous laptops have higher tests scores on average than their counterparts without such laptops?
2. Are the effects of laptops on achievement reduced or eliminated once appropriate controls are made for potentially confounding variables?
3. What are the implications of answers to the above questions for past and future research?
4. What are implications of answers to the above questions for education policy in the United States?

PAST RESEARCH

In recent years attention has focused on the use of computers as a means of helping American students achieve higher educational achievement, to compete with their counterparts around the world, and to eventually enter a work force with skills needed to succeed in a globalized economy. Computer literacy itself has come to be viewed as a job skill (Attewell & Battle, 1999) and thus students who lack such a human capital characteristic may be at a disadvantage in terms of future employment (NCES, 1996).

In an effort to close the achievement gap between U.S. students and their counterparts abroad, there has been a proliferation of technology, especially ubiquitous computers in schools in the past 10 years (Sheumaker, Slate, & Onwuegbuzie, 2001). An emerging and common feature of most computer initiatives, at both state and local levels, is that students have individual access to both hardware and software at all times. Despite this trend, relatively little is known about the effectiveness of these technologies on student achievement. As Penuel (2006, p. 329), observes: "The educational technology community's collective knowledge about one-to-one initiatives has not to date kept up with the rapid expansion of these initiatives or with their breadth."

Some analysts have focused attention on student attitudes toward computers and the link between these attitudes and their learning environment. Fisher and Stolarchuk (1998) examine associations between laptop computer students' perceptions of their classroom environment and their cognitive and attitudinal achievements. They found a strong relationship between students' perception of science laptop classroom environment and their attitude toward science. It is important to note that this research did not address a fundamental question, as to whether computer ownership itself influenced test scores. In a similar vein, an Australian-based study by Newhouse (1999) reported that students generally had positive attitudes toward computers even prior to receiving laptops. Using a 120-point scale, he observed that only 5% of students had negative attitudes (below 60). According to Newhouse (1999), this category comprises students who will always exhibit negative attitudes regardless of computer provision.

Recent research has concentrated on the impact of computers upon test scores, instead of simply attitudes. Dunleavy and Heinecke (2007), examined the impact of one-to-one laptop use on middle school mathematics and science standardized tests scores using a pre-test/post-test control group design. The researchers found no significant laptop effect for mathematics, but they did find that one-to-one laptop instruction was more effective in increasing science achievement for male students than it was for female students (Dunleavy & Heinecke, 2007, p. 15). A similar pattern of gender differences was observed for English and writing achievement. Dunleavy and Heinecke (2007) cautioned that future research should focus on differences of technology impact by content areas.

A study by Lei and Zhao (2007) showed that there may be a threshold at which computer use affects test scores. The analysts evaluated the impact of a laptop project launched at a middle school in Ohio in fall 2003. The outcome variable utilized in the study was grade point average (GPA). Lei and Zhao (2007, p. 288) found in regression analysis that 3 hours per day was the threshold. For instance, among students that spent less than 3 hours per day, the more time spent on computers the higher the returns to their GPA. At the same time, students who spent more than 3 hours per day experienced reductions in their GPA. Findings from the Lei and Zhao (2007) study seem to suggest that some law of diminishing returns may be at work, whereby computer use benefits rise up to a point (3 hours), but beyond that threshold, benefits turn into deficits. According to the analysts, it may not be the amount of time spent on computers that influences achievement, but the quality of time (activities done), for example, doing homework versus playing computer games, writing or taking notes versus e-mailing friends, researching for educational purposes versus visiting non-academic websites, etc.

In his study of technology enriched classrooms, Page (2002, p. 402) found that participants in technology enriched classrooms appeared to have higher achievement in mathematics than their counterparts in non-technology enriched classrooms. According to Page (2002), the differences may be due to the fact that technology enriched classrooms are more likely to produce more student-centered and individualized interactions, whereas non-technological classrooms tend to follow a traditional model of teacher centeredness (Clements, Nastasi, & Swaminathan, 1993).

In a recent study of 5th, 6th, and 7th graders by Lowther et al. (2003), a chi-square test of independence revealed that laptop classes had no significant advantage over control classes. At the same time, in the 6th grade, laptop students were rated significantly higher than control students on meaningfulness of computer usage. Lowther et al. (2003, p. 33) further looked at specific measures of learning achievement, for example writing and problem solving. Using MANOVA, they reported a highly significant difference between ubiquitous laptop students and control students in the 6th grade. In the area of writing skills, they also found nontrivial program effects favoring laptop students.

Becker (2000) studied students' access to computers at school and at home. He reported that while the number of instructional computers in U.S. schools has risen by millions since 1983, there are wide variations in terms of how these machines are used. Becker (2000) observed that students from higher socioeconomic backgrounds used computers at home at a higher rate than those from low socioeconomic backgrounds. He found, however, that regardless of socioeconomic status, a higher percentage of students used computers for playing games than school work, including doing school assignments or working on educational programs.

Fan and Orey (2001) reported that integrating computers into the curriculum was beneficial to students in Language Arts. While Fan and Orey (2001) found significant differences in pre-test and post-test scores, however, no statistically significant differences were observed between the experimental group and the control group. Jones and Paolucci (1998) performed a meta-analysis of over 800 journal articles to examine whether technology improved student achievement. They concluded that the existing body of evidence failed to support the claim that computers raise student test scores.

In an Australian-based study, Newhouse and Rennie (2001, p. 230) performed a longitudinal study of the use of student owned portable computers in a secondary school. They reported that the impact of computers was inconsistent in the first 2 years. They also noted that students and teachers viewed computers as writing machines rather than flexible educational technology. Newhouse and Rennie (2001) concluded that on the whole computer use was associated with higher career aspirations.

Numerous studies report that the effectiveness of computers in raising student achievement depends on teachers (Barron, Kemker, Harmes, & Kalaydjian, 2003; Garthwait & Weller, 2005; Newhouse, 2001; Norton, McRobbie, & Cooper, 2000). No matter the availability of computer technology, unless teachers incorporate them into the curriculum, students are unlikely to get any beneficial effects (Barron et al., 2003). It has been noted that mathematics teachers have been especially slow to introduce computers into their classroom activities (Norton et al., 2000) even when hardware and software are available (Rosen & Weil, 1995). Although some of the reluctance of teachers to incorporate computers into the curriculum may have to do with lack of expertise (Norton et al., 2000), there are indications that some just prefer traditional teaching practices that are often teacher centered (Hughes & Ooms, 2004).

A report by Angriest and Lavy (2002, p. 737) found no evidence that increased use of computers in schools raise children's test scores. Their results did not support the view that computer use in the classroom improves learning. Angriest and Lavy (2002, p. 760) reported finding consistently negative and marginally significant effects of computer use on 4th grade Mathematics scores. Similar results were observed at higher grade levels. They concluded that computer-aided instruction may not be better or more effective than other teaching methods. They also speculated that technology-oriented instruction (including hardware) may have consumed scarce school resources (p. 760).

The above review shows that the existing body of knowledge with regard to computers and achievement is inconclusive. Given the fact that states and local school districts that decide to incorporate computers into the school curriculum are often faced with the prospect of spending enormous financial resources on the technology, it is crucial that more research be done.

METHODS

Background

The present study was conducted at an elementary school in the Palm Springs Unified School District (PSUSD) in Eastern Riverside County, California.

Neighborhood Characteristics

To describe neighborhood characteristics, the institution's zip code (92264) was utilized. Nearly 65% of students in the sample resided within this zip code. According to the 2000 U.S. Census of Population (U.S. Census Bureau, 2009), the percentage of persons of Hispanic or Latino ethnicity was 18.3%, while the corresponding figure for California was 32.4%, and that of the United States was 12.5%. Non-Hispanic Whites comprised 84.4% of the school area population in 2000, while they made up 59.5% of the California's population, and 75.1% of the U.S. population (U.S. Census Bureau, 2009). The school area population had much smaller percentages of other racial/ethnic groups. For instance, African Americans were 1.4%, American Indians were 0.9%, Asians were 4.4%, Native Hawaiian and Pacific Islanders made 0.1%, and other races were 8.7%. The average household size in the Cielo Vista vicinity was 1.9 persons in 2000. Figures for the state and for the nation were slightly higher (2.87 and 2.59 respectively). The percentage distribution of persons that reported themselves as speaking a language other than English at home was as follows: 23.5% (Cielo Vista), 39.5% (California), and 17.9% (United States). Immigration remains a contentious issue in the United States. In 2000, the Cielo Vista area foreign-born population was 20.2%, a figure that was much higher than the U.S. average (11.1%), but lower than the state average (26.2%) (U.S. Census Bureau, 2009).

With regard to economic characteristics, median household income in the school vicinity was $39,173. Comparable figures for the state and the nation were $47,493 and $41,994 respectively. The percentage of persons below poverty in the zip code encompassing the school was 12.1%. Corresponding figures for the city of Palm Springs (15.1%) and California (14.2%) were both above the U.S. average (12.4%). In terms of educational attainment, the percentage with a Bachelor's degree or higher was 29.5% in the Cielo Vista vicinity. Figures for California and the United States were 26.6% and 24.4% respectively. The labor force participation rate in the Cielo Vista vicinity was 48.2% in 2000. This number was lower for the Palm Springs average (52.4%), the California average (62.4%), and the U.S. average (63.9%).

The School Profile

The school is one of 16 elementary schools within the Palm Springs Unified School District. Enrollment has been on the decline since the 2001-2002 academic year. This decline is conveyed by the data shown in Figure 1. As may be observed,

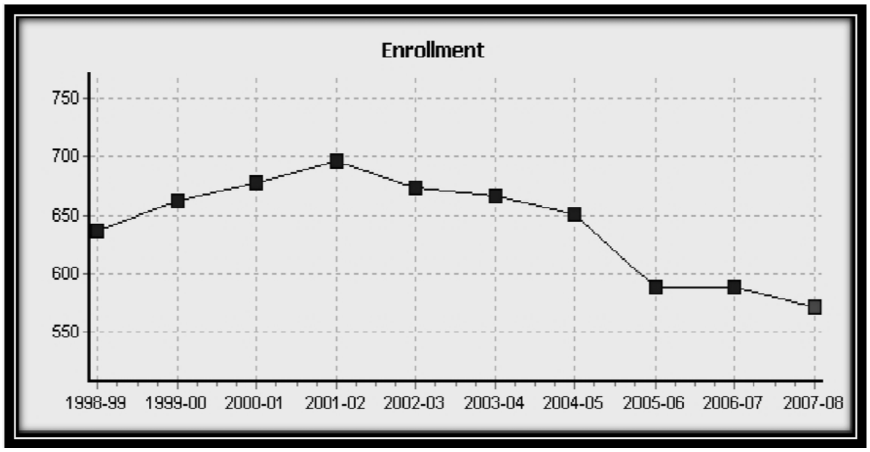

Figure 1. Trends in enrollment, Cielo Vista Elementary School, 1998 to 2008.
Source: CDE, 2009.

the school experienced a steady increase in enrollment from the 1998-1999 school year, followed by a gradual decline. It then experienced a precipitous drop in student enrollment between 2004-2005 and 2005-2006. This period was accompanied first by a stable enrollment until 2006-2007, and then by a slight decline. In the 2007-2008 academic year, student enrollment at Cielo Vista was 565. This represented a drop of over 19.3% from 2001-2002 when enrollment stood at nearly 700.

Average class sizes at the school have fluctuated over the years based on enrollment, state mandates, supply of teachers, and the fiscal impacts of federal, state, and local budgets. As shown in Figure 2, the average school-wide class size was 24 in the 1999-2000 school year. It then dropped to 21 the following academic year, rose all the way to 23 in 2006-2007. By 2007-2008, the class size had declined to 21, a figure that was below the state average (25).

Based on the 2007-2008 school year, the school had 90% fully credentialed teachers. This was relatively close to the state average of 95%. There were 7% emergency credential waiver teachers, compared to the 4% statewide average. The mean teacher experience at the school was 14 years of teaching (state mean = 13 years). The percentage of students participating in free or reduced lunch programs was 76% compared to the state average of 51%. Data show that 44% of students were English language learners (ELLs). The corresponding statewide average was 25% in 2007-2008. What was the home language of English Language Learners? The distribution was as follows: Spanish (93%), Filipino

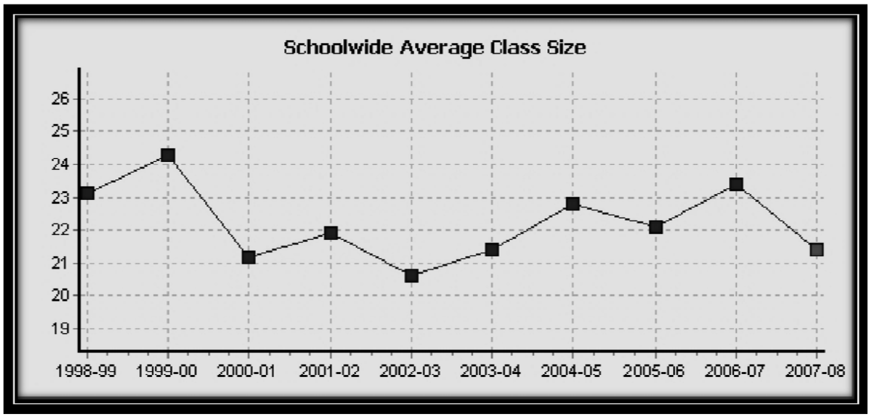

Figure 2. School-wide average class size,
Cielo Vista Elementary School, 1998 to 2008.
Source: CDE, 2009.

(4%), and Illocano (2%). Comparable state figures were 85% (Spanish), 1% (Filipino), and less than 1% (Illocano). Per capita spending per pupil in the Palm Springs Unified School District as a whole was $7,639 in 2007-2008, compared with the statewide average of $10,805 (California Department of Education [CDE], 2009).

The distribution of students at the selected school by race/ethnicity is depicted in Figure 3. As may be observed, 68% of students were of Hispanic/Latino background, 16% were non-Hispanic White, 11% were Filipino, and 4% were African American/Black. Persons of other or multiple races comprised 3%. Comparable state figures were 49% (Hispanic), 29% (non-Hispanic White), 3% (Filipino), 7% (African American/Black), and 5% (other races) (CDE, 2009).

Participants and Research Design

In spring of 2007, laptop computers were donated to the Elementary School for student use, with the intention of launching a 24/7 laptop program the following school year. Over summer 2007, various preparations were made by the Principal, teachers, and staff for initiating this 24/7 Laptop Program. The program would entail students using the machines in an ubiquitous manner (that is, both at home and school). Due to the fact that the number of laptops donated was limited, not all classrooms received them. The selection criteria were based on:

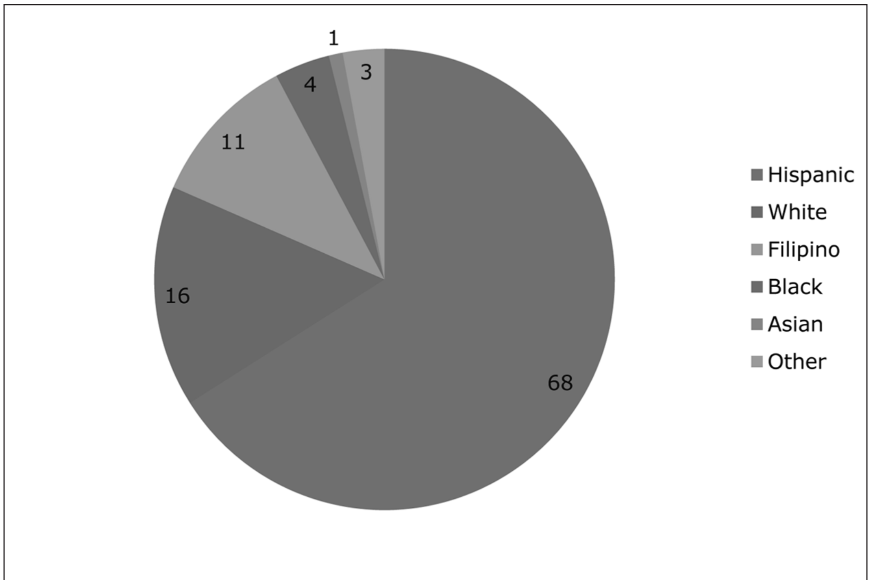

Figure 3. Percentage of racial/ethnic background of Cielo Vista Students, 2007-2008 academic year.
Source: CDE, 2009.

1. teachers' willingness to incorporate the technology into their teaching curriculum; and
2. teachers' willingness to participate in technology training for computer use in the classroom.

Based on these criteria, students in two classrooms (1-4th grade and 1-5th grade), obtained iBook laptops. Over the summer, teachers received 5 days of Apple Training during which they learned all programs that were on the laptops, as well as how to maintain the hardware. Teachers trained with programs such as KidBiz and learned how to compose PowerPoint presentations for classroom instruction. After program inception, teachers continued to receive classroom technology training as part of their professional development. Training is usually held at the school site. Demonstration lessons and instruction on designing curriculum-based classroom lessons using research and websites are also provided. Apart from the Apple training, the school is supplied with a district and Apple coach. Teachers are to employ their acquired knowledge of the technology until they feel they are ready to expand. When this occurs, a coach will provide additional demonstration lessons to introduce new techniques. These coaches are also contacted if a teacher is experiencing difficulties. Thus, demonstration lessons will be provided for further assistance and clarification. Teachers also gather together for peer coaching, during which they share previously mastered techniques with their counterparts.

Participants in the study were students in grades 4 and 5 in the 2007-2008 academic year. Due to the criteria by which laptops had been assigned to classrooms, the present study employed a case-control design of the unmatched type.

Instruments and Data Collection

Data were obtained from two sources. First, information was collected via surveys over a 3 week period in May and June, 2008 using face-to-face interviews. Prior to the interviews, written consent was sought from students and their parent(s) or guardian. The entire study protocol was also presented to and approved by the Human Research Review Board (HRRB) at the University of California, Riverside. In addition, permission letters to conduct the interviews and carry out the study at the school were obtained from the Principal of the institution and the Superintendent of Schools for the Palm Springs Unified School District. Specially trained interviewers were hired to administer the survey instruments in the form of face-to-face interviews. The survey instrument employed was a modified version of that used by Warschauer and Grimes (2005) in their study of a similar program in the Fullerton School District. In all, out of 154 consent forms sent, 143 (92.9%) were returned. Out of the 143 returned, 122 agreed to be interviewed, representing a response rate of 86%. In all, 102 interviews were completed. The discrepancy in the number of interviews versus the actual number of returned consent forms was due to student absences or other school functions (i.e., field trips during the survey period). The second source of data comprised student information obtained from existing school records. Although 20 students were not interviewed for the first source of data, further information on them was available in school records. Moreover, they were easily classified as cases or controls based on their teacher and classroom. Therefore, they were included in the analysis. One participant was deleted from the analysis because he lacked information on the outcome variables. There were 45 cases and 74 controls, reflecting an effective sample size of 119.

Variables and Measures

Dependent Variables

Three outcome variables were used in the analyses, including the California Standards Test (CST) scores for *English/Language Arts*, *Mathematics*, and *Science* for the 2007-2008 academic year. The selection of these dependent variables was based on the prevailing assumption that proficiency in these core content areas is a reliable indicator of successful progression through the various levels in the U.S. education system. The chosen subject areas may also prepare students better for competition at the global level (OECD, 2004). In California, Standardized Testing for Science begins at the 5th grade level. Therefore, when analyses are limited to the 4th grade, there will be only two dependent variables. The dependent variables were measured as overall raw scores and they were obtained from existing school records.

Independent Variables

The primary independent variable in this study was *status*. It was conceptualized in terms of whether a participant received a 24/7 laptop and therefore belonged to the case group, or whether he or she did not receive a 24/7 laptop and therefore belonged to the control group. The variable was measured as a dummy covariate with 1 for cases; the reference group comprised the controls.

All other variables in the analyses were used to assess whether any differentials between cases and controls persist after controlling for the potentially confounding effects of other relevant variables. The first variable controlled was *sex*. It was measured as 1 for females, and males were the reference group. *Parental education* was available in existing school records in an ordinal format, with the following codes: 1 = less than high school, 2 = high school graduate, 3 = some college, 4 = graduate school, 9 = unknown. For the purpose of this article, *parental education* was measured as a series of dummy variables, with 1 for parents with less than high school education, and 1 for those with some college education (including college graduates, graduate school). Parents with high school education constituted the reference group for comparison. The covariate *skill* was conceptualized in terms of ability to, knowledge of, and dexterity at using computers. Students were asked to rate themselves on an ordinal scale ranging from 1 = complete beginner, 2 = beginner, 3 = intermediate, 4 = advanced, and 5 = expert. Students who said they did not know or refused to answer the question were given a score of 8, and those with missing information were coded 9. For the analysis the variable was left in its ordinal form. No respondent scored 8, but 19 had a value of 9. To determine whether their exclusion from the analysis might bias results, a regression model was run whereby the missing cases were included as a covariate category (SKILLMIS = 1). The obtained regression coefficient was not statistically significant ($\beta = 34.34$, $t = 1.35$, $p = .180$), indicating no difference between those in the equation and those outside the model and, therefore, suggesting a reduced likelihood of selection bias in parameter estimates if the 19 missing cases were excluded from the analysis. To improve statistical power, however, the mean on skill level was substituted as the score for those participants with missing information and the 19 cases were kept in all analyses.

The variable *games* was specified in terms of the frequency of playing computer games at home per week. Respondents were asked to indicate how often they used computers to play games at home. Responses ranged from 1 = never, 2 = less than once a week, 3 = weekly, 4 = several times a week, 5 = everyday, for less than 1 hour, 6 = everyday, for more than 1 hour, 8 = don't know/refuse, and 9 = missing. In the statistical analysis, the variable was kept in its ordinal form. However, to determine whether selection bias problems might bedevil the analysis if those with missing information were left out of equations, a dummy variable was created (*GAMEMIS* = 1) and placed in a regression model. The variable was statistically significant ($\beta = -48.82$, $t = -2.12$, $p = .035$) indicating that parameter estimates would be biased if the missing cases were left out of the model. To minimize the problem and also to improve statistical power given the overall relatively small sample size, mean substitution was performed for respondents with missing game playing information. *GATE* refers to the Gifted and Talented Education program. Students are invited to the program based upon their scholastic aptitude. It was specified in the analysis as a dummy variable, with 1 for students in the program, and students not in the program being the omitted category.

Statistical Methods

To assess the association between the response variables and the predictors, bivariate analysis was performed by computing Pearson's correlation coefficients. To estimate the effect of 24/7 laptop use on test scores, multiple regression techniques were applied to the data. Ideally, we would have liked to use hierarchical linear modeling to estimate the effects of neighborhood characteristics on individual student test scores, but with 65% of respondents residing in one zip code, there were not enough cases at level 2 to permit such an analysis.

RESULTS

Descriptive Analysis

Student Use of 24/7 Laptops

The first stage of the analysis was to determine how ubiquitous laptop students used their machines. To investigate student use of technology, analysis was limited to those that had received the 24/7 laptops. Furthermore, both grades (4th and 5th) were combined. Given that in the school environment (within classrooms) there is organized or structured learning and teachers more or less guide students about which activities to engage in during a period, survey questions concentrated more on how students used their laptops outside school, primarily at home. Furthermore, attempts were made to gauge student morale since the program began.

The survey sought to elicit from students the frequency with which they used their laptops for specified activities at home. A typical item was asked as follows: "How often in the week do you use your laptop at home to write papers?" Response categories ranged from (1) Never; (2) Less than once a week; (3) Weekly; (4) Several times a week; (5) Everyday, for less than 1 hour; (6) Everyday, for more than 1 hour; (8) Don't know/refused to answer. To come up with percentage distributions for Figure 4, responses 5 and 6 were combined into "Daily Use" and determined to reflect the highest level of frequency. As shown in the figure, the most popular use of the laptops at home was for browsing the internet (37.8%), followed by writing papers (24.4%), and playing computer games (22.2%).

Attention shifted next to an inquiry into how often students used their laptops to obtain information relevant to selected subject areas. Like before, a typical question was asked as follows: "How often in the week do you use your laptop at home for English/Language Arts?" Response categories were as follows:

1. I do not take this class;
2. Less than an hour each week;
3. 1-2 hours each week;
4. 3-4 hours each week;
5. 5-6 hours each week;
6. 7 or more hours each week;
8. don't know/refused to answer.

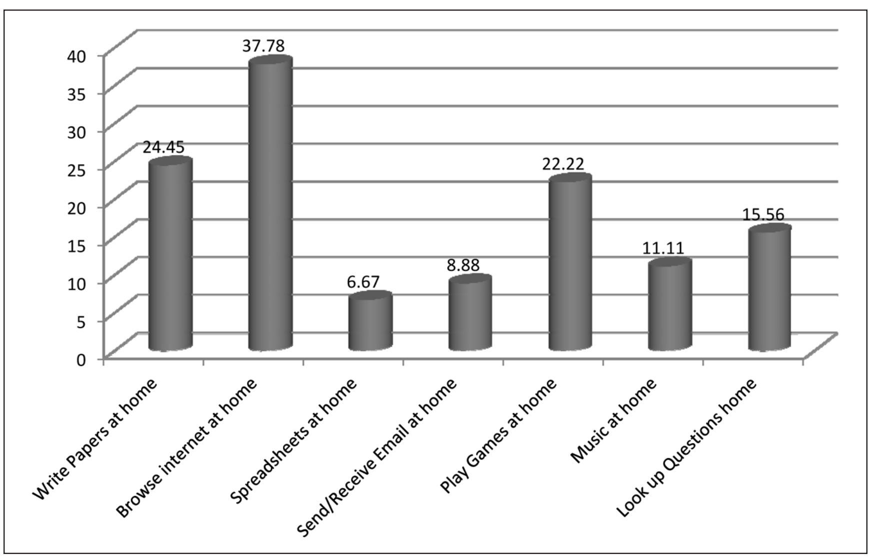

Figure 4. Percent of students reporting using laptop several times per day to perform various activities at home.

In preparing Figure 5, response category 3 (1-2 hours each week) was selected. Results show that the subject area with the greatest laptop usage was Science (35.6%), followed by Mathematics (31.1%), and then English/Language Arts and History, with 26.7% frequency of use in each area.

Finally, efforts were made to determine whether and to what extent the introduction of the laptop program has affected student attitudes and their general academic outlook. To accomplish this, a series of statements were made and students were invited to respond on a Likert-type scale. For instance: "Having a laptop helps me keep organized." Response format was: 1 = strongly disagree, 2 = disagree, 3 = neither agree nor disagree, 4 = agree, 5 = strongly agree, and 8 = don't know/refused to respond. In preparing Figure 6, category 5 (strongly agree) was chosen. As illustrated in Figure 6, the item with the highest percentage (42.2%) of students strongly agreeing was: "School work has been more interesting since the laptop." It was followed closely (40%) by the statement: "Having a laptop helps me keep organized." Next in rank order (37.8%) was the item: "The quality of my school work has improved since I received my laptop." Nearly 35.6% of respondents agreed strongly with the statement that "I understand my school work better when we use laptops." Only a small percentage (2.2%) agreed strongly with the statement: "I prefer to write assignments by hand instead of typing them on my laptop." These findings suggest that, on the whole, the laptops have enhanced student morale and attitude about their school work.

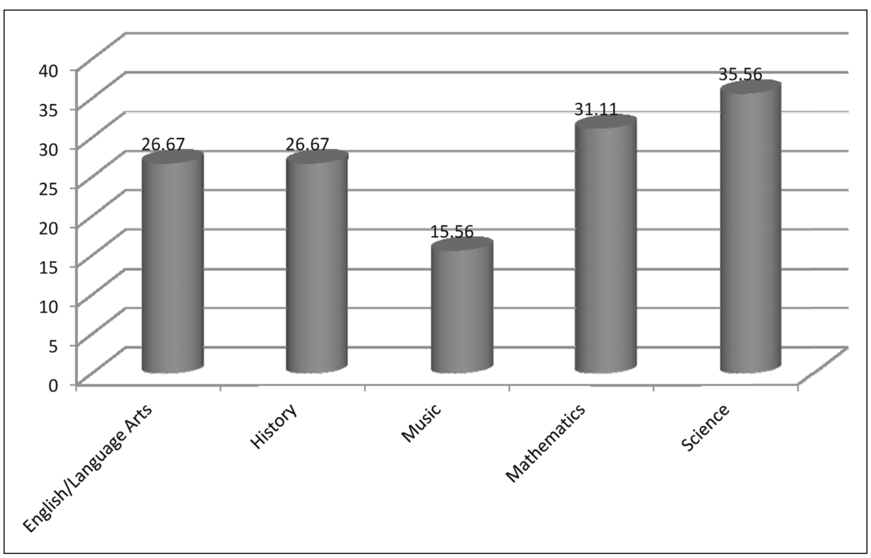

Figure 5. Percent of students reporting using laptop 1-2 hours each week in a subject area.

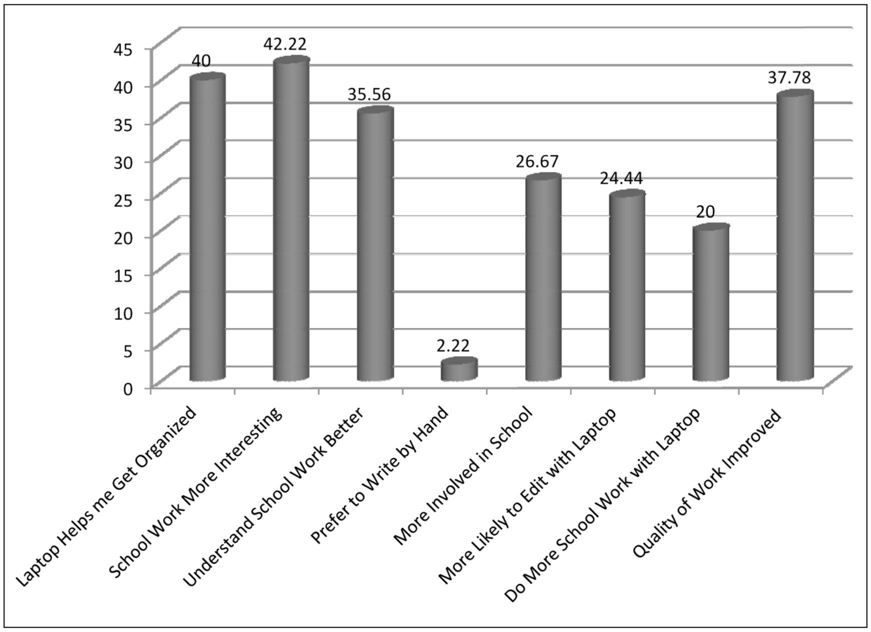

Figure 6. Percent of students agreeing strongly with statements about laptop effect since program inception.

Descriptive statistics of all the variables are shown in Table 1. As may be observed, the overall mean for the sample on English/Language Arts was a little over 359 in 2008. The corresponding figure for Mathematics was 396.4. When the cases for English/Language Arts are compared to the controls, the mean for the cases was 392.7 and that for the controls was 338.5. An independent sample *t*-test assuming equality of variances revealed that the two groups were significantly different ($t = –7.54$, $p = .001$). The findings suggest that students with laptops scored on average 54.13 points higher in English/Language Arts than those without laptops.

In Mathematics the mean score for the case group was 448.1, and comparatively the mean for the controls was 365.1. An independent sample *t*-test assuming equal variances revealed that the two groups were significantly different ($t = –8.10$, $p = .001$). An implication of these findings is that pupils with laptops on average scored 83.03 points higher than their counterparts who did not receive laptops. The sample comprised 55% females and 45% males. Forty-nine percent have parents with less than high school education. Corresponding percentages for high school and some college were both 25%. A little over 14% of the sample was GATE students.

Table 1. Descriptive Statistics of the Variables, 4th and 5th Graders, 2008

Variable	Mean	Standard deviation	Min.	Max.
ELACSTA	359.008	46.100	227	483
MathCSTA	396.453	67.480	234	555
Status (laptop = 1)	0.378	0.486	0	1
Sex (female = 1)	0.554	0.499	0	1
Parental education				
Less high school	0.495	0.502	0	1
High school	0.252	0.436	0	1
Some college	0.252	0.436	0	1
Computer skill	3.126	1.037	1	5
Games	3.285	1.390	1	6
GATE student (yes = 1)	0.142	0.351	0	1
Case group English	392.667	34.982	319	483
Control group English	338.541	39.683	227	410
Case group Math	448.089	56.829	328	555
Control group Math	365.054	52.641	234	488

Note: ELACSTA = California Standards Test (CST) Score for English/Language Arts, 2008; MathCSTA = California Standards Test (CST) Score for Mathematics, 2008; Status = whether student received a laptop (yes = 1); < HS = parents' educational attainment is less than high school; High School = parents' educational attainment is high school; Some College = parents' educational attainment is some college; Computer Skill = Self-reported computer skill level; Games = Frequency of playing computer games at home per week; GATE = whether student is a participant in the Gifted and Talented Education program, 2008.

The next stage of the analysis was to calculate the Pearson's correlation coefficients of the variables and relevant results are shown in Table 2. As may be observed, 24/7 laptop ownership was associated with significantly higher scores in Mathematics ($r = 0.599$, $p = .0001$) and English/Language Arts ($r = 0.572$, $p = .0001$). Female students had higher test scores than male students ($r = 0.250$, $p = .0061$) in English/Language Arts and in Mathematics ($r = 0.211$, $p = .0212$). Students whose parents had less than high school education were associated with significantly lower English/Language Arts scores ($r = -0.272$, $p = .0028$) and significantly lower Mathematics scores ($r = -0.223$, $p = .0146$).

Table 2. Pearson's Product Moment Correlation Coefficients of the Variables, 4th and 5th Graders, 2007-2008 School Year

	ELACSTA	MathCSTA	Status	Sex	< HS	High school	Some college	Comp skill	Games	GATE
ELACSTA	1.000									
MathCSTA	0.688**	1.000								
Status	0.572**	0.599**	1.000							
Sex	0.250**	0.211*	0.071	1.000						
< HS	–0.272**	–0.223**	–0.253**	–0.227**	1.000					
High school	0.002	–0.116	0.026	0.169	–0.576**	1.000				
Some college	0.311**	0.374**	0.266**	0.092	–0.576**	–0.337**	1.000			
Comp skill	0.509**	0.475**	0.558**	0.060	–0.253**	0.060	0.341**	1.000		
Games	–0.090	–0.034	0.039	–0.022	0.038	–0.008	–0.035	0.039	1.000	
GATE	0.387**	0.558**	0.523**	0.027	–0.308**	–0.071	0.426**	0.345**	–0.049	1.000

*Significant at $p < .05$; **significant at $p < .01$.

Note: ELACSTA = California Standards Test (CST) Score for English/Language Arts, 2008; MathCSTA = California Standards Test (CST) Score for Mathematics, 2008; Status = whether student received a laptop (yes = 1); < HS = parents' educational attainment is less than high school; High School = parents' educational attainment is high school; Some College = parents' educational attainment is some college; Computer Skill = Self-reported computer skill level; Games = Frequency of playing computer games at home per week; GATE = whether student is a participant in the Gifted and Talented Education program, 2008.

There was no significant association between students' parental high school education and any other covariate. Pupils from parents with some college education were associated with significantly higher English/Language Arts scores (r = 0.311, p = .0006) and Mathematics (r = 0.374, p = .0001). Students whose parents had some college education were more likely to be in the case group than in the control group (r = 0.266, p = .0035). Higher computer skill level was significantly correlated with English/Language Arts (r = 0.509, p = .0001), Mathematics (r = 0.475, p = .0001), parental education below high school (r = –0.253, p = .0001), and parental collegiate education (r = 0.341, p = .0001). Computer game playing was not significantly associated with any covariate. GATE students were significantly related to higher scores in English/Language Arts (r = 0.387, p = .0001), Mathematics (r = 0.558, p = .0001), and being in the case group (r = 0.523, p = .0001). Students in the GATE program were less likely to come from parents without high school education (r = –0.308, p = .0006). They were, however, more likely to have parents with some college education (r = 0.426, p = .0001) and they also reported having higher computer skill levels (r = 0.345, p = .0001).

Multivariate Analysis

In the multivariate analyses that follow, models on the effect of laptops on student achievement are estimated first for the entire sample combined (4th and 5th graders), then for 4th and 5th graders separately. Relevant regression estimates of the effect of laptops on English/Language Arts are shown in Table 3.

As may be observed, students that got laptop computers scored on average a little over 35 points higher (β = 35.02, t = 3.91, p = .0002) than students without laptops. Female students scored on average 18.83 points higher than male students (β = 18.83, t = 2.80, p = .0060). There was no significant association between parental education and English/Language Arts, but students reporting higher computer skill levels also tended to score significantly higher on English/Language Arts (β = 11.17, t = 2.83, p = .0056). Computer game playing at home had no statistically significant impact on English/Language Arts scores, although the estimated coefficients were in the negative direction. On the whole, the model was able to explain nearly 45% of the variance in English/Language Arts scores (F = [7,112] = 12.76, p = 0.0001).

Parameter estimates showing the effect of 24/7 laptops on student achievement in Mathematics are presented in Table 4. As may be seen, students that received laptops scored on average 45.62 higher than students without laptops (β = 45.62, t = 3.72, p = .0003). Female students scored on average 25.36 points higher than male students (β = 25.36, t = 2.75, p = .0069). Results also show that children whose parents had some college education scored on average 26.6 points higher than students whose parents had only high school education (β = 26.60, t = 2.00, p = .0482).

Table 3. Results of the Multiple Regression Analysis of the Impact of Laptaps on California Standards Test (CST) English/Language Arts Scores, 4th and 5th Graders, 2008

Variable	β	Standardized estimate	*t*-Value	Probability
Status				
Did not get laptop	(Reference)	(Reference)	(Reference)	
Got laptop	35.02**	0.370	3.91	.0002
Sex				
Male	(Reference)	(Reference)	(Reference)	
Female	18.83**	0.204	2.80	.0060
Parental education				
High school graduate	(Reference)	(Reference)	(Reference)	
Less high school	3.35	0.036	0.40	.6870
Some college	10.37	0.098	1.07	.2884
Skill				
Computer skill level	11.17**	0.251	2.83	.0056
Games				
Frequency of computer game playing at home	–3.347	–0.105	–1.47	.1431
GATE				
Not a GATE student	(Reference)	(Reference)	(Reference)	
GATE student	8.55	0.065	0.73	.4651
Intercept	306.32			
F-value	12.76***			
R^2	0.446			
Number of cases	45			
Number of controls	74			
Total observations	119			

*Significant at $p < .10$; **significant at $p < .05$; ***significant at $p < .01$.

Table 4. Results of the Multiple Regression Analysis of the Impact of Laptaps on California Standards Test (CST) Mathematics Scores, 4th and 5th Graders, 2008

Variable	β	Standardized estimate	*t*-Value	Probability
Status				
Did not get laptop	(Reference)	(Reference)	(Reference)	
Got laptop	45.62***	0.329	3.72	.0003
Sex				
Male	(Reference)	(Reference)	(Reference)	
Female	25.36***	0.188	2.75	.0069
Parental education				
High school graduate	(Reference)	(Reference)	(Reference)	
Less high school	20.81*	0.155	1.83	.0697
Some college	26.60**	0.172	2.00	.0482
Skill				
Computer skill level	11.44**	0.176	2.11	.0368
Games				
Frequency of computer game playing at home	–1.70	–0.035	–0.53	.5985
GATE				
Not a GATE student	(Reference)	(Reference)	(Reference)	
GATE student	56.22***	0.293	3.52	.0006
Intercept	309.92			
F-value	16.83***			
R^2	0.515			
Number of cases	45			
Number of controls	74			
Total observations	119			

*Significant at $p < .10$; **significant at $p < .05$; ***significant at $p < .01$.

In general the higher the self-reported skill level, the higher the test score (β = 11.44, t = 2.11, p = .0368). Computer game playing had no effect on Mathematics scores, although the regression estimate was in the negative direction. Students in the GATE program had elevated test scores compared to those not in the program (β = 56.22, t = 3.52, p = .0006). The model was able to explain nearly 52% of the variance in Mathematics test scores (F = [7,112] = 16.83, p = 0.0001).

The remainder of the analyses concentrates on the influence of laptops on achievement in grades 4 and 5 separately. Relevant multiple regression results of the effect of ubiquitous laptops on standardized scores in English Language/Arts in Grade 4 are shown in Table 5. As may be seen in the table, students that had 24/7l laptops scored significantly higher in English/Language Arts than those without laptops (β = 42.94, t = 3.22, p = .0024). Students reporting higher computer skill levels experienced higher test score returns on average (β = 14.48, t = 2.41, p = .0199). Parental education had no statistically significant effect on English Language/Arts scores. Similarly, the parameter estimates for frequency of playing computer games at home and belonging to the GATE program did not reach statistical significance by conventional criteria. The model explained nearly 49% of the variation in English/Language Arts scores.

Results showing the effect of laptops on standardized Mathematics scores for 4th graders are presented in Table 6. Laptop students scored on average 53.4 points higher than students without laptops (β = 53.40, t = 3.29, p = .0019). Parental education, computer skill level, and computer game playing frequency all had no significant effect on test scores. Students in the GATE program scored on average 56.22 points higher in Mathematics than non-GATE students (β = 56.22, t = 2.29, p < .0268). A little over 47% of the variance in Mathematics scores was explained by the relevant independent variables.

Results of the impact of 24/7 laptops on English/Language Arts scores among 5th graders are shown in Table 7. As may be observed from the table, 5th graders with ubiquitous laptops scored on average 26.04 points higher than students without laptops (β = 26.04, t = 2.25, p = .0286). Female students scored significantly higher than male students in English/Language Arts (β = 23.35, t = 2.67, p = .0098). Parental education, computer skill level, home computer game playing and belonging to the GATE program had no significant influence on 5th grade English/Language Arts scores. Nearly 48% of the variance in the response variable was explained by the model (F = [7, 58] = 7.47, p = 0.0001).

Relevant regression results of the effect of laptops on 5th grade Mathematics scores are shown in Table 8. Students with 24/7 laptops had much elevated test scores than their counterparts without laptops (β = 63.15, t = 3.40, p = .0012). More precisely laptop students had 63.15 points higher on average in their test scores than non-laptop students. Respondents whose parents had less than high school education scored a little over 41 points higher on average than those whose parents who had high school education (β = 41.03, t = 2.37, p = .0210).

Table 5. Results of the Multiple Regression Analysis of the Impact of Laptaps on California Standards Test (CST) English/Language Arts Scores, 4th Graders, 2008

Variable	β	Standardized estimate	*t*-Value	Probability
Status				
Did not get laptop	(Reference)	(Reference)	(Reference)	
Got laptop	42.94***	0.428	3.22	.0024
Sex				
Male	(Reference)	(Reference)	(Reference)	
Female	18.53*	0.189	1.74	.0890
Parental education				
High school graduate	(Reference)	(Reference)	(Reference)	
Less high school	6.09	0.062	0.47	.6417
Some college	8.79	0.074	0.59	.5558
Skill				
Computer skill level	14.48***	0.313	2.41	.0199
Games				
Frequency of computer game playing at home	–4.94	–0.129	–1.18	.2429
GATE				
Not a GATE student	(Reference)	(Reference)	(Reference)	
GATE student	14.97	0.088	0.74	.4629
Intercept	305.08			
F-value	6.39***			
R^2	0.488			
Number of cases	20			
Number of controls	34			
Total observations	54			

*Significant at $p < .10$; **significant at $p < .05$; ***significant at $p < .01$.

Table 6. Results of the Multiple Regression Analysis of the Impact of Laptaps on California Standards Test (CST) Mathematics Scores, 4th Graders, 2008

Variable	β	Standardized estimate	*t*-Value	Probability
Status				
Did not get laptop	(Reference)	(Reference)	(Reference)	
Got laptop	53.40***	0.444	3.29	.0019
Sex				
Male	(Reference)	(Reference)	(Reference)	
Female	24.42*	0.209	1.88	.0660
Parental education				
High school graduate	(Reference)	(Reference)	(Reference)	
Less high school	–3.67	–0.031	–0.23	.8174
Some college	1.14	0.008	0.06	.9499
Skill				
Computer skill level	5.94	0.107	0.81	.4203
Games				
Frequency of computer game playing at home	0.49	0.011	0.10	.9240
GATE				
Not a GATE student	(Reference)	(Reference)	(Reference)	
GATE student	56.22**	0.277	2.29	.0268
Intercept	328.34			
F-value	6.00***			
R^2	0.472			
Number of cases	20			
Number of controls	34			
Total observations	54			

*Significant at $p < .10$; **significant at $p < .05$; ***significant at $p < .01$.

Table 7. Results of the Multiple Regression Analysis of the Impact of Laptaps on California Standards Test (CST) English/Language Arts Scores, 5th Graders, 2008

Variable	β	Standardized estimate	*t*-Value	Probability
Status				
Did not get laptop	(Reference)	(Reference)	(Reference)	
Got laptop	26.04**	0.299	2.25	.0286
Sex				
Male	(Reference)	(Reference)	(Reference)	
Female	23.35***	0.272	2.67	.0098
Parental education				
High school graduate	(Reference)	(Reference)	(Reference)	
Less high school	7.69	0.091	0.71	.4792
Some college	17.39	0.183	1.28	.2054
Skill				
Computer skill level	8.08	0.196	1.62	.1100
Games				
Frequency of computer game playing at home	–2.46	–0.085	–0.89	.3792
GATE				
Not a GATE student	(Reference)	(Reference)	(Reference)	
GATE student	12.04	0.110	0.77	.4466
Intercept	302.4			
F-value	7.47***			
R^2	0.479			
Number of cases	25			
Number of controls	40			
Total observations	65			

*Significant at $p < .10$; **significant at $p < .05$; ***significant at $p < .01$.

Table 8. Results of the Multiple Regression Analysis of the Impact of Laptaps on California Standards Test (CST) Mathematics Scores, 5th Graders, 2008

Variable	β	Standardized estimate	*t*-Value	Probability
Status				
Did not get laptop	(Reference)	(Reference)	(Reference)	
Got laptop	63.15***	0.420	3.40	.0012
Sex				
Male	(Reference)	(Reference)	(Reference)	
Female	21.16	0.143	1.51	.1359
Parental education				
High school graduate	(Reference)	(Reference)	(Reference)	
Less high school	41.03**	0.280	2.37	.0210
Some college	56.87***	0.348	2.62	.0113
Skill				
Computer skill level	4.73	0.067	0.59	.5556
Games				
Frequency of computer game playing at home	–3.15	–0.063	–0.71	.4825
GATE				
Not a GATE student	(Reference)	(Reference)	(Reference)	
GATE student	33.38	0.177	1.33	.1898
Intercept	325.48			
F-value	9.96***			
R^2	0.550			
Number of cases	25			
Number of controls	40			
Total observations	65			

*Significant at $p < .10$; **significant at $p < .05$; ***significant at $p < .01$.

Likewise, pupils whose parents had some college education scored 56.87 points higher on average than their counterparts whose parents had only high school education ($\beta = 56.87$, $t = 2.62$, $p = .0113$). Home computer game playing and being a GATE student had no significant influence on standardized Mathematics scores in the 5th grade. Overall, the model explained 55% of the variance in Mathematics scores ($F = [7, 64] = 9.96$, $p = 0.0001$).

The multivariate results of the impact of laptops on standardized Science scores for the 5th grade are presented in Table 9. As seen in the table, students that had one-to-one laptops scored over 46 points higher on average than those without such laptops ($\beta = 46.74$, $t = 3.36$, $p = .0014$). No other variable in the model reached statistical significance using conventional criteria. The proportion of variance explained by the equation was nearly 56% ($F = [7, 57] = 10.19$, $p = 0.0001$).

DISCUSSION

The primary objective of this study was to examine the impact of ubiquitous (1:1) laptop computers on student academic achievement. Results of data analyses show evidence to suggest that provision of 24/7 laptops to students contributes significantly to achievement as measured by standardized scores. In the entire sample studied, that included both 4th and 5th graders, students that had ubiquitous laptops scored higher in English/Language Arts than their counterparts without laptop computers. Likewise, students with ubiquitous laptops had higher scores in Mathematics than those without 24/7 laptops. More importantly, the effects of laptops persisted even after controlling for the potentially confounding effects of variables such as sex and parental educational background.

When the sample was stratified by grade level, it was observed that in the 4th grade laptop computer ownership elevated scores in English/Language Arts and Mathematics. A similar result was found when analysis was limited to 5th graders. Among that group, test score in English/Language Arts were raised by laptop ownership; however, the disparity in scores between laptop students and non-laptop students was even more dramatic in Mathematics. Analysis further showed a significant difference between laptop and non-laptop students in Science scores in the 5th grade.

A key question to ask is: How or why might ubiquitous laptops elevate student scores? One explanation is that if the laptops are included in the curriculum, students may not only learn what is taught in the classroom, but over time they may look up information faster and in the process learn to take initiatives. It may well be that students with laptops develop better attitudes toward learning and the subject matter (Wong, 2001). In addition, access to computers has been shown to raise student self-esteem (Page, 2002) and to promote higher career aspirations (Newhouse & Rennie, 2001).

Table 9. Results of the Multiple Regression Analysis of the Impact of Laptaps on California Standards Test (CST) Science Scores, 5th Graders, 2008

Variable	β	Standardized estimate	*t*-Value	Probability
Status				
Did not get laptop	(Reference)	(Reference)	(Reference)	
Got laptop	46.74***	0.413	3.36	.0014
Sex				
Male	(Reference)	(Reference)	(Reference)	
Female	16.34	0.147	1.56	.1240
Parental education				
High school graduate	(Reference)	(Reference)	(Reference)	
Less high school	15.15	0.137	1.17	.2462
Some college	18.94	0.154	1.16	.2490
Skill				
Computer skill level	9.24	0.173	1.55	.1271
Games				
Frequency of computer game playing at home	0.40	0.011	0.12	.9041
GATE				
Not a GATE student	(Reference)	(Reference)	(Reference)	
GATE student	29.43	0.207	1.56	.1235
Intercept	282.81			
F-value	10.19***			
R^2	0.556			
Number of cases	25			
Number of controls	40			
Total observations	65			

*Significant at $p < .10$; **significant at $p < .05$; ***significant at $p < .01$.

Some analysts contend, however, that the use of computers may hinder learning or serve as a diversion (Angriest & Lavy, 2002; Bielefeldt, 2005; Lei, Conway, & Zhao, 2008). One path to hindrance noted by some observers is the likely use of computers by students on non-curricular related matters, such as playing video/computer games, sending e-mail, visiting chat rooms, surfing the internet for fun, and so on (Angriest & Lavy, 2002; Bielefeldt, 2005; Lei & Zhao, 2007). The present study, however, found no evidence of computers being distractions in relation to achievement indicators. For example, frequency of playing computer games at home was not significant in any equation. Furthermore, laptop use showed a consistent and statistically strong effect on student scores. Ultimately, one policy implication arising out of this study to address the concern about student use of computers as a diversion is better teacher training and more efficient student use of computers for obtaining academic related information, completing assignments, etc. If positive results are forthcoming, then there is less likelihood of detrimental consequences stemming from student use of laptops on extra-curricular affairs.

Results presented here are at variance with those reported by Angriest and Lavy (2002). In their study, computers had negative effects on student test scores in 4th grade Mathematics. It should be noted, though, that the Angriest and Lavy (2002) study was based on classroom computers, and its findings may not be comparable to studies on ubiquitous laptops. Results are consistent with those of Dunleavy and Heinecke's (2007), which found access to laptops at school having a positive effect on science learning. However, results here are inconsistent with their findings that laptops had no impact on Mathematics achievement.

A further pathway that computers may aid in raising students' overall achievement is that they have the potential to help students acquire problem-solving skills, communicate better, and conduct research through looking up information. Indeed, Barron et al. (2003, p. 501) found in their study of technology investigation in K-12 schools that computer integration and its use as a problem-solving tool was statistically significant. The same result held for the association between computers and their use as a research tool. Their utilization for communication and productivity, however, was not statistically significant.

There are limitations to the study that need to be pointed out. The first is that analyses have been undertaken using only one school site in a relatively large school district. It would be inappropriate to generalize results to other schools, especially those outside the state of California. The second limitation is that the research did not control for all possible sources of distraction in terms of how students use laptops. Although the impact of computer game playing at home was not statistically significant, the sign of the coefficient was negative in most models. Therefore, the distraction argument advanced by some analysts should not be completely dismissed. Indeed, Lei and Zhao (2007, p. 290) found that

58% of students in their sample reported using computers to surf online for fun. A further 48% used the machines to play computer games. Despite the above caveats, results from this study suggest that public policies aimed at increasing ubiquitous laptop use in elementary schools have the potential to raise student academic achievement.

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