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Laptop Use, Interactive Science Software, and Science Learning Among At-Risk Students

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Abstract This year-long, quasi-experimental study investigated the impact of the use of netbook computers and interactive science software on fifth-grade students' science learning processes, academic achievement, and interest in further science, technology, engineering, and mathematics (STEM) study within a linguistically diverse school district in California. Analysis of students' state standardized science test scores indicated that the program helped close gaps in scientific achievement between at-risk learners (i.e., English learners, Hispanics, and free/reduced-lunch recipients) and their counterparts. Teacher and student interviews and classroom observations suggested that computer-supported visual representations and interactions supported diverse learners' scientific understanding and inquiry and enabled more individualized and differentiated instruction. Finally, interviews revealed that the program had a positive impact on students' motivation in science and on their interest in pursuing science-related careers. This study suggests that technology-facilitated science instruction is beneficial for improving at-risk students' science achievement, scaffolding students' scientific understanding, and strengthening students' motivation to pursue STEM-related careers.

Keywords One-to-one laptop · Interactive science software · Science achievement · Scientific inquiry · At-risk learners

Introduction

Students in the USA lag behind their counterparts in most other developed countries in scientific achievement (Baldi et al. 2007). This is due in part to the considerable gap in the USA between high- and low-achieving students' science achievement (Lee 2005). This gap is caused in large measure by the low performance in science literacy among minority students, students from low-income homes, and English language learners (ELLs, Gonzales et al. 2008). Over 20 % of school-aged children in the USA are ELLs who are primarily Hispanic (US Census 2010), and this English learner population is projected to rapidly grow (Goldenberg et al. 2011). Consequently, a growing subgroup of the school population is at risk for failing to develop the scientific literacy skills necessary for the twenty-first century.

There are also gaps in young people's access to and use of technology, with, for example, non-English-speaking Hispanics having much less access to computers and the internet than other groups in the USA (Warschauer and Matuchniak 2010). This digital divide contributes to a disproportionately small number of Hispanics prepared to pursue advanced study in technology-intensive fields such as computer science (National Center for Education Statistics 2006). There is considerable optimism that greater and more effective use of digital media can improve

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science achievement and technological proficiency, especially among low-performing students, but there has been little study of this issue.

This study investigates how technology use influences the science learning process, academic achievement, and interest in further science, technology, engineering, and mathematics (STEM) study among students from four linguistically and culturally diverse elementary schools that participate in a one-to-one laptop program.

Literature Review

This study is framed by prior research on technology and science learning among diverse K-12 students. Before proceeding to our study, we briefly review relevant prior research on at-risk learners and science education, technology use in K-12 science instruction, and laptop programs and science achievement.

Science and At-Risk Learners

Historically, ELLs and underrepresented ethnic minorities have shown weaker academic performance in STEM fields compared with their peers (Schwartz 1988) and are thus less likely to pursue STEM education and careers (Mbamalu 2001; Slovacek et al. 2012). According to the National Center for Education Statistics (Franceschini et al. 2008), only 2 % of ELLs achieve science proficiency in eighth grade, compared with 32 % of native English speakers at the same grade level (NCES 2010). A more recent report from NCES (2012) showed that 66 % of eighth graders who scored below the 25th percentile in 2011 were Hispanic or Black, while 86 % of those who scored above the 75th percentile were not.

Research suggests that hands-on, inquiry-based interventions, in which students are encouraged to construct their own knowledge by conducting investigations using scientific methods, are helpful for promoting at-risk learners' understanding of science concepts and increasing their science achievement (August et al. 2009; Lara-Alecio et al. 2012; Lee et al. 2005; Minner et al. 2010; NRC 1996). For example, following a year-long teacher professional development focusing on an inquiry-based approach, third-grade ELLs showed significant improvement in science learning outcomes, as measured by the project-developed science test (Lee et al. 2008). Similarly, inquiry-based science instruction was found to promote gains in science and reading achievement for a diverse group of fifth-grade students (Lara-Alecio et al. 2012).

The integration of technology into science education is also widely believed to be beneficial for facilitating inquiry-based instruction (e.g., Ebenezer et al. 2011; Korwin and Jones 1990; Lee et al. 2010; Penuel and Means 2004; Plass et al. 2012; Sandoval and Reiser 2004). The use of multimedia software, virtual labs, simulations, and demonstrations of scientific phenomena enables students to experiment and acquire scientific knowledge with considerably less time and effort than that involved in setting up traditional experiments (Scalise et al. 2011). The integration of technology into inquiry-based science instruction is potentially more beneficial for at-risk learners in many ways. First, it could assist at-risk students to learn academic vocabulary and scientific genres through captions and voiceovers on multimedia representations, thereby providing students with immediate comprehensible input and reducing their reliance on textbooks. Second, visual representations could facilitate at-risk learners' higher-order thinking and problem-solving skills, through engaging them in the processes of problem definition, hypothesis generation, experimentation, observation, and data interpretation (Plass et al. 2012). Finally, visual representations of scientific phenomena and of science experiments could provide at-risk learners with more opportunities to interact with multimedia resources, to which (as previously mentioned) they are likely to have limited access in out-of-school settings.

Technology Use and Scientific Inquiry

Technology is useful at all stages of hands-on, inquiry-based science learning, including the generation and discussion of topics and questions, online information searches, the collection, organization, and analysis of data and the communication of results. Ebenezer et al. (2011) have identified three major science education domains in which technology use may be integrated with scientific inquiry: conceptualization, investigation, and communication.

Scientific Conceptualization

Many scientific concepts are very abstract and can be difficult for students, especially at-risk learners, to understand. These concepts are presented using academic language that is characterized by complex linguistic structures, the heavy use of passive and hedges, and specialized scientific vocabulary (Schleppegrell 2004). The disconnection between the features of academic language used in science and the language used in their everyday lives is challenging for at-risk learners, especially ELLs (Bailey et al. 2011; Billings and Mathison 2012; Moje et al. 2001). Without adequate language and conceptual scaffolding, those linguistic and cognitive demands often become overwhelming obstacles for ELLs (Billings and Mathison 2012). Technology may be used to help students master the language and literacy demands of the science. For example, supports for ELLs that focus on providing students with direct instruction of vocabulary and integrating writing into students' science learning has promoted gains in students' science and reading achievement (Lara-Alecio et al. 2012). Students may obtain a deeper understanding of scientific knowledge and concepts by using various technologies to facilitate their learning (e.g., Bell and Trundle 2008; Ebenezer et al. 2011).

Technologies such as interactive visualizations, text-to-speech tools, and computer simulations can provide multimodal representations of information, which supports students' understanding of academic language in specific context and visualization of complex scientific concepts and processes. For example, concept maps enable students to organize their understanding (Mouza 2008) and discuss and negotiate meaning with their peers during collaborative learning (Cañas et al. 2001). Computer-assisted illustration and animation have also proved helpful in facilitating understanding of abstract scientific concepts (e.g., Ardac and Akaygun 2005; Barak and Dori 2005; Bell and Trundle 2008; Frailich et al. 2009; Marbach-Ad et al. 2008). Frailich et al. (2009) found that tenth-grade students who used computer-based visual models to demonstrate the structure of matter significantly outperformed control students—who learned the same concepts but without exposure to the visualization tools—in understanding chemical bonding. Similarly, Barak and Dori (2005) found that students who were given access to 3D simulations of molecular models, and encouraged to participate in technology-based home projects, gained better chemistry understanding than the control students, who were based in traditional science classrooms. Furthermore, Ardac and Akaygun (2005) found that providing dynamic visuals, especially on an individual basis, significantly improved eighth graders' performance when presenting molecular representations.

Scientific Investigation

Science learning involves more than understanding scientific concepts and principles. It is of critical importance that students develop scientific research skills, such as generating relevant research questions or hypotheses, designing and conducting scientific investigations, using mathematical and statistical tools to collect, analyze, and present data, and communicating the scope and results of their work to others (NRC 1996). Technology is beneficial at each of these stages of students' scientific investigation. Reid-Griffin and Carter's (2008) examination of middle school students' use of portable data-collection devices (in scientific investigations of temperature and heat) found that technology was a helpful tool with which students construct knowledge about complex scientific phenomena, conduct scientific inquiry, and engage in scientific discourse. In addition, studies found that spreadsheets are routinely used for collecting and analyzing data in classroom science projects, and electronic newsletters have been used to communicate results with peers (Mouza 2008), while wikis have been used for both purposes (Oliver and Corn 2008). Other studies also describe how various kinds of technology are used for different purposes. Lee et al. (2010) conducted a 1-year quasi-experimental study of middle school students using the Web-based Inquiry Science Environment (Slovacek et al. 2012); the technological features that were examined included temperature-sensitive probes, classroom experiments, interactive visualizations, online discussion boards, and embedded assessment. This study suggests that students who participate in technology-assisted experiments develop a more integrated understanding of science topics. Among the technologies examined, it was found that visualization tools were most successful in helping students to make connections between new science topics and their existing knowledge. Zucker and Hug (2008) investigated high school students' physics learning in a one-to-one laptop environment and described how students used different tools to facilitate their scientific investigation in laboratories. In their study, all students used a software called LoggerPro to collect and analyze data, but some of them also recorded videos of the science experiments, imported video into their computers, and then measured speed, acceleration, and other phenomena from the video using computer-based data analysis software. However, the impact of these technologies on students' science learning was not directly investigated in that study.

Scientific Communication

Many studies have examined students' scientific conceptualization and scientific investigation. Fewer have investigated another area—scientific communication—that is, nevertheless, an indispensable part of science learning. National Science Education Standards explicitly set forth a transition from "Science as exploration and experiment" to "Science as argument and explanation" (NRC 1996, p. 113). A number of studies have demonstrated that elementary and middle school students' scientific communication could be facilitated through the use of technology, including videos, web pages, PowerPoint presentations, videoconferencing (Swan et al. 2007), electronic newsletters (Mouza 2008), online chat (Ebenezer and Puvirajah 2005), and asynchronous discussion boards (Hoadley and Linn 2000). For example, Hoadley and Linn (2000) investigated the use of asynchronous discussion in science classrooms for eighth-grade students to understand the nature of light, from a sociocultural perspective that learning is most effective in social context, where students can participate in a cognitive apprenticeship. Their study found that a well-designed online asynchronous discussion improved students' knowledge integration and enhance scientific comprehension.

Although many studies have investigated technology use in most aspects of science learning, few have focused on the relationship between students' technology use and their science achievement. In addition, technology use in learning cannot be fully explored unless students are provided with convenient access to computers in their school time. Thus, the next section will review studies on one-to-one laptop programs and students' science achievement.

Laptops and Science Achievement

There has been a rapid increase across the USA in the number of 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, and in many cases, to use at home (Warschauer 2006). Though most laptop programs are popular among teachers, students, and parents, disagreement still exists about the benefits, if any, that they bring to students' learning outcomes (e.g., Dunleavy and Heinecke 2008). Although many studies have investigated one-to-one laptop programs and student academic achievement, only a few have looked at these programs' impact on science achievement (Bebell and Kay 2010; Dunleavy and Heinecke 2008; Shapley et al. 2008).

Among these, a single study examined the effects of laptop programs on science achievement using an experimental design (Dunleavy and Heinecke 2008). Dunleavy and Heinecke found that a 2-year laptop program had a positive effect on middle school students' standardized science achievement, with an effect size of 0.24. Furthermore, they reported a significant interaction between the laptop use and gender, in which the laptop program yielded larger effects for boys (effect size = 0.55) than for girls (effect size = 0.04). Similarly, Bebell and Kay's (2010) examination of the specific relationship between students' science achievement and their use of technology in classrooms found that eighth-grade students who reported more frequent use of laptops also demonstrated higher standardized science test scores than the laptop students who reported less frequent use of technology. In contrast, Shapley et al.'s (2008) quasi-experimental study found that laptop program did not yield significant effects on eighth-grade students' standardized science test scores. In fact, Shapley et al. reported a significant negative effect on the science scores of high-achieving students at laptop schools, yet this finding may result from ceiling effects at pretest.

Apart from the aforementioned studies, there has been scant research examining the effects of one-to-one laptop environments and technology use on students' science achievement and even less that is focused on at-risk learners such as Hispanics, ELLs, and students from low-income families. Thus, we undertook this study to investigate in depth the impact of a one-to-one laptop program combined with an interactive online program on students' science learning processes and outcomes, especially for these at-risk learners. Three research questions were addressed:

1. What impact does the program have on academic achievement in science, and how is this moderated by ELL status, ethnicity, and socioeconomic status?
2. In what ways do participating teachers make use of netbooks and an online science program in their classrooms to facilitate students' science learning?
3. In what ways does the laptop program transform science teaching and learning, and what impact does the program have on students' STEM-related college and career readiness?

Table 1 Demographic composition of fifth-grade experimental and control students in 2010–2011

	Experimental ($n = 205$)		Control ($n = 163$)	
	n	Percentage	*n*	Percentage
Male	90	43.9	84	51.5
Hispanic	115	56.1	128	78.5
ELL	114	55.6	113	69.3
Free- or reduced-lunch	141	68.8	134	82.2

Methods

Sample

The present study took place in an urban school district in Southern California. A federal grant for Enhancing Education Through Technology (EETT) was used to introduce the one-to-one laptop program in September 2010. Fifth-grade students in four schools within the district were chosen by that district as the experimental group, and students from the same grade in four other schools in the same district were selected as the control group. Table 1 summarizes the demographic composition of students in the experimental and control conditions. All participating schools served a high percentage of Hispanics and ELLs and had a high percentage of free- or reduced-lunch recipients.

In the experimental group, low-cost netbooks were provided for all fifth-grade students for use throughout the school day and at home. As part of the laptop program, the school district provided professional development to teachers that included a four-day introductory training program during summer and weekly teacher meetings throughout the 2010–2011 school year. Professional development focused on teachers' technological proficiency and the integration of technology into the science curriculum. In addition to face-to-face meetings, a wiki discussion forum was created in which teachers could share resources and teaching experiences and discuss questions with each other. They were also trained to use discovery education science (DES) software in their science teaching, and all experimental students also had access to this software, which features e-Book reading passages, virtual laboratories to explore investigation design and scientific processes, inquiry-based exploration of science concepts, and interactive glossaries. Each of these features is supported by audio, video, animations, and still images. This software, with content aligned with state standards to support classroom instruction, "offers a breadth and depth of digital media content that is immersive, engaging and brings the world into the classroom to give every student a chance to experience fascinating people, places, and events" (Discovery Education 2014). Since students were permitted to bring their netbooks home, they were encouraged to use DES in after-school settings. In addition, the teachers in the experiment were not limited to DES, but were encouraged to use other kinds of social media, such as blogs, Glogster, and wikis, that they considered to be helpful for student learning.

Sources of Data

Standardized Test Score

De-identified California Standards Test (CST) science scaled scores (150–600) for fifth-grade students in Spring 2011 were collected in both the experimental and control schools as the outcome data. Since California does not provide CST science tests for fourth graders, and because a high correlation exists between students' mathematics scores and their science scores, students' CST mathematics scale scores in 2010 were used as the baseline data.

Interviews

Semi-structured group and individual interviews were conducted with 19 teachers and 20 students in the experimental group at the beginning and end of the school year, for a total of 20 h. Interviews focused on the professional development that teachers received; how teachers and students used DES and any other technologies in their science teaching and learning; teachers' and students' attitudes toward technology use in science classrooms; and students' interest in future STEM studies and careers.

Observations

Classroom observations were conducted in two focal schools for a total of 110 h. Observations focused on teacher and student experiences with and use of various technologies in science. The research team developed an observation protocol focused on types of pedagogy, quality of classroom management, teachers' use of online resources for instruction planning and implementation, and teachers' use of technology to enhance productivity.

Data Analysis

Quantitative Analysis

To answer the first research question, regarding the impact of the program on students' science achievement, a residualized change model was used to investigate the impact of the one-to-one laptop program on students' CST science test scores, after controlling for their previous year's CST mathematics test scores, as well as demographic information. The regression equation is:

$$Y_{\mathrm{Spring2011}} = b_0 + b_1 T + b_2 T \times X + b_3 Y_{\mathrm{Spring2010}} + b_4 X + e \tag{1}$$

In this equation, the dependent variable is student CST science achievement in Spring 2011. The dummy variable (T) represents the treatment effect. X represents all other control variables, including ethnicity, ELL status, and eligibility for free- or reduced-cost lunch programs. The interaction between T and X describes whether the effect of the laptop program differs among different demographic groups.

Qualitative Analysis

Observational field notes and interview transcripts were coded using a bottom-up scheme (Miles and Huberman 1994) that considered data trends that emerged regarding technology use as well as science teaching and learning. Hyper research was used to code data focusing on the following themes: use of DES, student learning change, at-risk learners, future careers, and professional development.

Results

One-to-One Laptop Program and Science Achievement

We examined the impact of the one-to-one laptop program on fifth-grade students' CST science achievement.

Table 2 Descriptive statistics of student achievement in 2010 Math and 2011 CST science in experimental and control groups

	Experimental		Control		*t* value
	Mean	Std.	Mean	Std.	
Outcome					
2011 science	382.52	68.28	353.23	65.13	4.17***
Baseline					
2010 math	393.18	74.15	350.43	58.13	6.03***
N	205		163		

*** $p < 0.001$

Descriptive statistics of students' achievement on 2010 math scale scores and 2011 science scale scores for both the experimental and control groups are presented in Table 2. As this table indicates, experimental students significantly outscored control students in the baseline math scores ($t = 6.03$, $p < 0.001$), as well as in the outcome science scores ($t = 4.17$, $p < 0.001$). Thus, in order to control for the baseline differences, we used students' math score as a covariate in our analysis.

A residualized change model analyzed the impact of the laptop program on students' Spring 2011 science achievement, after controlling for their Spring 2010 mathematics achievement. We used ELL status, Hispanic status, and Free- and reduced-lunch status as moderators in each respective regression model. The results are shown in Tables 3, 4, and 5. It can be seen from all three regression tables that, overall, the laptop program does not have a significant positive effect on students' science scores; however, there are significant interaction effects. As shown in the final model in Table 3, the interaction between ELL and treatment revealed a significant positive effect, indicating that ELLs who participated in the laptop program had significantly higher science scores, compared with their counterparts in the control group (coef. = 86.48, $p < 0.05$, effect size = 0.59). Figure 1 shows the corresponding regression-predicted science scores (controlling for students' baseline mathematics score) in both the experimental group and the control group for ELLs and non-ELLs. Further, although the laptop program showed little effect for non-ELLs' science achievement, it was beneficial for ELLs. Similarly, Table 4 and Fig. 2 present findings for the Hispanic students and likewise indicate that the laptop program helped Hispanics improve their science achievement, compared with their peers in the control group (coef. = 77.40, $p < 0.05$, effect size = 0.53). In addition, Table 5 and Fig. 3 show that free-lunch recipients within the laptop program had significantly higher science achievement than their counterparts in the control group (coef. = 74.24, $p < 0.05$, effect size = 0.53), after controlling for their prescores. In sum, although the laptop program did not have an overall positive effect on students' science achievement, it did provide differential support in promoting gains specifically for at-risk students (i.e., ELLs, Hispanics, and Free-lunch recipients) in their science achievement.

Technology Use and Scientific Understanding

In addition to the impact of laptop and technology use on students' academic achievement, this study also examined how students used technology, especially DES, to facilitate their scientific understanding. Qualitative analysis on classroom observations and interviews with both teachers and students revealed that computer-supported experimental simulations and animations potentially reinforced students' scientific conceptualization and comprehension. With access to online resources, students were able to interact with visual representations of those science phenomena. Students were given clear visual examples, from the smallest of subjects—atoms at the molecular level—to larger-scale phenomena, such as the stages of the water cycle. In one classroom, when presenting a lesson about the periodic table, the teacher asked students to watch a video about this topic on DES, which provided them with a better understanding of elements, compounds, and chemicals. In another classroom, students were learning about tsunamis. The teacher indicated that pre-intervention, when learning entirely from textbooks, students could only read a paragraph and possibly see a picture of a crack in the ocean floor, but with technologically supported visual aids, students were able to see approximately 70 animations of the causes of a tsunami, as well as a video clip of the physical destruction that results afterward. In this way, they were more easily able to memorize and understand that scientific information than they would have solely by reading textbooks. Students were also able to engage in the program's interactive activities to enrich their understanding of scientific phenomena. For example, during one classroom observation, when students were learning about soil and Ph levels, the activity allowed them not only to view the layers of the soil, but also to choose different types of weather, such as rain or snow, and see their effects on the soil. According to our classroom observations, students appeared to experience greater enjoyment when participating in the interactive activity than when only watching the videos.

Additionally, teacher and student interviews suggested that students obtained more hands-on understanding through interactive videos and virtual laboratories than previously used traditional instruction. According to an interview with one teacher whose students were learning about volcanoes, the program allowed them to create different models of a volcano in the virtual laboratory through

Table 3 Additive and interactive regressions of 2011 CST science test scores with ELL as a predictor

	5th grade CST science scaled score				
	(1) Pre-math and treatment	(2) (1) with ELL status	(3) (2) with interaction between ELL and treatment	(4) (2) with interaction between pre-math score and ELL	(5) final model
4th math scaled	0.65***	0.61***	0.61***	0.54***	0.54***
	(0.04)	(0.04)	(0.04)	(0.06)	(0.06)
Treatment	1.63	0.43	3.49	0.05	5.68
	(5.58)	(5.50)	(8.87)	(5.50)	(8.91)
ELL		−20.38***	−17.46*	−61.00^{+}	−119.32**
		(5.59)	(8.66)	(31.23)	(38.09)
ELL × treatment			−4.86		86.48*
			(11.03)		(38.42)
ELL × Pre-math				0.11	0.29**
				(0.08)	(0.10)
ELL × treatment × pre-math					−0.27**
					(0.10)
Constant	126.45***	153.60***	151.27***	180.37***	180.16***
	(14.32)	(15.93)	(16.81)	(25.75)	(25.56)
R^2	0.453	0.472	0.472	0.475	0.485
N	368	368	368	368	368

Coefficients are unstandardized. Standard errors in parentheses. Pre-math = 4th grade CST math subtest scores

$^{+}$ $p < 0.10$; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

Table 4 Additive and interactive regressions of 2011 CST science test scores with Hispanic as a predictor

	5th grade CST science scaled score				
	(1) Pre-math and treatment	(2) (1) with Hispanic status	(3) (2) with interaction between Hispanic and treatment	(4) (2) with interaction between pre-math score and Hispanic	(5) final model
4th math scaled	0.65***	0.58***	0.58***	0.49***	0.49***
	(0.04)	(0.04)	(0.04)	(0.06)	(0.06)
Treatment	1.63	−2.38	−5.95	−3.06	−3.53
	(5.58)	(5.45)	(9.83)	(5.44)	(9.85)
Hispanic		−30.37***	−33.67***	−88.06**	−132.68***
		(5.85)	(9.58)	(31.75)	(38.18)
Hispanic × treatment			5.07		77.40*
			(11.64)		(38.56)
Hispanic × pre-math				0.15^{+}	0.28**
				(0.08)	(0.10)
Hispanic × treatment × pre-math					−0.22*
					(0.10)
Constant	126.45***	173.23***	175.99***	210.92***	211.04***
	(14.32)	(16.51)	(17.70)	(26.21)	(26.21)
R^2	0.453	0.490	0.491	0.495	0.501
N	368	368	368	368	368

Coefficients are unstandardized. Standard errors in parentheses. Pre-math = 4th grade CST math subtest scores

$^{+}$ $p < 0.10$; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

Table 5 Additive and interactive regressions of 2011 CST science test scores with free-lunch as a predictor

	5th CST science scaled				
	(1) Pre-math and treatment	(2) (1) with free-lunch status	(3) (2) with interaction between free-lunch and treatment	(4) (2) with interaction between pre-math score and free-lunch	(5) final model
4th math scaled	0.65***	0.56***	0.56***	0.43***	0.43***
	(0.04)	(0.04)	(0.04)	(0.08)	(0.09)
Treatment	1.63	0.67	−5.73	0.30	−2.50
	(5.58)	(5.38)	(11.00)	(5.37)	(11.09)
Free-lunch		−34.59***	−40.05***	−105.68**	−151.16***
		(6.45)	(10.42)	(39.64)	(45.41)
Free-lunch × experiment			8.31		74.24*
			(12.45)		(36.91)
Free-lunch × pre-math				0.17^{+}	0.30*
				(0.10)	(0.12)
Free-lunch × experiment × pre-math					−0.20*
					(0.10)
Constant	126.45***	185.07***	189.95***	242.43***	242.58***
	(14.32)	(17.61)	(19.08)	(36.11)	(36.00)
R^2	0.453	0.493	0.493	0.497	0.503
N	368	368	368	368	368

Coefficients are unstandardized. Standard errors in parentheses. Pre-math = 4th grade CST math subtest scores

$^{+}$ $p < 0.10$; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

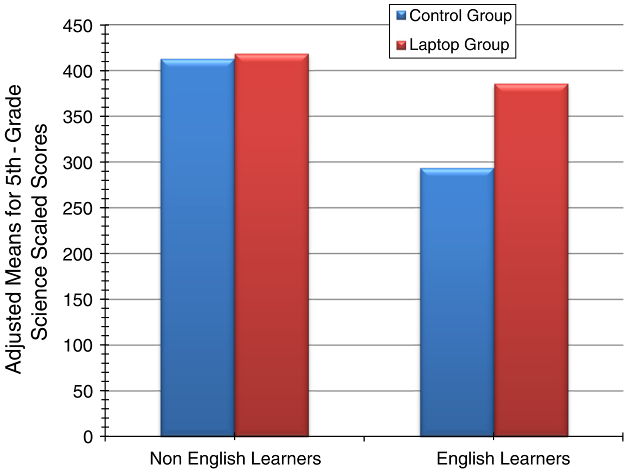

Fig. 1 Regression-adjusted science scores in laptop group and control group between ELLs and non-ELLs

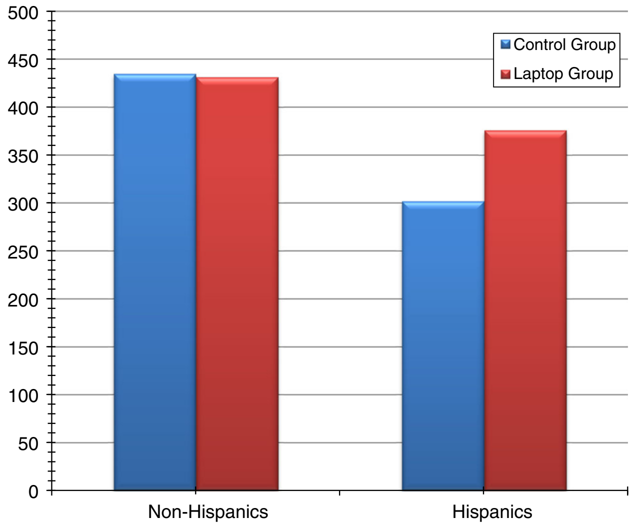

Fig. 2 Regression-adjusted science scores in laptop group and control group between Hispanics and non-Hispanics

control of various parameters (such as viscosity, temperature, and gas content). After setting the parameters, students viewed the different kinds of volcanoes they had created. In another classroom, students studying tsunamis were working in collaborative groups and used the search tool in DES to research the subject. In addition to the information provided by DES, students also collected videos, animations, and texts from the encyclopedia. Later, each group created a presentation using PowerPoint to introduce the concept of tsunamis to their peers, in which way students gained a deeper understanding about tsunamis through sharing with others.

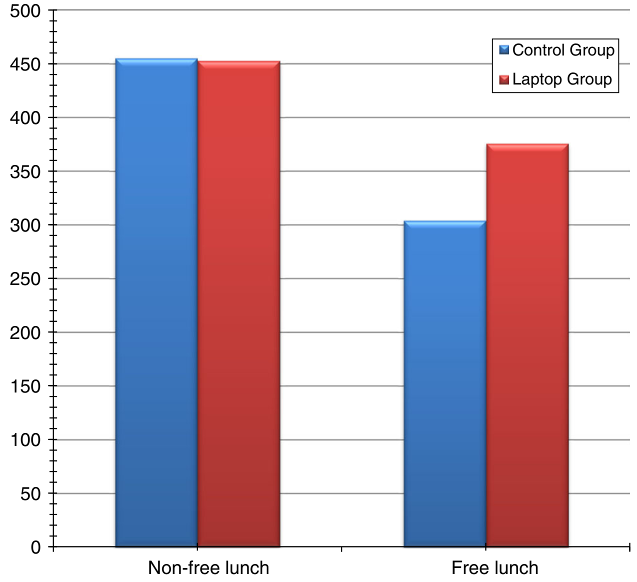

Fig. 3 Regression-adjusted science scores in laptop group and control group between free-lunch receivers and non-free-lunch receivers

Teacher interviews further indicated that access to visual resources was especially helpful for ELLs, who were provided with better background knowledge and were able to make better connections with the aid of these resources. In addition, DES includes an electronic textbook, in which video and audio elements are embedded, and vocabulary support was provided. For example, text-to-speech software is embedded in DES so that students could access a word's pronunciation by clicking on the text. Students were more engaged and motivated to learn with these scaffolding tools. As a fifth-grade teacher noted,

> There are certain things, especially in science, that are nuanced or very esoteric and very hard for [ELLs] to understand because they don't have a great deal of cultural context, and so if they can see a video or play an animation, it really helps them out.

In some classrooms, social media was also used extensively by students and teachers to support science learning. During the observation of one focal classroom, the teacher conducted the learning activity using Glogster, an interactive poster which can combine text, audio, video, still images, and hyperlinks and can be shared with others electronically. In one lesson, students were asked to choose one topic among earthquakes, volcanoes, and the atmosphere and make a Glogster poster in which they could embed pictures, videos, and informative links that they found on the Internet and on DES. Students then shared their products with each other, thus learning about various topics through different lenses. Our observations indicated that students expressed enjoyment when working with Glogster and demonstrated creativity with the information they learned (as observed in one case, by the addition of animated arrows to highlight key points).

Individualized Learning and College/Career Readiness

Access to netbooks and the increased use of technology in classrooms also transformed student learning in a more individualized and differentiated direction. The one-to-one laptop environment allowed each student to work at his or her own pace and to choose learning materials at their own level. Even when collaborating on the same project, students were able to work at different levels with the support of technology. One teacher mentioned that when she had several students working on the same projects, she selected videos that met each student at his or her individual learning level, and they all worked together to analyze and discuss the similar types of videos through different lenses; additionally, those who finished early could move on to other academic activities. Another finding of both the observations and the interviews is that laptop use helped foster positive peer interaction. One teacher noted, "They are becoming good teachers, not just good learners. I have some kids [who] can teach some of the stuff in small groups."

Both teachers and students told us that access to online resources helped open up new horizons of future science-related study and careers for all students. According to teacher interviews, the technology opened up many doors for the students; having all the knowledge and resources at their fingertips—as well as the opportunity to perform their own research—really helped students to see the opportunities available to them. As one teacher stated,

> Being…more tech savvy is beneficial for everyone and they understand how to go into those resources. I think it's opened up a lot of kids' eyes of kids as far as possibilities for later on. So it will be interesting when we start the project to see where the kids really kind of home in on their career path as well as their university interests.

Furthermore, equal access to technology and online resources was perceived as particularly beneficial for low-income, at-risk students, since they may have less access to these resources in their out-of-school environments. One teacher commented, "We've seen how far they can rise in a year with the technology…because a lot of students don't have computers and Internet in their home and we've just opened up so many doors for them."

During student interviews, several students talked about how their frequent use of computers for science learning strengthened their motivation to pursue STEM-related careers. As one student said, "Using netbooks helps us know about what we need in college and in high school to get to that job." A few students said that they became more interested in medicine after watching anatomical videos online. An ELL boy, according to one teacher, became completely fascinated by the respiratory system after watching videos on the subject and said that he "can't wait to be a doctor." Another student was intrigued by the videos shown on DES website and indicated that using a netbook and various other technologies has increased his interest in becoming a videogame designer. In summary, technology and online resources appear to have substantially expanded students' interests in future careers and provided them with a vast amount of information, including some familiarity with STEM-related majors and careers at an early stage.

Discussion

This study investigated fifth-grade students' use of the online science program, DES, and other technologies in a one-to-one laptop environment and the effects of this program on diverse learners' science achievement. Our results suggest that one-to-one laptop programs can be helpful in closing the gap for at-risk students' science achievement, as gains were limited to students who were ELLs, Hispanic, and low-income. Interviews and observations suggest that computer-supported visual representations and interactions aid students' science understanding and facilitate scientific inquiry. These technologies appear especially beneficial for at-risk students, allowing them equal access to online resources that were less accessible to them in out-of-school environments. At-risk students also receive better scaffolding when learning science by these methods, due to the greater prominence of visual clues and instructional support. The combination of the one-to-one laptop environment and students' technology use not only changes the means by which students learn science, but also makes their learning more individualized. Students are able to learn at their own pace with the support of level-appropriate online material. Finally, science-related videos and other resources also strengthen some students' motivation to pursue STEM-related careers.

It is also important to note that providing students and teachers with access to technology will never generate a positive "technology effect" by itself and will not automatically increase students' achievement or change the nature of teaching and learning (Zucker 2004). Rather, access to laptops and other technologies can be the very first step toward the effective use of technology in the form of instructional and learning tools (Shapley et al. 2010). This study re-affirmed that laptops can be a valuable tool for science instruction, but it also reconfirmed that effective implementation of technology requires sufficient and ongoing professional development, robust infrastructure and technical support, a supportive school culture, and positive teacher belief and readiness to use technology in the context of instruction.

In the following section, we will present the implications of this study for professional development, policy and practice, and future research.

Professional Development

Teaching approach and teachers' beliefs are crucial to the integration of technology in teaching and learning. The amount of professional development and support provided proved to be a vital factor in influencing teachers' beliefs and their readiness to use technology in teaching (Inan and Lowther 2010; Murphy et al. 2007). In this study, although professional development was provided extensively and continually, teachers still voiced concerns about the challenges they encountered in the program and made suggestions for better training in the future.

According to our interviews and classroom observation, at the beginning of this program, a few teachers felt overwhelmed by the array of new technologies provided and expressed frustration. For example, some teachers mentioned that although it was nice to have such a large amount of resources at hand, their actual use in instruction was challenging. Teachers lacked specific guidance about which picture, video, or activity should be used in a given lesson plan. It took some teachers additional time and energy to explore the new tools, and they sometimes felt frustrated and isolated using these technologies. Other teachers pointed out that certain videos were outdated and/or not geared toward grade-level science standards, making it difficult to select the most appropriate and suitable segments. This demonstrates the need for strengthened professional development, which focuses on helping teachers better integrate technology into their lessons. According to teachers' feedback, future professional development could be improved in the following ways.

First, some teachers suggested that the summer training was too extensive and that they were given too much information, too quickly. Teachers pointed out that they should be given more time to play with the technology, explore its use, and ask questions. Further, some teachers suggested that professional development should ideally focus on one new tool at a time, allow enough time to practice its use, and discuss challenges or problems before moving on to the next one. Second, some teachers stated that they would have preferred to receive more specific guidance about how these technologies could be used for classroom learning. As one stated, it is better to "go through the whole lesson step by step and know exactly how you are going to use technology with students." Third, some suggested that professional development should be adjusted to the individual skill levels of the teachers. In this way, professional development could be provided to teachers in smaller groups based on their technological skills: those who seem new to technology, those who have been exposed to it, and those who are more advanced. Professional development could also be differentiated for people who have different teaching needs so that teachers spend time learning only about the components of the technology that are relevant to their teaching styles. Finally, teachers suggested that there should be more collaboration and sharing among teachers during the implementation of technological innovations. As one teacher stated,

> It will be neat to talk about and hear what teachers do in classrooms with technology, like what things are really working, and that maybe give us ideas [about what to] use in our classrooms… Maybe collaborate and share a little bit more, you know on Discovery Education Science you can share with the district and just create [a] kind of database for good lessons per grade level, internet sites and address, things like that they do in their classrooms that we can use.

Also, it was suggested that small groups working together, even simply to offer encouragement, have the potential to be helpful for teachers in this sphere.

Policy and Practice

Policymakers, educators, and school administrators always want to be ensured of the benefits of technology-related programs for improving educational outcomes before investing in such programs (Bebell and O'Dwyer 2010; Lei and Zhao 2008). It is important for policymakers to note that technology-innovation decisions should not just be concerned with providing devices. Besides the costs of purchasing hardware, the costs of ongoing professional development provided for teachers, timely and available technical support, and updated hardware and software over time must also be budgeted, because all of them are tightly linked to the success of a technology program (Dunleavy et al. 2007; Lei and Zhao 2008).

For classroom practices, this study suggested that computer-based visual presentations and animations facilitated students' learning and understanding of abstract science concepts, particularly for ELL students and that the use of technology helped students better conduct inquiry-based scientific activities. It is important to note that not all technologies automatically benefit students' and especially at-risk students' science learning. Schools and teachers need to choose those technologies that could be best integrated into their curriculum. For example, in our study, because of the large number of at-risk students and considering the academic language demands as well as the cognitive demand imposed on them, the school district chose software that features e-reading, text-to-speech software, and interactive glossaries, which could scaffold students' scientific concept learning and computer-supported experimental simulations and animations, which could facilitate students' comprehension of scientific phenomena and processes. In addition, in the one-to-one laptop environment, teachers also made use of free social media to engage students in science learning and to improve students' development of other skills such as digital literacy and collaborative learning.

In terms of the implication for product designers, it is suggested that software- and online-program designers should focus on improving not just the quality of visual representations, but also how they are labeled/described, and on close collaboration with schools, in order to develop standards-based materials for teachers that are compatible with current common core standards.

Future Research

Several limitations also exist in this study. First, because the state of California does not test fourth grade students in science, the study had to instead use students' mathematics scores as the baseline data. Second, we could only use CST scores to measure students' science learning achievements; however, some of the benefits that technology brought to students' learning could not be measured by standardized tests, such as students' scientific literacy and other twenty-first century skills. Third, interview data alone was used to assess student attitudes, rather than also surveys. Fourth, this study only examined the first year use of technology on students' science learning.

To overcome these limitations, future research focusing on examining the effects of technology use on students' science learning should gather better baseline data on scientific and technological knowledge and also use assessments that better capture the range of learning outcomes that technology could contribute to. Though new tests for the Next Generation Science Standards have not been developed, due to the nature of these standards—which emphasize a broader range of scientific understanding, skills, and competencies—test designed to the standards could potentially be valuable in this kind of research. Changes in attitudes should be assessed by a range of measures, to include not only interviews, but also pre- and post-surveys. In addition, longitudinal studies can better evaluate whether any impacts are enduring.

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