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DIGITAL WRITING AND DIVERSITY: THE EFFECTS OF SCHOOL LAPTOP PROGRAMS ON LITERACY PROCESSES AND OUTCOMES*

BINBIN ZHENG
MARK WARSCHAUER
GEORGE FARKAS
University of California, Irvine

ABSTRACT

Over the last decade, the number of one-to-one laptop programs in U.S. schools has steadily increased. Though technology advocates believe that such programs can assist student writing, there has been little systematic evidence for this claim, and even less focused on technology use by at-risk learners. This study examined the effect of daily access to laptops on the writing outcomes and processes of 2,158 upper elementary students in two school districts, and the effect among diverse students. In a California district, students showed improved English language arts achievement in both a partial laptop program year and a full laptop program year. In a Colorado district, overall writing test score gains were not statistically significant; however in both districts, at-risk student groups (i.e., Hispanics and low-income learners) showed significant gains. In addition, survey results, interviews, and observations indicate that at-risk learners used the laptops more frequently than their counterparts at school for a variety of learning purposes. This study suggests that well-planned use of laptops and digital media can help diverse learners improve their literacy processes and outcomes.

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In recent years, a growing number of U.S. schools have adopted one-to-one laptop programs, in which all the students in a class, grade level, school, or district are provided individual laptop computers for use throughout the school day (Warschauer, 2006). A key goal of many of these programs is to increase educational and social equity by providing technology-intensive instruction to students who may lack access to digital media outside of school. In addition, a major use of laptops is for literacy activities, and there is the hope among some educators that focused instruction with laptops can help learners improve their writing (see discussion in Warschauer, 2011). The declining cost of laptops and the increasing availability of free or low-cost open source software mean that the appeal of one-to-one programs will likely continue to grow. Yet while many educators have shown an interest in implementing such programs, they are often reluctant to invest in them without better evidence of their benefits (see discussion in Lei & Zhao, 2008). There has as yet been little systematic research on the impact of laptop programs on the literacy achievement of diverse students, with most prior studies of one-to-one programs either lacking rigor or involving very small implementations (see discussion in Penuel, 2006).

This article analyzes the impact of upper elementary students' individual use of netbook computers on their writing processes and outcomes in two medium-sized school districts that implemented technology-intensive writing curricula. Our study examines the overall effects of the programs on writing and literacy achievement as well as the particular impact on the major groups of at-risk learners in the two districts, which include Hispanics, students from low-income families, and English language learners.

Prior Research

To contextualize our study, we briefly review several strains of prior research related to laptops and literacy. First, we examine the use of digital media for writing, particularly in relationship to the ways that such media are used in these districts. Next we review research on laptop programs and literacy processes and outcomes. Finally, we summarize research on technology and learning among at-risk students.

Digital Media and Writing

The development and diffusion of computers and the Internet have impacted writing in different forms and genres and for different purposes both inside and outside the classroom (Warschauer, 2007; Black, 2008). Studies of these changes can be traced back to the 1980s. Kulik (2003) reviewed 12 controlled studies and meta-analyses published since 1990 on the effects of technology use on student writing, focusing on word processing (with and without the use of assigned prompts) and what he describes as computer enrichment for writing (based on games, simulations, tutorials, and online resources). Overall, he found a mixed but

generally positive effect of word processing on writing, and suggested that the use of writing prompts could amplify the benefits of ordinary word processing. Examination of computer enrichment activities also suggested mixed effects, with later studies tending towards more positive outcomes than earlier ones.

In the districts investigated in this study, the major uses of digital tools for writing involved social media and automated writing evaluation (AWE). We briefly summarize research in each of these areas.

Social Media and Writing

Many students are actively engaged in using social media to support writing outside of school, such as blogs, wikis, and online communities; however, a disconnect exists between students' out-of-school and in-school literacy practices (see, e.g., Harklau & Pinnow, 2009; Weinstein, 2002). Research conducted in out-of-school settings suggests that the use of social media can be highly effective for developing young writers as they can take advantage of online tools to sharpen their message in response to comments and feedback from others and build their identity as authentic writers (Black, 2008; Lam, 2000). These benefits of out-of-school online writing may be especially important for English language learners (ELLs), who often disengage from classroom activities. An example of this is provided by Lam (2000), who investigated a Chinese immigrant who, while disaffected from school, honed his English writing skills through his multilingual website and e-mail interactions. Similarly, Black (2008) explored how young English learners' participation in the online forum *fanfiction.net* developed their online identity as popular, multi-literate writers. Both of these studies illustrate that online environments provide an opportunity for writing in diverse genres and make possible a process of meaning making and identity development beyond the constraints of geography, language, and culture.

There has been little published research on the use of social media for writing development among K-12 students in school settings. A few studies on the topic have been carried out among adult learners. For example, Sun and Chang (2012) examined seven graduate students' writing on blogs in an academic writing class. The study suggested that the interactive and collaborative features of blogs provide a means for students to scaffold each other in their writing and in building their academic identity. Bloch (2007) provides a case study of an adult immigrant English learner who made use of blogs to transition from spoken discourse to academic writing. Most generally, published studies on social media use in K-12 settings have focused on the ways that such media may increase students' understanding of, and critical thinking about, written texts (e.g., Carico & Logan, 2004; Grisham & Wolsey, 2006).

Despite these potential advantages, many educators are hesitant to use social media in instruction. The impact of social media use on standardized writing outcomes has not been investigated, and many teachers either lack sufficient hardware

to engage students in online writing or fear that such writing will expose them to distractions or even danger (see discussion in Alliance for Childhood, 2004).

Automated Writing Evaluation

A major disincentive to writing instruction in the K-12 classroom is the large amount of time and effort required to provide feedback on papers. Automated Writing Evaluation (AWE) programs promise to help ease this burden by off-loading some of the assessment responsibility to software rather than teachers. Such software can provide nearly instantaneous computer-based scoring and feedback to students (for an overview, see Warschauer & Ware, 2006). Much of the prior research on AWE investigates its psychometric properties (e.g., Cohen, Ben-Simon, & Hovav, 2003; Wang & Brown, 2007) or its use with university students. There have been relatively few studies of its use in K-12 classrooms. One study conducted by Shermis, Burstein, and Bliss (2004) investigated the use of *Criterion*, an AWE software, on students' writing development, by randomly assigning 1,000 high school students to either a treatment group using Criterion, or a control group that did not use the software for writing assignments. This study found no significant difference between these two groups on a state writing exam, although treatment students did show a significant increase in average essay length as well as a reduction in mechanical errors such as spelling, capitalization, punctuation, and grammar. Although some research suggests that automated scoring engines are flawed for evaluating classroom writing (Chen & Cheng, 2008), studies by Grimes and Warschauer (2008, 2010) find that such software may assist teachers to manage large classes by keeping learners positively engaged. However, with relatively little research on the use of AWE in K-12 classrooms, it is too early to draw firm conclusions as to its benefits or drawbacks.

Laptop Programs and Literacy

One-to-one laptop programs have been adopted in North American schools since the development of Microsoft's Anytime Anywhere Learning Program in the mid-1990s (see discussion in Johnstone, 2003), and have grown steadily over the years. The Maine Learning Technology Initiative (MLTI) launched a one-to-one laptop initiative in fall 2002, which made Maine the first state to use technology in an attempt to transform and improve teaching and learning in classrooms statewide. The MLTI provided all seventh and eighth grade students and teachers with laptops; technical support and professional development were also provided for teachers to integrate the technology into curriculum and instruction (Silvernail & Lane, 2004). Though no other state provides laptops to all students in particular grades, other relevant statewide initiatives include Michigan's Freedom to Learn (FTL) program, Texas's Technology Immersion Pilot (TIP) program, Florida's Enhancing Education through Technology (EETT) program, and Pennsylvania's Classroom for the Future (CFF) program. Individual

school districts, including Birmingham, Alabama (see discussion in Warschauer, 2011), have also launched one-to-one programs. With the Birmingham program as an important exception, most of these programs emphasize new forms of curriculum and pedagogy, and a number are directly tied to writing-based curricular reform (for an example, see Jeroski, 2008).

A number of studies have looked at the relationship between one-to-one laptop programs and writing processes. Several surveys suggest that writing and editing is the principle use of laptops in one-to-one classrooms (see, e.g., Suhr, Hernandez, Warschauer, & Grimes, 2010). Another consistent finding, demonstrated by surveys (e.g., Bebell & Kay, 2009), interviews and observations (e.g., Russell, Bebell, & Higgins, 2004) is that students write more in classes where all students have individual computers. For example, in an observation study involving timed measurements, Russell, Bebell, and Higgins (2004) found that students in one-to-one laptop programs composed text on either laptop or paper an average of 1.99 instances per 10-minute observation, while students in shared laptop classrooms composed texts in either medium an average of 0.26 instances per observation. Surveys, interviews, and observations have also demonstrated that in laptop classrooms students receive more feedback on their writing, edit their papers more, draw on a wider range of resources to write, and publish or share their work with others more often (e.g., Grimes & Warschauer, 2008; Bebell & Kay, 2009; Hill, Reeves, Grant, & Wang, 2002; Lei & Zhao, 2008). For all these reasons, both teachers and students have been found to have positive attitudes about laptops in the writing class (e.g., Suhr et al., 2010; Bebell & Kay, 2009; Ross, Lowther, Relyea, Wang, & Morrison, 2003), indicating that one-to-one laptop programs provide a favorable environment for student writing processes.

In addition to examining writing processes, a few studies have also examined the use of laptops on writing outcomes, but these are mostly unpublished evaluation reports (e.g., Jeroski, 2008; Ross et al., 2003; Shapley, Sheehan, Maloney, & Caranikas-Walker, 2008; Silvernail & Gritter, 2007) or studies of relatively small interventions (e.g., Grimes & Warschauer, 2008; Suhr et al., 2010). Three of these studies have found a small statistically significant positive impact on writing or broader literacy outcomes, in each case after the second year of implementation (Grimes & Warschauer, 2008; Shapley et al., 2008; Suhr et al., 2010). Other studies offer only descriptive evidence of writing improvement (see, e.g., Jeroski, 2008), sometimes with weak evidence using uncertain methodology (see, e.g., Silvernail & Gritter, 2007). The limited number of rigorous studies and peer-reviewed articles leaves the impact of one-to-one laptop programs on student writing outcomes inconclusive.

Technology and Diverse Learners

One rationale for many educational technology programs is to reduce educational inequity by providing access to digital resources that is lacking in

low-income homes (Culp, Honey, & Mandinach, 2005). However, research suggests that these positive goals are not typically achieved. For example, Wenglinsky (2005) analyzed 3 years of data from the National Assessment of Educational Progress (NAEP), finding that students' socio-economic status (SES) was the strongest single factor predicting whether technology use would be positively or negatively associated with increased test scores, with lower SES students achieving the least benefit from technology use. Bebell and Kay (2010) found that eighth grade students who reported more frequent use of computers for recreation at home tend to have higher ELA achievement; however, the positive effect diminishes greatly after controlling for students' SES. Similarly, a range of studies on home access to computers conclude that any benefits such access brings for academic achievement occur disproportionately among higher SES students (for a review, see Warschauer & Matuchniak, 2010).

Few studies of school laptop use have examined the impact of this instructional technology on at-risk learners. In a qualitative study of ten schools where laptops had been introduced, Warschauer (2006) found that the implementation of a laptop program was more challenging in low SES schools, although there were no quantitative comparisons. Two studies of the One Laptop per Child program in Latin America reported greater benefits for more cognitively advanced learners, based on observations of children's technology use in Paraguay (see discussion in Warschauer & Ames, 2010) and on a quantitative analysis of pre-post scores on a cognitive skill measure in Peru (Severin, Santiago, Cristia, Ibarraran, Thompson, & Cueto, 2011). Laptop programs in Texas middle schools have been found to raise the technology skills of economically disadvantaged learners, but the skills of economically advantaged learners improved as well, with no indication of which group of students improved more in technological proficiency (Shapley et al., 2008).

In summary, there is little evidence that school technology or laptop programs narrow the gap between at-risk students and their non-at-risk peers. Additionally, none of the studies on technology and diversity have examined the use of laptops in carefully tailored curricular interventions that are designed to improve literacy outcomes among diverse learners. We undertook this study to investigate the impact of two district-wide laptop programs that were specifically designed to support the type of writing-intensive curriculum believed to be beneficial for at-risk elementary school students.

METHODS

Drawing on a range of quantitative and qualitative data, this study investigated the effect of one-to-one laptop programs that were implemented in each of two school districts for fourth and fifth grade writing. Three research questions were addressed:

1. What is the effect of one-to-one laptop programs on student writing outcomes?
2. How does the effect vary among students in different demographic groups?
3. What is the effect of one-to-one laptop programs on student writing processes?

Sample and Context

This study was part of a broader national study of the use of netbooks and open source software in K-12 schools. Two districts, in California and Colorado respectively, were chosen for this analysis because in each district the focus of technology implementation was on improving writing. The Colorado school district also used netbooks in secondary schools; however, in this article we only analyzed data for the elementary grades, both for consistency across the two districts, and because elementary students had netbook access throughout the day, while secondary students' access was limited to 50 minutes per day. Thus, fourth grade students in the California school district and fifth grade students in the Colorado school district were selected for the purpose of this study, as these were the upper elementary grade levels that implemented the program in these two districts.

A federal grant for Enhancing Education Through Technology (EETT) was used to introduce the laptop program in the California school district in January 2008. This program, Student Writing Achievement Through Technology Enhanced Collaboration (SWATTEC), focuses on writing as a mechanism to improve academic achievement. The program emphasizes the *six traits writing approach* that focuses on students' ideas, organization, voice, word choice, sentence fluency, and conventions (Spandel, 2009). Low-cost Asus netbooks were provided for all fourth grade students during school time, and the district has developed a customized installation of the Linux Ubuntu operating system, with a total of 59 free software applications to support students' creativity and learning. Two district-wide online learning communities, created by using the open source social networking engine ELGG, were implemented, one for teachers and one for students. The resulting online communities provide a platform for sharing and contributing blog postings, comments, files, podcasts, slide presentations, and other media. In the first 18 months of the program, an AWE program, MY Access! (Vantage Learning, 2011), was also provided for all students in the program. Professional development was provided to teachers as part of the SWATTEC program. This included about 40 hours per year for all teachers in the program, with one teacher at each school selected to serve as a coach/mentor for the other teachers, and provided an additional 40 hours of training per year.

We analyzed test score data in the district every school year from 2007-2008 to 2009-2010. During this period, netbooks were available to fourth grade students for about half of the 2008-2009 school year and all of the 2009-2010 school year. Consequently we analyzed achievement data for:

1. 1,328 fourth grade students with scores for spring of third and fourth grade prior to the laptop program (2007-2008);
2. 1,228 fourth grade students with scores for spring of third and fourth grade during the partial program year (2008-2009); and
3. 1,158 fourth grade students with scores for spring of third and fourth grade during the full program year (2009-2010), for a total of 3,714 students.

The Colorado school district used Lucy Calkins's (1994) Writer's Workshop model to implement a district-wide writing curriculum. This model focuses on writing for an authentic purpose and audience. To support this curriculum, a laptop initiative, called *Inspired Writing*, was implemented among all fifth grade classes, sixth grade reading classes, and ninth grade language arts classes in the 2009-2010 school year. Each student involved was provided with an Asus Eee netbook for use throughout the school day, using the open source Linux operating system and, for the most part, open source software. Netbooks and social media such as blogs and wikis were substantively used in these schools to support their authentic writing. Teachers involved in this laptop program participated in a week-long training on the hardware, software, and especially technology integration into the curriculum.

The test score achievement of 1,000 fifth grade students participating in this program was statistically examined in this study. Additionally, two schools in each district were selected for observations and interviews.

Sources of Data

Test Score Data

Statewide California Standard Test (CST) English Language Arts (ELA) scores for all third and fourth graders were collected in the California district for 2007-2008, 2008-2009, and 2009-2010 school years. In the Colorado district, we collected statewide Colorado Student Assessment Program (CSAP) writing scores for third, fourth, and fifth grade students in 2007-2008, 2008-2009, and 2009-2010 school years.

Teacher and Student Surveys

Teachers and students in both school districts completed online surveys. These queried basic demographic information, self-perceived computer skills, frequency of student laptop use for particular tasks and activities (including specific use of different technologies), how students' study habits or attitudes changed since receiving laptops, how teaching with laptops compared with previous teaching without them, and overall evaluation of the laptop program. A total of 1,589 students, including 914 students in the California school district (a response rate of 78.9%) and 675 students in the Colorado school district (a response rate of 67.5%), responded to the survey. In addition, 40 teachers in the California district

and 33 teachers in the Colorado district (a response rate of 100% in each district), responded to the teacher survey.

Observations

Observations were conducted in two focal schools in each district, chosen to be demographically representative of the district, for a total of 50 hours. Observations focused on methods of writing instruction, use of digital media in writing, and teacher and student experiences with the technology used.

Interviews

Semi-structured group and individual interviews were conducted with a total of 60 teachers, staff, students, and district officials in the two school districts. Individual and group interviews were carried out with the teachers and staff at the four focal schools and with other teachers and staff who attended district-wide training sessions. Group interviews with students took place at the four focal schools, with participants selected by teachers to represent diverse student experiences in demographic background, academic achievement, and attitudes toward technology. Interviews focused on how teachers and students used the tools involved and their perceptions of the contribution of technology to the learning process. Interviews ranged from 15 to 45 minutes and were all digitally recorded and transcribed.

Documents

Documents collected in this study included teacher-created lesson plans, rubrics, online materials, and blog posts written by students.

Measurement

Writing Achievement

In the California school district, there is no test involving response to a writing prompt given to students in all elementary grades every year. A writing prompt test was given to fourth grade students only up until the 2009-2010 school year and then discontinued. Though we could use this test to examine changes in fourth grade writing achievement from the non-laptop year of the study to the partial-laptop year of the study, we could not use this test to examine writing changes from third to fourth grade during the full course of program implementation. As a proxy, we used the California Standards Test English Language Arts (CST ELA) exam, which is given to all students from second grade on in California every spring and includes a variety of questions related to reading, writing, and language. CST ELA scores were collected for third and fourth grade students in all years from 2007 to 2010.

In the Colorado school district, the CSAP writing test scale score was used for this study. CSAP is Colorado's state standards-based assessment. The writing test asks students to write essays on the basis of a given writing prompt. For example, the fifth grade writing prompt in 2008 was the following: "Growing up involves taking on added responsibilities. Write a paragraph to tell about one responsibility that you have in your life." According to the CSAP Technical Report (Colorado Department of Education, 2010), Cronbach's alpha of the state level writing assessment is 0.91, indicating that the CSAP writing test produces relatively stable scores.

The definitions of student characteristic variables used in this study draw directly from the language provided by the Colorado Department of Education (2011), as follows:

English Language Learner (ELL): ELL is defined as students who have a language background other than English and are currently being served or monitored by either a Bilingual or an English as Second Language (ESL) Program. In this study, ELL is a dummy variable, in which "1" refers to ELL, and "0" refers to non-ELL (i.e., English proficient student).

Ethnicity: Dummy variables are used to represent each ethnicity in this study. Since the majority ethnicities in both districts are Whites and Hispanics, two dummy variables ("Hispanics" and "Others") were generated with the base category being "Whites."

Free or reduced price lunch recipients: This variable identifies students who meet the eligibility criteria for free or reduced lunch pursuant to the provisions of the Federal National School Lunch Act. In this study, free lunch is a dummy variable, in which "1" refers to students who receive free/reduced lunch, and "0" refers to non-free/reduced lunch recipients.

Gifted: Gifted is defined as students who are endowed with a high degree of potential in mental ability, academics, creativity, or talents (visual, performing, musical arts, or leadership). Gifted is a dummy variable in this study in which "1" refers to students who are identified as gifted students and "0" refers to students who are not identified as gifted students.

Individualized Education Program (IEP): IEP identifies students with disabilities receiving an Individualized Education Program, including classroom instruction, instruction in physical education, home instruction, and instruction in hospitals and institutions. IEP is indicated by a dummy variable in this study in which "1" refers to students who receive an IEP program, and "0" refers to students who do not receive an IEP program.

Data Analysis

Quantitative data analysis was used to answer the first question about the effect of the one-to-one laptop program on student writing outcomes as well as the

second question regarding the variation of this effect across demographic subgroups. Separate analyses were conducted for each of the two districts, due to the different implementation approaches carried out in the two districts, and the corresponding data that was provided to us.

For the California school district, a gain score analysis compared the third to fourth grade ELA gains of students who experienced one of three instructional conditions:

- 2007 (third grade) to 2008 (fourth grade) [no laptop program]
- 2008 (third grade) to 2009 (fourth grade) [partial laptop program]
- 2009 (third grade) to 2010 (fourth grade) [full laptop program]

The regression equation, which included school fixed effects, is:

$$\text{Gain}_i = \beta_0 + \beta_1 \text{Year2009}_i + \beta_2 \text{Year2010}_i + \beta_3 X_i + \beta_4 X_i * \text{Year2009}_i + \beta_5 X_i * \text{Year2010}_i + \varepsilon \quad (1)$$

In this regression, the dependent variable was student ELA achievement gains from third to fourth grade. The dummy variable "Year2009" represented whether student *i* was in the partial laptop program or not, and the dummy variable "Year2010" was used to represent whether student *i* was in the full laptop program or not. "X" represents all other control variables, including ethnicity, ELL status, free lunch status, Gifted, IEP, and parent education. The interaction between "Year2009" and "X" describes whether the effect of the partial laptop program varies among different demographic groups, and the interaction between "Year2010" and "X" represents whether the effect of the full laptop program varies among different demographic groups.

Whereas in California, the laptop program was implemented within existing programs, and over a 2-year period (with partial implementation the first year and full implementation the second year), in Colorado, the implementation model was different. The Writer's Workshop model was implemented district-wide in 1 year, and the laptop program was implemented simultaneously but only in one elementary grade level. To distinguish the separate effects of the writing reform and the use of laptops, a difference-in-differences analysis was applied. Since teachers in both fourth and fifth grade in the 2009-2010 school year participated in the writing reform and professional development, the inclusion of fourth grade students in this difference-in-differences analysis allowed us to control for the effect of writing reform and the year effect. Specifically, we compared A and B:

A) Fourth to fifth grade writing growth from spring 2008 to spring 2009 (both years without the writing reform or the laptop program for fifth graders) as compared to fourth to fifth grade writing growth from spring 2009 to spring 2010 (with the spring 2010 scores reflecting participation in the writing reform with laptops).

B) Third to fourth grade writing growth from spring 2008 to spring 2009 (both years without the writing reform or laptop program for fourth graders) as compared to third to fourth grade writing growth from spring 2009 to spring 2010 (with the spring 2010 scores reflecting participation in the writing reform but without laptops).

The regression equation is as follows:

$$\text{Writing post}_i = b_0 + \beta_1 \text{Writing pre}_i + \beta_2 \text{Year2010}_i + \beta_3 \text{Grade5}_i + \beta 4 \text{Year2010}_i * \text{Grade5}_i + \beta_5 X_i + \varepsilon \quad (2)$$

In this regression, the dependent variable was student writing post-test achievement. Student writing pre-test was controlled. "Year2010" was a dummy variable for the treatment year (Year2010 = 1 when it was 2009 to 2010), and "Grade5" was a dummy variable for the treatment group (Grade5 = 1 when it was for fourth to fifth grade growth). The interaction between "Year2010" and "Grade5" identified the specific year and grade in which the program was implemented. Thus, the coefficient on this interaction term estimated the program effect of how much the average achievement for this year and grade was above that expected in the absence of a treatment effect.

The third research question was addressed by using both quantitative and qualitative data analysis. Both teacher and student survey responses were analyzed using descriptive statistics. Field notes and interviews were coded using a bottom-up approach (Bogdan & Biklen, 1982) to best capture the experiences of teachers and students in using the netbooks for writing, literacy, and learning. Student blog posts were also coded using a similar bottom-up approach to identify common themes in students' opinions about laptop use. Other documents such as teacher lesson plans and rubrics were reviewed for triangulation purposes.

FINDINGS

The Effect of the One-to-One Laptop Program on Writing Achievement Gains

Findings in the California School District

First we examined the effect of the one-to-one laptop program in the California school district. The demographic composition of fourth grade students was shown in Table 1. In the 2007-2008 school year, 55% of the students were Whites, 26% were Hispanics, and 19% were Asians, Blacks, and others. The district had 20% ELLs and 13% on free or reduced lunch. Both the 2008-2009 and the 2009-2010 school years had similar demographic compositions.

Table 1. Demographic Composition of Fourth Graders in the 2007-2008, 2008-2009, and 2009-2010 School Years in the California District

	2007-2008		2008-2009		2009-2010	
	Number	(Percentage)	Number	(Percentage)	Number	(Percentage)
Whites	733	(55.20)	734	(59.77)	682	(58.89)
Hispanics	340	(25.60)	314	(25.57)	262	(22.63)
Others	251	(19.20)	178	(14.66)	209	(18.48)
ELL	261	(19.65)	228	(18.57)	215	(18.57)
Free lunch	175	(13.19)	139	(11.34)	148	(12.81)
Gifted	135	(10.17)	40	(3.26)	44	(3.80)
IEP	145	(10.92)	109	(8.88)	103	(8.89)
N	1328		1228		1158	

Descriptive statistics of ELA scores are presented in Table 2. ELA year-to-year growth increased from 6.90 (from spring 2007 to spring 2008) to 9.18 (from spring 2008 to spring 2009). Although both pre-test and post-test average scores were higher in 2009 to 2010 than in 2008 to 2009, the growth of ELA scores from 2009 to 2010 was 9.17, which was almost the same as the growth from 2008 to 2009.

Results of the regression of ELA gains against predictor variables with school fixed effects are presented in Table 3. Model 1 included two dummy variables, Year2009 and Year2010, both using Year2008 as the base category. Model 2 added all other demographic information. Models 3 to 5 added the interaction between each demographic variable (i.e., ELL, Ethnicity, Free-lunch status) with the year effect respectively. Model 6 finally controlled all interactions between the student demographic variables and the year effect. In Model 2, the coefficients of both Year2009 and Year2010 were significantly positive ($p < .001$). Students' ELA gains from 2008 to 2009 were .23 (= 2.24/9.88) of a standard deviation higher than gains from 2007 to 2008, and students' ELA gains from 2009 to 2010 was .22 (= 2.27/10.31) of a standard deviation higher than gains from 2007 to 2008. Students whose ethnicity was categorized as others (most of them Asians), non-free lunch receivers, not in the Special Education group, and whose parents' education was higher tend to have higher ELA gains over all three years. In Model 3, the coefficient of the interaction between ELLs and year effects was not significant, which means there is no difference for ELLs on their ELA gains from 2008 to 2009 and 2009 to 2010, as compared to 2007 to 2008. Model 4 tells us that the coefficient of the interaction between Hispanics and Year2010 was significantly positive ($p < .05$), and Hispanics experienced .14 (= 1.40/10.31) of a standard deviation of ELA gain higher than Whites in 2010. Also, Model 5 indicated that the coefficient of the interaction between free lunch status and Year2010 was significantly positive ($p < .05$), and free lunch recipients tended to have .19 (= 1.97/10.31) of a standard deviation of ELA gain higher than

Table 2. Descriptive Statistics of Student ELA Achievement Gains for Third to Fourth Graders from 2007 to 2008, 2008 to 2009, and 2009 to 2010 in the California District

	2007 to 2008		2008 to 2009		2009 to 2010	
	Mean	(*SD*)	Mean	(*SD*)	Mean	(*SD*)
Pre-test	46.98	(10.42)	47.78	(9.88)	49.86	(10.31)
Post-test	53.88	(12.57)	56.96	(11.72)	59.03	(11.94)
Growth	6.90	(7.07)	9.18	(6.93)	9.17	(6.66)
N	1328		1228		1158	

Table 3. Additive and Interactive Regressions (with School Fixed Effects) of Third to Fourth Grade ELA Gains, 2008 to 2010

	Third to Fourth ELA Gains					
	(1) Year	(2) (1) Plus Demographic Information	(3) (2) Plus ELL Interaction	(4) (2) Plus Ethnicity Interaction	(5) (2) Plus Free Lunch Interaction	(6) (2) Plus All Interactions
Year2009	2.21***	2.24***	2.09***	2.01***	2.19***	2.00***
	(0.27)	(0.27)	(0.30)	(0.36)	(0.29)	(0.36)
Year2010	2.23***	2.27***	2.08***	2.03***	2.01***	1.97***
	(0.27)	(0.28)	(0.31)	(0.37)	(0.30)	(0.37)
Hispanic		–0.26	–0.26	–1.01*	–0.26	–0.78
		(0.32)	(0.32)	(0.48)	(0.31)	(0.52)
Others		0.72*	0.72*	0.94+	0.71*	1.07*
		(0.33)	(0.33)	(0.51)	(0.33)	(0.53)
ELL		0.47	–0.08	0.45	0.44	0.09
		(0.33)	(0.50)	(0.33)	(0.33)	(0.54)
Free Lunch		–1.03*	–1.03*	–1.02*	–1.72**	–1.26+
		(0.41)	(0.42)	(0.41)	(0.60)	(0.64)
Gifted and Talented		0.52	0.49	0.44	0.49	0.44
		(0.49)	(0.49)	(0.49)	(0.49)	(0.49)
Special Education		–0.86*	–0.86*	–0.87*	–0.86*	–0.86*
		(0.38)	(0.38)	(0.38)	(0.38)	(0.38)
Parent Education		0.35**	0.35**	0.35**	0.36**	0.36**
		(0.12)	(0.12)	(0.12)	(0.12)	(0.12)
ELL*Year2009			0.79			0.69
			(0.69)			(0.78)
ELL*Year2010			0.98			0.40
			(0.70)			(0.83)
Hispanic*Year2009				1.02		0.89
				(0.64)		(0.72)
Hispanic*Year2010				1.40*		0.76
				(0.67)		(0.78)
Others*Year2009				–0.17		–0.39
				(0.75)		(0.79)
Others*Year2010				–0.58		–0.81
				(0.74)		(0.78)
Free Lunch*Year2009					0.26	–0.51
					(0.83)	(0.93)
Free Lunch*Year2010					1.97*	1.35
					(0.82)	(0.95)
School Fixed Effect	√	√	√	√	√	√
Constant	6.93***	2.55	2.64+	2.70+	2.51	2.54
	(0.19)	(1.57)	(1.57)	(1.58)	(1.57)	(1.58)
R^2	0.059	0.072	0.072	0.074	0.074	0.075
Observations	3712	3616	3616	3616	3616	3616

Note: Standard errors in parentheses.
$^{+}p < 0.10$, $*p < 0.05$, $**p < 0.01$, $***p < 0.001$.

non-free lunch recipients in 2010. Thus, all students experienced higher ELA gains during both the partial laptop program and the full laptop program. In addition, while different demographic groups experienced similar ELA gains in the partial laptop program year with the gains in the no laptop program year, Hispanics and free-lunch recipients experienced higher ELA gains in the full laptop program year than in the no laptop program year.

Findings in the Colorado School District

In the Colorado school district we examined the effect of the laptop program on fifth grade students. Here, the research design involved comparing writing growth for fourth to fifth graders tested from spring 2008 to spring 2009 when the laptop program was not implemented, to the growth experienced by fourth to fifth graders from spring 2009 to spring 2010, during the time period when the laptop program was received by all fifth grade students. Since this comparison could be biased by year-specific effects, we also compared spring to spring writing growth from third to fourth graders from 2008 to 2009, to the growth experienced by third to fourth graders from 2009 to 2010. During these years the laptop program was not in operation for these grade levels.

The demographic composition of all four student groups was shown in Table 4. For fifth graders in the 2009-2010 school year, 78% of the students were Whites, 14% were Hispanics, and 8% were Asians, Blacks, and others. The district had 9% ELLs and 22% free or reduced lunch receivers. All the other three groups had similar demographic composition as fifth graders in the 2009-2010 school year.

Descriptive statistics of student writing scores in all four groups were also presented in Table 4. The growth of fourth to fifth graders from 2009 to 2010 with the laptop program implemented during the 2009-2010 school year was 24.64; growth for 2008 to 2009 without the laptop program was 23.60. The difference between these was 1.04 which was not statistically significant, according to a *t*-test analysis. In an attempt to adjust for year-specific effects we also compared growth from spring of third to spring of fourth grade from 2008 to 2009 with such growth from 2009 to 2010, both years when the laptop program was not implemented in fourth grade. The first growth was 21.71; the second was 21.42. The difference between these was –.29 which was not statistically significant. However, the difference between these two differences was 1.33 which was statistically significant ($p < .001$). This suggested that the difference between the growth of fourth to fifth graders from 2009 to 2010 (with the laptop program), and the growth of fourth to fifth graders from 2008 to 2009, was significantly higher than the difference between the growth of third to fourth graders from 2009 to 2010, and the growth of third to fourth graders from 2008 to 2009.

In order to investigate the effect of the laptop program on student writing post-test scores when controlling for all other individual characteristics, a multiple regression using residualized change model (which controls the lagged dependent

Table 4. Descriptive Statistics of Variables for Comparison between Fourth to Fifth Grade Growth and Third to Fourth Grade Growth in 2009 to 2010 and 2008 to 2009 in the Colorado District

	Comparison of spring fourth to fifth grade gains				Comparison of spring third to fourth grade gains			
	2009 to 2010 with the laptop program		2008 to 2009 without the laptop program		2009 to 2010 without the laptop program		2008 to 2009 without the laptop program	
	Mean	(*SD*)	Mean	(*SD*)	Mean	(*SD*)	Mean	(*SD*)
Outcomes								
Pre-writing	506.03	(51.47)	510.08	(49.12)	487.90	(46.69)	484.51	(54.53)
Post-writing	530.66	(54.34)	533.68	(50.29)	509.32	(49.05)	506.22	(51.37)
Writing gain	24.64	(35.26)	23.60	(32.53)	21.42	(33.41)	21.71	(38.31)
Controls								
Male	.51	(.50)	.49	(.50)	.51	(.50)	.51	(.50)
White	.78	(.42)	.78	(.41)	.80	(.40)	.78	(.41)
Hispanic	.14	(.35)	.14	(.35)	.13	(.34)	.14	(.34)
Others	.08	(.27)	.08	(.27)	.07	(.26)	.08	(.27)
ELL	.09	(.28)	.08	(.27)	.09	(.28)	.09	(.29)
Free lunch	.22	(.42)	.18	(.38)	.22	(.41)	.22	(.41)
Gifted	.21	(.41)	.24	(.43)	.20	(.40)	.21	(.41)
IEP	.10	(.30)	.09	(.29)	.10	(.30)	.11	(.31)
N	1000		932		969		975	

variable) was applied in this study (see Table 5). Model 1 included standardized writing pre-test score, year effect, grade effect, and the interaction between year and grade as independent variables. In this model and in the following models, the interaction between year and grade indicated the laptop program effect; Model 2 added student individual characteristics as covariates; Model 3 to Model 6 respectively added the interaction between each demographic variable (i.e., gender, ELL, Ethnicity, Free-lunch status) with the year effect, the grade effect, and the program effect. Finally, Model 7 included all the main effects and the interaction effects together. Model 2 showed that, although fifth grade students had significantly higher writing growth than fourth grade students, the program effect (i.e., the interaction between laptop program year and laptop program grade) was not significant. This suggested that, overall, the laptop program did not result in significantly higher growth for fifth grade students. Female, ELLs, Gifted students, non-Hispanics, and non-free lunch receivers tend to have higher writing gains on average. When looking into the interactions of student demographic information with the program effect, Model 3 revealed that the difference between writing gains of females and males did not vary in laptop program and non-laptop program, as indicated by the interaction effect of male and year and grade; Model 4 showed that the difference between ELLs and non-ELLs were similar in laptop program and non-laptop program, as indicated by the interaction effect; however, as shown in Model 5, Hispanics experienced significantly higher writing gains than Whites in the laptop program year ($p < .05$), and Hispanics experienced .23 (= 11.69/51.47) of a standard deviation of writing post-test score higher than Whites on writing post-test for fifth grade students in the laptop program year, when controlling for their writing pre-test. Besides, the laptop program was marginal-significantly more effective for free-lunch recipients compared to non free-lunch recipients ($p < .10$), and free lunch receivers scored .18 (= 9.07/51.47) of a standard deviation of writing post-test higher than non-free lunch receivers for fifth graders in the laptop program year, as shown in Model 6. These findings were consistent with the findings from the California school district, that Hispanics and free-lunch receivers benefited more from the laptop program than their peers.

To summarize, in the California school district all students benefited from the laptop program. In the Colorado school district, the laptop program had no overall effect; however, in both districts, at-risk students (i.e., Hispanics, free-lunch receivers) benefited from the laptop program more than their non-at-risk peers.

One-to-One Laptop Program and Student Writing Processes

Overall, the one-to-one laptop program appeared to be thoughtfully implemented and well-received by teachers and students in both school districts. Survey responses suggested that netbooks were used extensively in classrooms. According to the survey responses in both districts, students spent about 2 hours

per day using their laptops. Student responses to the different usages of their netbooks at school were shown in Figure 1. The usages of their netbooks were measured by number of times per week. The most frequent self-reported use of netbooks was for writing or editing papers. Following that, other frequent uses included getting news or information online, doing drills or games for learning, and learning basic use of the laptop or new software.

When asked about the benefits that the laptop program has brought to their schoolwork and writing, more than 60% of all students agreed that they became more organized, schoolwork has become more interesting for them, and the quality of their schoolwork has improved since they received their laptops; more than 70% of all students agreed that they wrote more, and revised or edited their papers more when they used their laptops. Furthermore, about 64% of the students agreed that the quality of their writing has improved since receiving their laptops.

Students believed that laptops helped them to draft, revise, and publish their written work. They also told us how writing on laptops helped them to avoid fatigue. As one fifth grade student, Tristan, mentioned in his blog,

> I've actually enjoyed writing more, because personally, in the past, I haven't been able to write for very long without wrist starting to hurt. Having a laptop, the pain has ended, and my writing has improved so very much within just this year. . . . I've written my best essays, poems, summaries, anything, you name it, this year.

Our interviews also suggested that the use of laptops at school helped students increase their enthusiasm for writing. As a Colorado fifth grader, Lupita, wrote on her blog,

> I used to not like writing but now I keep looking at the time and inside I am saying, "Is it time for writing yet?" If you don't believe me come visit us. . . . You have to see it to believe it because your eyes will pop out.

Additionally, students used different forms of technology for their writing practices in the two school districts. In the California school district, students used an AWE software, MY Access!, in their writing in the first 2 years of the laptop program. This software provided students immediate feedback on student writing, and not only provided a total writing score, but also subscales on focus, development, organization, language use, and mechanics and writing conventions. However, observations and interviews with teachers suggested that enthusiasm for the software among teachers decreased during the year. This seemed to be partly due to concerns about inaccuracy in scoring and subsequent negative effects on student writing: teachers said that students would make small changes in their writings simply to get a higher score, whether or not that contributed to improved student writing, and that the program is not very helpful in detecting and providing feedback on voice and creativity in student writing. The most negative attitudes toward AWE were in low-SES classrooms, where teachers felt

Table 5. Regression on Writing Post-Test Scores when Controlling for Writing Pre-Test Score for Fourth to Fifth and Third to Fourth Grades from 2009 to 2010 and from 2008 to 2009 in the Colorado District

	Writing post-test scale score						
	(1) Pre-test, Year2010, and Grade5	(2) (1) Plus Demographic Information	(3) (2) Plus Gender Interaction	(4) (2) Plus ELL Interaction	(5) (2) Plus Ethnicity Interaction	(6) (2) Plus Free lunch Interaction	(7) (2) Plus All Interactions
Pre-test (standardized)	42.41***	35.28***	35.28***	35.36***	35.26***	35.30***	35.30***
	(0.56)	(0.67)	(0.67)	(0.67)	(0.67)	(0.67)	(0.67)
Pre-test square	–3.95	–3.38***	–3.39***	–3.42***	–3.40***	–3.44***	–3.47***
	(0.31)	(0.31)	(0.31)	(0.31)	(0.31)	(0.31)	(0.32)
Year2010	–0.92	–0.12	–0.55	0.42	1.34	1.23	1.48
	(1.48)	(1.41)	(2.02)	(1.48)	(1.59)	(1.60)	(2.21)
Grade5	5.87***	8.26***	8.12***	8.64***	10.23***	10.53***	11.25***
	(1.52)	(1.46)	(2.03)	(1.52)	(1.64)	(1.62)	(2.22)
Year2010*Grade5	1.41	1.31	2.57	1.81	–1.11	–0.44	–1.07
	(2.09)	(2.00)	(2.84)	(2.09)	(2.26)	(2.25)	(3.11)
Male		–8.69***	–8.63***	–8.63***	–8.69***	–8.69***	–8.78***
		(1.03)	(2.01)	(1.03)	(1.03)	(1.03)	(2.02)
ELL		3.84+	3.88+	10.73**	3.65+	3.76+	6.03
		(2.18)	(2.18)	(3.72)	(2.19)	(2.18)	(4.33)
Gifted and Talented		21.27***	21.30***	21.22***	21.24***	21.28***	21.23***
		(1.38)	(1.38)	(1.37)	(1.38)	(1.37)	(1.37)
Individualized Education Program		–11.09***	–11.05***	–10.96***	–11.14***	–11.17***	–11.08***
		(1.82)	(1.83)	(1.82)	(1.83)	(1.82)	(1.83)

Hispanic	–4.19* (1.74)	–4.21*** (1.74)	–4.21* (1.74)	–0.68 (3.05)	–4.08* (1.74)	–3.89 (3.42)
Others	0.51 (1.95)	0.48 (1.95)	0.57 (1.95)	8.45* (3.77)	0.47 (1.95)	6.46 (3.93)
Free lunch	–6.92*** (1.41)	–6.91*** (1.41)	–6.90*** (1.41)	–6.95*** (1.41)	–0.57 (2.52)	–1.77 (2.75)
Male*Year2010		0.84 (2.82)				0.95 (2.82)
Male*Grade5		0.30 (2.85)				0.29 (2.85)
Male*Year2010*Grade5		–2.48 (4.00)				–1.72 (4.00)
ELL*Year2010			–6.21 (4.95)			0.58 (6.19)
ELL*Grade5			–4.38 (5.13)			7.14 (6.20)
ELL*Year2010*Grade5			–5.68 (7.12)			–23.27** (8.71)
Hispanic*Year2010				–4.97 (4.18)		–3.34 (5.07)
Hispanic*Grade5				–7.87+ (4.13)		–5.57 (4.84)
Hispanic*Year2010*Grade5				11.69* (5.84)		16.32* (6.96)

Table 5. (Cont'd.)

	Writing post-test scale score						
	(1) Pre-test, Year2010, and Grade5	(2) (1) Plus Demographic Information	(3) (2) Plus Gender Interaction	(4) (2) Plus ELL Interaction	(5) (2) Plus Ethnicity Interaction	(6) (2) Plus Free lunch Interaction	(7) (2) Plus All Interactions
Others*Year2010					–10.16^{+}		–8.78
					(5.35)		(5.57)
Others*Grade5					–11.00*		–9.58^{+}
					(5.35)		(5.54)
Others*Year2010*Grade5					10.57		13.61^{+}
					(7.53)		(7.80)
Free lunch*Year2010						–6.26^{+}	–4.80
						(3.41)	(3.79)
Free lunch*Grade5						–11.35**	–10.89**
						(3.58)	(4.07)
Free lunch*Year2010*Grade5						9.07^{+}	9.96^{+}
						(4.92)	(5.52)
_cons	520.63***	521.10***	521.06***	520.51***	520.05***	519.79***	519.43***
	(1.12)	(1.24)	(1.51)	(1.26)	(1.32)	(1.31)	(1.60)
R^2	0.622	0.655	0.655	0.656	0.656	0.656	0.658
Observations	3876	3876	3876	3876	3876	3876	3876

Note: Standard errors in parentheses.
$^{+}p < 0.10$, $*p < 0.05$, $**p < 0.01$, $***p < 0.001$.

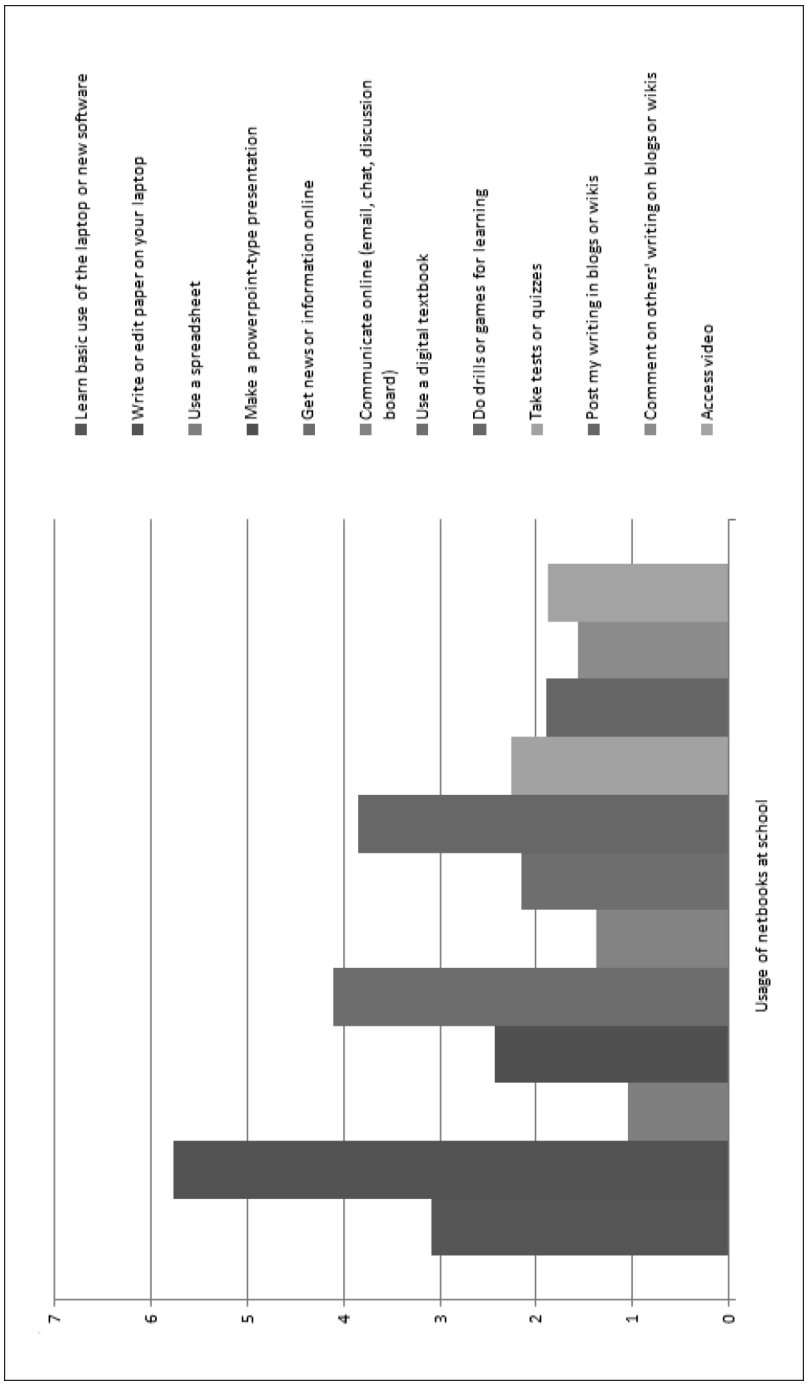

Figure 1. Usage (number of times/week) of netbooks at school in the two school districts.

that students were least able to benefit from the feedback the program provided. However, teachers also mentioned that MY Access! lessened their burden by helping evaluate student essays.

Students showed very positive attitudes toward the use of MY Access! for writing, based on their survey responses. More than 50% of students responded that they like writing with the tool, it is easy to use, they revise their writing more, and their confidence in writing has increased when using MY Access!. In representative comments, students reported that, when using MY Access!, "you get a feedback in seconds," "you can get your score right away," "it shows all of the problems in your writing and you keep improving with your writing," and "it is fun!" In summary, in the California school district, students tended to have higher enthusiasm toward the use of MY Access! than their teachers because of the instant scores and immediate feedback they received from the program. Although teachers had concerns about the accuracy of MY Access! scoring, many teachers continued using it in their classrooms to facilitate their teaching and classroom management.

In the California school district, in addition to MY Access!, teachers also mentioned their use of social media to motivate student writing. For example, one teacher explained how she set up a Skype conversation with a relative serving in Iraq to give students more of a firsthand view of the conflict there. After that, students were asked to follow up by writing about the topic in their blogs. It was mentioned that students tend to be more engaged and motivated in their writing when they have an authentic audience for their writing.

In the Colorado school district, there was no district-wide use of AWE, but students in many schools wrote with social media on a more frequent basis than students in the California school district, according to our observations. During our observations we witnessed students publishing their writing on blogs and wikis, discussing readings and commenting on others' writing through online discussion tools, and writing collaboratively via real-time text tools. We also saw how students interacted with people outside their classrooms or district in these online forums. In interviews we were told that even having a single outside interlocutor for a class could motivate better writing by letting students know their blogs were being followed by an interested reader.

We also examined the use of laptops in writing processes among different groups of students in the two districts, based on students' self-reported survey responses. *T*-tests were used to investigate students' use of netbooks at school between ELLs and non-ELLs, Hispanics and non-Hispanics, and free lunch receivers and non-free lunch receivers, respectively in the California school district (see Table 6) and the Colorado school district (see Table 7). The results showed that, in the California school district, ELLs, Hispanics, and free-lunch receivers in general used netbooks more than their non at-risk peers, although most of the differences were not statistically significant; while in the Colorado school district, ELLs, Hispanics, and free-lunch receivers used their netbooks

significantly more than their peers. These at-risk learners spent more time at school using their netbooks to write or edit their paper, use a spreadsheet, get online information, communicate online, take tests or quizzes, write in blogs or wikis, and comment on others' writing on blogs or wikis. This finding suggests that in the one-to-one laptop environment, at-risk students used their netbooks for writing related tasks much more frequently than their peer students.

Interviews and observations showed similar findings for at-risk students. Teachers we interviewed at several sites in the Colorado school district spoke to the particular advantages of laptop use for language minority students, including the effectiveness of laptops in offering multimodal input and in giving learners opportunities to catch up in communication and language skills through computer-mediated writing and interaction. For example, in one of the two focal schools in Colorado, more than half the students were Hispanics and ELLs. Students in that school made extensive use of social media throughout the 2009-2010 school year, including the regular use of an online discussion platform to provide a written channel for discussing class readings. In a separate case study (Zheng & Warschauer, 2011), we examined in more depth the development of students' participation, writing, and use of cognitive strategies during this ongoing collaborative discussion, finding that the online writing was particularly valuable in all these areas for at-risk learners. Our findings in this case study suggested that, while all students increased their participation in online discussion over time, ELLs increased at a higher rate. Students also demonstrated higher language complexity, deeper thinking, and advanced cognitive skills as the online discussion activity went on.

In summary, the surveys, interviews, and observations suggest that students use the laptops for language arts activities extensively, that at-risk students use them the most, and that teachers and students perceive many benefits for writing and literacy development. There is widespread belief in the two districts that use of laptops bring many benefits for writing that may not be well captured by standardized tests, such as heightened student autonomy and engagement in the writing process, better understanding of why and how to write for a specific audience, and mastery of new writing tools. For example, student interviews suggest that with individual laptops provided, they were able to learn and write at their own pace, and they have learned to take responsibility of their own learning. As they realized that a broader authentic audience will read their work, they were more motivated and inspired to write in better quality.

DISCUSSION

Laptop programs are a complex intervention that introduces substantial changes to the overall classroom environment. The potential benefits of laptops may be difficult to assess with the tools currently available to us. Thus, many of the benefits of writing with laptops may not be accurately measured by

Table 6. *T*-Test Results of Students' Perceived Usage (Number of Times/Week) of Netbooks at School for Different Demographic Groups in the California District

	Usage of netbooks at school among diverse students					
	ELLs (*N* = 180)	Non-ELLs (*N* = 713)	Hispanics (*N* = 211)	Non-Hispanics (*N* = 692)	Free lunch receivers (*N* = 70)	Non-free lunch receivers (*N* = 823)
Learn basic use of the laptop or new software	4.51 (.41)	4.05 (.18)	4.05 (.35)	4.18 (.19)	4.72 (.69)	4.10 (.17)
Write or edit paper on your laptop	6.17 (.46)	6.05 (.23)	5.49 (.40)	6.26 (.24)	6.03 (.72)	6.08 (.22)
Use a spreadsheet	.96 (.16)	1.07 (.09)	.97 (.14)	1.07 (.09)	1.39 (.32)	1.01 (.08)
Make a PowerPoint-type presentation	3.37 (.36)	3.20 (.18)	3.26 (.33)	3.23 (.19)	4.17*[c] (.64)	3.15 (.17)
Get news or information online	5.32 (.45)	5.03 (.22)	5.80*[b] (.37)	4.86 (.16)	5.34 (.71)	5.06 (.21)
Communicate online (e-mail, chat, discussion board)	1.52 (.27)	1.41 (.12)	1.70 (.25)	1.35 (.12)	1.37 (.42)	1.44 (.11)

Use a digital textbook	2.60	2.16	2.41	2.20	2.48	2.23
	(.34)	(.15)	(.30)	(.16)	(.53)	(.14)
Do drills or games for learning	6.08	5.57	6.19	5.52	6.50	5.61
	(.44)	(.22)	(.41)	(.22)	(.72)	(.20)
Take tests or quizzes	2.38	2.05	2.48*	2.01	2.27	2.11
	(.25)	(.13)	(.25)	(.12)	(.42)	(.12)
Post my writing in blogs or wikis	1.95	1.97	2.20	1.89	1.72	1.98
	(.30)	(.14)	(.29)	(.14)	(.43)	(.13)
Comment on others' writing on blogs or wikis	1.88	1.47	2.00*	1.42	2.29	1.49
	(.30)	(.12)	(.27)	(.12)	(.56)	(.11)
Access video	3.25*[a]	2.27	3.15**	2.26	3.20	2.41
	(.39)	(.15)	(.35)	(.15)	(.60)	(.15)
Average school use	3.33	3.02	3.31	3.02	3.46	3.06
	(.20)	(.10)	(.20)	(.10)	(.37)	(.09)

Note: Standard errors in parentheses.
$^{+}p < 0.10$, $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$.
[a]Significantly different from non-ELLs.
[b]Significantly different from non-Hispanics.
[c]Significantly different from non-free lunch receivers.

Table 7. *T*-Test Results of Students' Perceived Usage (Number of Times/Week) of Netbooks at School for Different Demographic Groups in the Colorado District

	Usage of netbooks at school among diverse students					
	ELLs (N = 43)	Non-ELLs (N = 446)	Hispanics (N = 59)	Non-Hispanics (N = 430)	Free lunch receivers (N = 101)	Non-free lunch receivers (N = 388)
Learn basic use of the laptop or new software	1.10 (.36)	1.29 (.11)	1.31 (.36)	1.27 (.11)	1.37 (.26)	1.24 (.12)
Write or edit paper on your laptop	7.69*[a] (.97)	5.51 (.27)	6.62 (.84)	5.57 (.27)	6.67*[c] (.62)	5.45 (.28)
Use a spreadsheet	2.77*** (.52)	.95 (.12)	1.82*[b] (.41)	1.01 (.12)	1.95*** (.23)	.95 (.06)
Make a PowerPoint-type presentation	1.64 (.36)	1.07 (.12)	1.59 (.42)	1.05 (.12)	1.89*** (.35)	.92 (.11)
Get news or information online	6.53*** (.98)	2.23 (.18)	4.02** (.72)	2.42 (.20)	4.83*** (.59)	2.03 (.18)
Communicate online (e-mail, chat, discussion board)	4.63*** (.95)	1.08 (.14)	2.52** (.62)	1.23 (.16)	2.98*** (.52)	.98 (.14)

Use a digital textbook	2.41	1.89	1.81	1.95	2.56*	1.77
	(.38)	(.16)	(.30)	(.17)	(.37)	(.17)
Do drills or games for learning	1.78*	.95	1.38	.97	1.49*	.90
	(.48)	(.09)	(.36)	(.10)	(.29)	(.09)
Take tests or quizzes	6.10***	2.23	4.60***	2.29	4.64***	2.03
	(1.02)	(.19)	(.81)	(.19)	(.62)	(.18)
Post my writing in blogs or wikis	5.63***	1.39	3.37***	1.54	4.01***	1.18
	(.97)	(.15)	(.71)	(.17)	(.59)	(.14)
Comment on others' writing on blogs or wikis	7.13***	1.19	4.14***	1.38	4.66***	.95
	(1.05)	(.15)	(.84)	(.17)	(.65)	(.13)
Access video	1.56*	.75	.95	.81	1.41**	.68
	(.22)	(.10)	(.16)	(.11)	(.27)	(.10)
Average school use	4.08***	1.71	2.84***	1.79	3.20***	1.58
	(.45)	(.09)	(.36)	(.09)	(.30)	(.08)

Note: Standard errors in parentheses.
$^{+}p < 0.10$, $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$.
[a]Significantly different from non-ELLs.
[b]Significantly different from non-Hispanics.
[c]Significantly different from non-free lunch receivers.

standardized tests, due to a mismatch between the conditions of those tests (short essays written in a single setting) and the type of writing done on laptops (involving gathering of information, drafting, getting feedback, revising, and publishing in a variety of genres). A study by Russell and Plati (2002), for example, found that mode of test administration (computer vs. paper) had a significant effect on writing test scores of both fourth and eighth grade students, with tests taken on computer rated higher, yet writing tests are frequently administered on paper. The recent National Assessment of Educational Progress writing test (see National Center for Education Statistics, 2012) was given on computer, and found a positive correlation between test score outcomes and prior time spent writing and revising with computers.

In addition, the steep learning curve associated with laptop use by both teachers and students, and the disruptive impact of laptops on prior ways of teaching, means that gains might not be fully realized in the first few years after their introduction. Indeed, it is not unusual for test scores to drop following the first year of a laptop program, only to rebound in subsequent years (see, e.g., Grimes & Warschauer, 2008). Finally, both of these two districts were high-performing, so a ceiling effect may have occurred, especially for the groups of students that are already increasing the most in test scores year to year.

For all of these reasons, the fact that writing achievement growth in the California school district improved in both the partial and full laptop program years, and that the gains were strongest for Hispanic and low-income learners, is encouraging. It is also encouraging that Hispanics and learners from low-income families in the Colorado district experienced significant positive results. Additionally, survey results, interviews, and observations indicated that at-risk students used the laptops as much or more frequently than their counterparts at school and in ways that addressed their particular needs.

Also importantly, these interventions were carried out with low-cost open source netbooks. Total hardware and software purchase cost was $250-$300 per student, and the overall implementation cost averaged over a 4-year laptop cycle, including professional development, replacement costs, and technical support, was calculated by staff in the districts to be well under $150 per student per year. Though we did not conduct a separate cost-benefit analysis, the expenses involved, which roughly parallel the costs of decreasing class size by 0.5 students per teacher, suggest that some benefits can be achieved through comparatively low-cost technology programs. Furthermore, for the elementary school students in the study, program costs provided laptops not only for literacy instruction, but also for use throughout the school day in a wide variety of subjects and ways that we did not investigate, including accessing science videos, doing individualized math assignments, working on social studies research projects, and completing formative and summative assessments.

In conclusion, this study provides evidence that school laptop programs focusing on student writing can help improve literacy and educational equity for at-risk

learners. Further research can help determine what approaches to teaching writing with laptops are most effective, and whether 1-year gains lead to better long-term outcomes, with or without continued access to laptops in subsequent grades.

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Direct reprint requests to:

Dr. Binbin Zheng
3200 Education, School of Education
University of California, Irvine
Irvine, CA 92697-5500
e-mail: binbinz@uci.edu