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PROCEDURES AND EXAMPLES FOR EXAMINING A WIDE RANGE OF STUDENT OUTCOMES FROM 1:1 STUDENT COMPUTING SETTINGS

Procedimientos y ejemplos para examinar la variedad de resultados de aprendizaje a partir de aplicaciones del programa 1:1

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Abstract:
Past research has shown one-to-one student computing programs can have a variety of different impacts depending on their context. Using a wide range of data, this paper summarizes the second year implementation results from a newly opened US high school where every student and teacher has a MacBook laptop computer. Measures like attendance, behavior, and course taking patterns are routinely collected by schools but are rarely used in research and evaluation efforts. In the current project, a rich empirical dataset was developed to help better understand the complex relationships between technology practices over time and student outcomes across different student cohorts. It is our hope that the procedures and examples herein will illuminate the potential efficacy and opportunities for examining a wider range of potential quantitative impacts from 1:1 computing programs.
Key Words: *1:1 computing, exploratory data analyses, outcome measures, student achievement, research and evaluation, attendance data, survey methods.*

Resumen:
La investigación ha mostrado que los programas de un ordenador por niño tienen diferente impacto según el contexto en el que se lleven a cabo. Usando un amplio abanico de datos, este estudio resume los resultados de un año de aplicación en un instituto americano recién inaugurado en el que cada alumno y profesor tenían un portátil MacBook. Se recogen sistemáticamente medidas como la asistencia, el comportamiento y los patrones de realización de los cursos en las escuelas, pero no se suelen usar para investigar o evaluar. En este estudio, se desarrolló una base de datos empírica rica para ayudar a comprender las complejas relaciones entre las prácticas tecnológicas a lo largo del tiempo y los resultados de aprendizaje en diferentes grupos de alumnos. Esperamos que los procedimientos y ejemplos que presentamos iluminen la posible eficacia y otras oportunidades para examinar un abanico más amplio de impactos cualitativos de los programas 1:1.
Palabras clave: Programa 1:1, análisis de datos exploratorios, medidas de resultados de aprendizaje, logros de los alumnos, investigación y evaluación, datos de asistencia, métodos de cuestionario.

1. Introduction

> In a nutshell: schools are spending billions on technology, even as they cut budgets and lay off teachers, with little proof that this approach is improving basic learning (Richtel, 2011, p. 8).

Few modern educational initiatives have been as far-reaching as placing computer-based technologies into school classrooms. Believing that increased use of computers will lead to improved teaching and learning, greater efficiency, and the development of important student skills, educational leaders and policy makers have made major investments in educational technologies.

As increased access and more powerful technologies have permeated classrooms, the variety of ways in which teachers and students use computer-based technologies has also expanded. Research exploring the role and effects of computers on teaching and learning suggests a wide variety of potential benefits including increased student engagement, increased efficiency, and the potential to increase student learning. However, for any effect to be realized from educational technology, the technology must be actively and frequently used. Understanding this, research has continually explored what factors and conditions are necessary to allow different technology uses to occur (Bebell, Russell, & O'Dwyer, 2004; Becker, 1999; O'Bannon & Thomas, 2014).Technology access, training and professional development, school leadership, and teacher’s pedagogical beliefs all play major roles in how teachers’ use educational technology.

Given the ways in which technology resources have been traditionally distributed within schools (e.g., in labs, libraries, or on shared carts), many observers have theorized that the scarcity of major student achievement outcomes are in part because shared computer and technology access typically results in such limited use and impact (Bebell & O'Dwyer, 2010; Papert, 1996). In fact, both proponents and opponents of educational technology agree that the full effects of any digital resource in school cannot be fully realized until the technology is no longer a shared resource (Oppenheimer, 2003; Papert, 1993; Papert, 1996). Recognizing the limitations of traditional educational technology shared across students and classrooms, there has been a steady and growing interest in 1:1 technology scenarios, whereby all teachers and students have full access to technology.

Initiatives to provide computers to students at a 1:1 ratio first began in 1989 when the Methodist Ladies College in Australia required all incoming Grades 5 through 12 students to purchase a school-approved Toshiba laptop. Similar programs were adopted by other Australian schools and by the late 1990s over 50,000 Australian children were reported to have their own laptop computer in school (Stager, 1998). Within the United States, several schools experimented with laptop programs during the 1990's. Typically, these isolated programs were financed through one-time budget opportunities, fund-raisers (Stevenson, 1999), local foundations and grants (Cromwell, 1999), and increases in tuition at private schools (Thompson, 2001). In addition, district or state funded 1:1 programs have been piloted in a wide variety of US settings including initiatives in South Dakota, Pennsylvania, New Hampshire, Texas, California, Florida, Massachusetts, Maine, and Michigan (Bebell & O'Dwyer, 2010; Zucker & Hug, 2008). Over the past five years, Uruguay launched the world's first country-wide 1:1 initiative, having distributed over one million laptops to primary school students.

Despite the massive investments and expectations for 1:1 computing programs, there has been only limited research showing the "proof that this approach is improving basic learning" (Richtel, 2011, para. 8). One obstacle in summarizing the impacts of 1:1 student computing programs is that 1:1 only defines the access ratio of technology to students, and says nothing of the actual teaching and learning practices. There is a general presumption that 1:1 enables more constructivist pedagogies and student centered classrooms, but the only unifying feature of 1:1 program is the ubiquity of the student device, not a specific application or use. In addition, it is critically important to realize that 1:1 programs can be initiated for vastly different purposes and intended student outcomes. One program may equip all students in fifth grade with iPads for the sole purpose test preparation and practice drills before a high-stakes exam. Another school may use these same resources and technologies to provide their fifth graders with more opportunities to share and comment on each other's work. In each of the settings, the goals, teaching and learning practices, and the relevant study outcomes would be markedly different.

The available research and evaluation results suggest that 1:1 laptop initiatives can have a number of positive outcomes, including: increased student engagement (Bebell & Kay, 2009; Cromwell, 1999; Donovan, Green, & Hartley, 2010; Mouza, 2008) decreased disciplinary problems(Maine Education Policy Research Institute, 2003)increased use of computers for writing, analysis and research (Baldwin, 1999; Bebell & Kay, 2009; Grimes & Warschauer, 2008; Lowther, Inan, Ross, & Strahl, 2012), and a movement towards student-centered pedagogy (Lowther, Inan, Ross, & Strahl, 2012; Mouza, 2008; Russell, Bebell, & Higgins, 2004). Early research in 1:1 computing programs (Baldwin, 1999) documented students spending less time watching television and more time on homework. Despite these results, it is important to consider that educational technology and its uses are evolving so quickly that much of the literature from even five years ago fails to address the dynamic digital learning tools that are now accessible.

With increased pressure for more quantitative outcomes, a smaller number of studies have focused on the relationship between student achievement and participation in laptop programs. For example, Gulek and Demirtas (2005) examined state test scores of students participating in a voluntary 1:1 laptop program at a California middle school. A significant difference in both math and English Language Arts (ELA) test scores was found for students participating in the program a year or more, even after statistically controlling for prior achievement levels. A 2010 special edition of the *Journal of Technology, Learning and*

Assessment published a special issue exclusively on empirical research emerging from 1:1 technology settings and included three papers that explored student achievement outcomes. Studies from Massachusetts (Bebell & Kay, 2010), Texas (Shapley, Sheehan, Maloney, & Caranikas-Walker, 2010) and California (Suhr, Hernandez, Grimes, & Warschauer, 2010) each examined the impact of 1:1 participation and practices on measures of student achievement and found statistically significant impacts in English/Language Arts performance.

Although many political leaders suggest that providing students access to powerful and widespread technology will result in a wide array of positive potential outcomes, the impacts on student learning (as typically measured by annual test scores) remains a focus for many. Despite growing interest in and excitement about 1:1 computing, there remains a lack of sufficient, sustained, large-scale research and evaluation that focuses on teaching and learning in these intensive computing environments (Fairbanks, 2013). Specifically, there is a lack of empirical evidence relating use of technology in 1:1 settings to measures of student achievement and other quantitative outcomes. This is a particularly salient issue in light of costs implementing and maintaining 1:1 laptop initiatives and the current climate of educational policy whereby student achievement is held as the benchmark of successful school reforms and initiatives. As documented in the opening quote of this paper, many observers feel that research and evaluation of educational technology has failed to keep pace with the investments and expectations of the public.

This paper aims to serve two related purposes. First, we seek to contribute to the growing literature on 1:1 computing by summarizing the second year implementation results from a newly opened US high school where every student and teacher has a MacBook laptop computer. These results portray a wide range of evolving teaching and learning practices over a short 1:1 implementation period. Moreover, students individual survey results were merged with a wide range of school-provided datasets (test scores, attendance data, course history, socio-economic status, disciplinary records, and a host of demographic variables) to create a unique opportunity for exploratory data analysis. It is our hope that the procedures and examples we share herein will inspire others to think critically about the importance of how they define and measure “success” or what constitutes “proof”. Thus, the second purpose of this paper is to demonstrate the potential efficacy and opportunities for examining a wider range of potential quantitative impacts from1:1 computing using survey methods and secondary data analyses.

2. About the NPS-21 Teaching and Learning Study (September 2012 to June 2014)

This paper presents selected results from the Natick Public Schools 21st Century Teaching and Learning Study. The aim of the research was to document the implementation and explore short-term impacts of a 1:1 student-computing program at a newly opened US high school. By combining longitudinal student survey data with school records, it was possible to explore more nuanced differences in student experience and a wide range of outcomes. Thus, this paper provides a summary of the study results, but also exemplifies how increasingly nuanced investigations across a range of success indicators/outcomes may provide a fuller picture of program implementation and outcomes. First, we provide some context by describing the Natick School, their overarching research/evaluation questions, and a summary of the methodology/response rates. Additional information about the school community, methodology, results and study partnership can be found at: www.bc.edu/Natick21.

Natick High School lies in the western suburbs of Boston, Massachusetts and was entirely rebuilt as one of region's most technology rich high school campuses, with 1:1 MacBooks for all students and other state-of-the-art digital teaching and learning resources. Beginning with the school opening in Fall 2012, Natick schools partnered with Boston College researchers to document and quantify the extent and ways students and teachers were incorporating digital teaching and learning tools across the curriculum (Fairbanks, 2013). A two-year pre/post descriptive research and evaluation study was funded independently by the school district. A serendipitous pilot survey collected from 92% of Natick seventh grade students in Fall 2010 provided a valuable snapshot of learning practices as well as attitudes and beliefs towards school and computing technologies before 1:1 computing was available. Two years later, this same cohort of students became the first group of entering ninth graders at the new school facility and 1:1 computing initiative. Over the course of the 2012-2013 and 2013-2014 school years, students' and teachers' practices in the new technology-rich high school were documented through a series of online surveys, focus groups, and classroom observations. Practices observed and recorded during these two years were compared to past levels (recorded in the 2010 student survey) and used to provide feedback and formative evaluation results to the school and community leadership.

As shown below in Table 1, teacher survey response rates ranged from 95% to 85%. Student response rates never dropped below 85%. These response rates suggest the results presented herein are likely representative of the entire school population.

Table 1

Natick student and teacher response rates/parental consent eligibility

School Name	2012 – 2013 Total # of students	Fall Surveys (2012) # Completed Surveys	Fall Surveys (2012) Response rate	Spring Surveys (2013) # Completed Surveys	Spring Surveys (2013) Response rate	Parent Consent Parent Consented	Parent Consent % of students	2013 - 2014 Total # of students	Spring Surveys (2014) # Completed Surveys	Spring Surveys (2014) Response rate
Kennedy Middle School	303	292	96%	283	93%			318	306	96%
Wilson Middle School	426	411	96%	410	96%			462	411	89%
Natick High School	1354	1217	90%	1072	79%	819	60%	1415	1166	82%
Total	2083	1920	92%	1765	85%	819	60%*	2195	1883	86%

School Name	2012-2013 Total # of teachers	Fall Surveys (2012) # Completed Surveys	Fall Surveys (2012) Response rate	Spring Surveys (2013) # Completed Surveys	Spring Surveys (2013) Response rate	2013-2014 Total # of teachers	Spring Surveys (2014) # Completed Surveys	Spring Surveys (2014) Response rate
Kennedy Middle School	31	30	97%	23	74%	29	29	100%
Wilson Middle School	47	44	94%	37	77%	43	28	65%
Natick High School	96	92	96%	92	96%	105	93	89%
Total	174	166	95%	152	87%	177	150	85%

*Parent consent was only obtained for high school students, where school records such as standardized test scores were used. During Year 2, consent was obtained for 236 of the incoming 9th graders, a rate of 63%.

In addition to documenting the range of practices afforded through the new facilities and resources, the study sought to examine the impacts of these emerging practices on a wide range of student outcomes. Such quantitative student measures like attendance, behavior, and course taking patterns are routinely collected by schools but have been only rarely used for exploratory research and evaluation purposes. Through this research collaboration, a rich empirical data set was developed to help better understand the complex relationships between technology practices over time and student outcomes across different student cohorts.

3. Example procedures and results from the NPS-21 Teaching and Learning Study

The purpose of sharing these study results is two-fold. First, the pre-post results demonstrate how increased access to student laptops shifted teaching and learning practices over the initial year of a new 1:1 implementation. Second, the results serve to demonstrate how a wide range of analytic approaches and student outcomes can be explored using secondary analyses of school data and survey results.

Perhaps one of the most universal and salient results from most 1:1 computing implementations is the major increase in students' use of technology in school. To empirically demonstrate changes in teaching and learning practice over time, pre/post study designs are typically employed. However, schools too often cannot measure how teaching and learning is evolving in 1:1 settings because data is never collected in pre-1:1 settings. In the current example, a fortuitous coincidence occurred in Fall 2010 when 92% of the seventh grade student population field-tested an extensive survey of practices and attitudes towards learning practices and technology, providing an ideal student measure of pre-1:1 conditions. Figure 1 shows the frequency of pre-1:1 computing practices for seventh grade students measured by the Fall 2010 survey (blue) and again two years later at the end of their ninth grade year and first year in the 1:1 student computing setting (red). To provide an additional comparison point, a new cohort of seventh grade students (still without 1:1 computing access) completed the same survey in Fall 2012 (green).

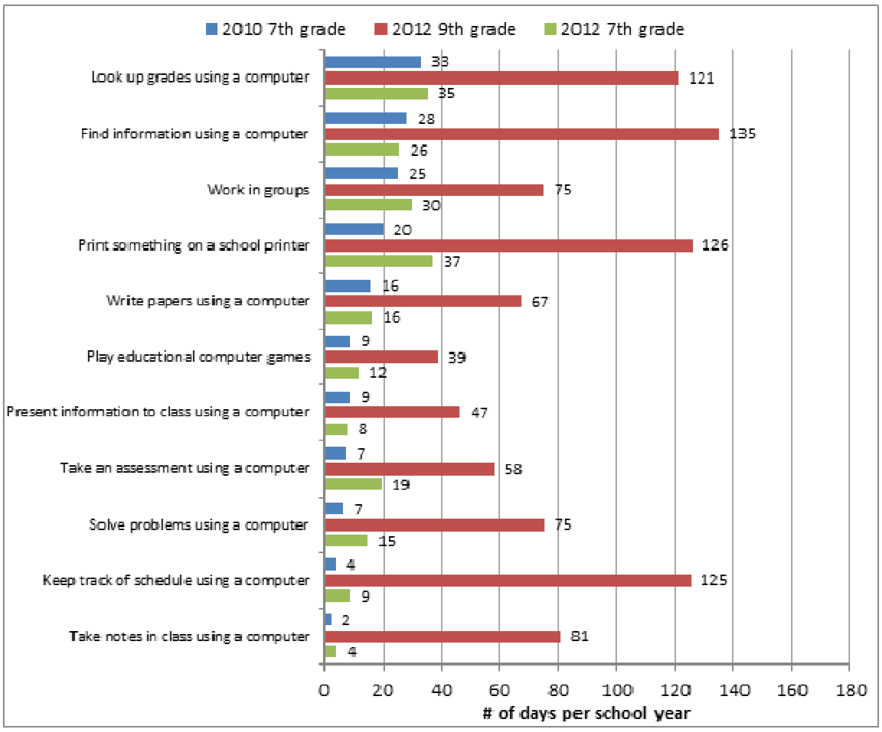

Figure 1. Average frequency of student classroom activities as reported by 7th graders' in 2010, the same student cohort as 9th graders in 2012, and the 2012 7th grade cohort.

When examining the Fall 2012 student survey results across the 1:1 computing grades, students' use of computers in class was extremely frequent, often occurring nearly every day in most classes. Seventh grade students, who lacked 1:1 computing access across all survey administrations served as a natural comparison group. They reported relatively little use and little change in how they used computers in school. Comparing the Fall 2010 and Fall 2012 survey results, we observe a robust increase in the frequency of students' computer use. Collectively, in the two years between survey administrations, students' use of technology increased more than ten-fold for the 2012 9th grade cohort. In these two years, the 9th grade student cohort reported major increases across a wide variety of educational technology practices. Some of the largest proportional increases occurred with activities such as taking notes in class and keeping track of schedules, which occurred about 30 times more often (approaching every day) for 9th graders in 2012 than they reported as 7th graders in 2010.Because few differences were observed between the 2010 the 2012 seventh grade results, it is justified in attributing these changes to the increase in student resources through the 1:1 program and new school facility.

Figure 1 shows that even in the first year of implementation, students were greatly increasing how frequently they used technology in school for a variety of purposes. In these pre-post analyses of survey results the student average is used to demonstrate and quantify how teaching and learning is changing. Such summative evidence showing changes in practices may be extremely valuable for demonstrating the efficacy of the new programs and their impact. However, another benefit of research and evaluation is using data for formative reflection to improve action planning, decision-making, and resource allocation grounded in program data and results.

Using school or program-wide averages are of limited value for explaining the complex dynamics of learning in these settings. Too often, research and evaluation in 1:1 computing environments focuses on documenting the overall program outcomes, and schools miss opportunities to leverage research and evaluation data in monitoring and sustaining their efforts. Even in the age of computer-based surveys, few school or district-based initiatives use their own data to address how their programs may be impacting different students or to increase their understanding of the implementation process. For example: How is a 1:1 program impacting different cohorts within the school differently? If you imagine a school as a dark, complex network of caves/classrooms, exploring the data for such formative reflection is akin to turning on a flashlight. Using a single survey administration can provide a cross-sectional snapshot of the program at a specific moment in time, as shown below in Figure 2.

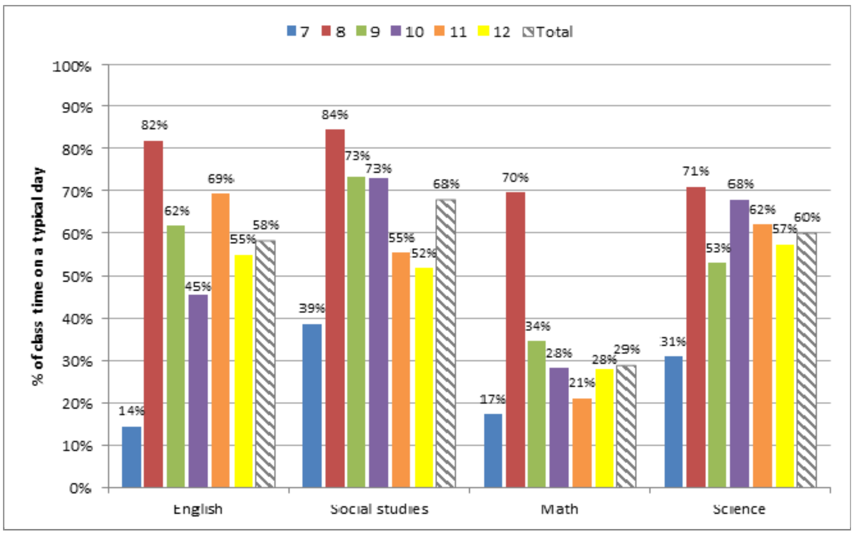

Figure 2. Average frequency of students' technology use across 7th through 12th grade.

Figure 2 provides a snapshot of student computer use at the end of the first year of the 1:1 Natick implementation across grade levels and subject areas. Examining the Spring 2013 averages across grade levels, students' average use of computers in the 1:1 grade levels (Grade 8-12) varied across grade levels ad subject areas. Student use of technology in seventh grade classes, included here to provide a non-1:1 comparison, was substantially less frequent in the same classes than for those students at the end of their first year with 1:1 computing access. Variations across average student computer use in the different 1:1 grade levels (8-12) suggests further differences in student experiences across the program implementation. For example, 8th grade students who had 1:1 computing access but were not in the new high school facility reported the most frequent overall use of any participating grade level, suggesting that student devices may be a more critical component of the implementation than other features of the new building facility. Figure 2 also demonstrates how student experience with technology varied across their subject areas.

Such variation across subject areas and grade levels demonstrates how students' computing access is not the only important variable in understanding how and why students use technology in their classes. The literature has identified many important considerations in the success of 1:1 student computing programs that can be defined and measured via surveys (teachers' pedagogical background, leadership, etc.)(Russell, Bebell, & Higgins, 2004). However, every implementation will be as unique as its program or school. As such, more deeply exploring patterns of use and 1:1 implementation strategies is a valuable tool for schools in evaluating and sustaining their 1:1 programs. In other words, the more a school or program can empirically reflect on its implementation, the greater their ability to understand potential obstacles and deepen best practices. For a variety of reasons, even programs engaged in research and evaluation efforts often fail to capitalize on using exploratory data analysis to better understand the vagaries of their own program and implementation. In the following examples, we continue exploring student survey data from the Natick study to demonstrate how such results can illuminate an early stage of implementation.

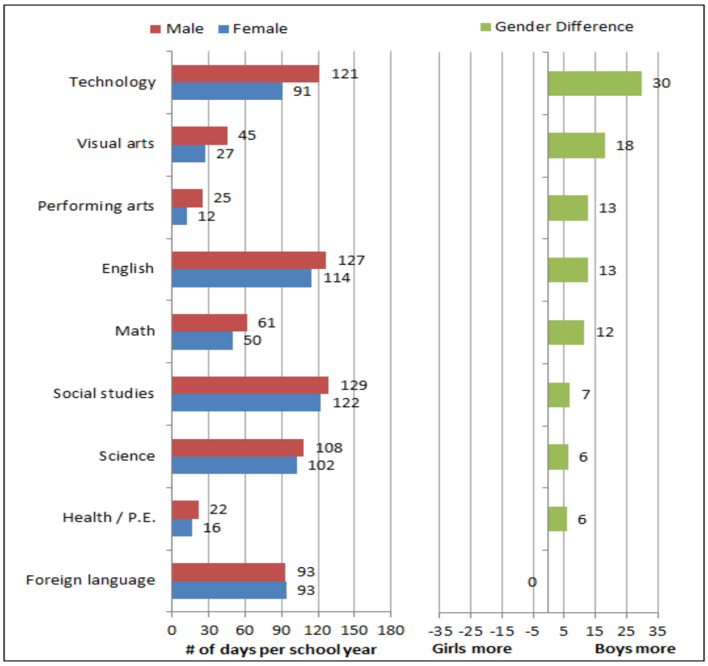

Figure 3. Gender differences in students' classroom uses of technology across different subject areas.

In Figure 3 students' technology use in class is measured using a 0-180 point scale (approximate number of days in their school year) as well as across a wider spectrum of subjects. In Figure 3, students' average frequency of technology use is summarized across the 1:1 grade levels allowing for a direct comparison of boys and girls use of technology in class. Overall, boys reported more frequent use of technology in class than girls. From survey data alone it is impossible to discern if such differences represent actual differences in students' classroom experience or if boys were simply more likely to overestimate their class use when surveyed. To better illustrate the potential differences in boys' and girls' experience, results in Figure 3 were ranked so that classes with the greatest gender differences are found at the top of the figure. What is particularly striking looking across subject areas is that some had relatively small gender differences (foreign language, Health/PE, Science) while other classes (Technology and Visual Arts) had more use reported by boys, on average.

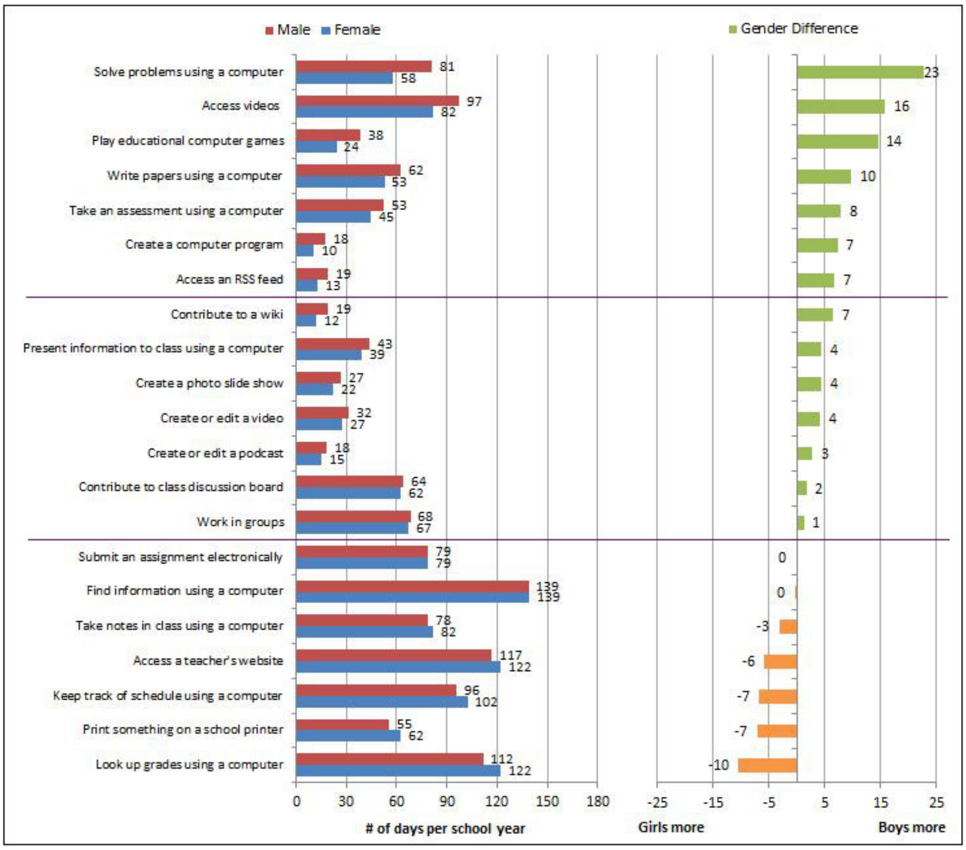

*Figure 4***.** Average frequency of students' classroom practices by gender (Spring 2013).

Figure 4 examines the frequency of student practices at the completion of their first year in a 1:1 computing program and compares these practices across gender. Although knowing how much students are using technology can be useful, if we are to understand how a 1:1 program is impacting learning, it is also essential for formative and summative evaluation to know specifically which student behaviors are changing. These results show that Natick students used their 1:1 computing resources for a wide number of teaching and learning applications and uses in school. So, our emphasis is not on the students' access, but specifically on measuring the frequency that students employ these resources to support their development and learning.

Such student-level measures can also be of great value when used as independent/predictor variables in exploring the impacts and outcomes of a program or initiative. In the Natick results, the most common classroom computing activities tended to be the relatively passive forms of learning on the list (e.g. searching for information and accessing a video) or procedural tasks (e.g. looking up grades and keeping track of assignments). The more constructive and learner-centered activities occurred only about half as often, on average. In terms of gender differences, boys reported more frequent use of computers to solve problems, access videos, and play educational games while girls reported more frequent use of technology for looking up grades and using school printers. Such results have the potential to reveal interesting nuances and patterns that would be overlooked in more general investigations. Again, survey results in isolation are not intended as proof of gender differences, but instead serve to provide educators and leadership an opportunity to pause, think critically and consider potential implementation issues.

Although some of the most commonly explored student background variables include gender, age, socio-economic status, and home language, there are numerous demographic and student background variables that can be examined. In this study, we merged student survey results and school records to explore the potential relationship between student experiences in the 1:1 program and their course enrollment history. Like many large US high schools, Natick High School offers multiple different academic levels for many classes, which provide an opportunity to explore student practices and sentiment across different course levels. Although there are numerous ways to categorize and compare students' course history, for the sake of simplicity, we identified and compared students who had completed at least one honors-level course (about half of all students) to those who had never taken an honors-level course. Figure 5 shows students' and teachers' reported use of technology across subject areas in Spring 2013 comparing students who were enrolled in one or more honors-level course to those students who had not.

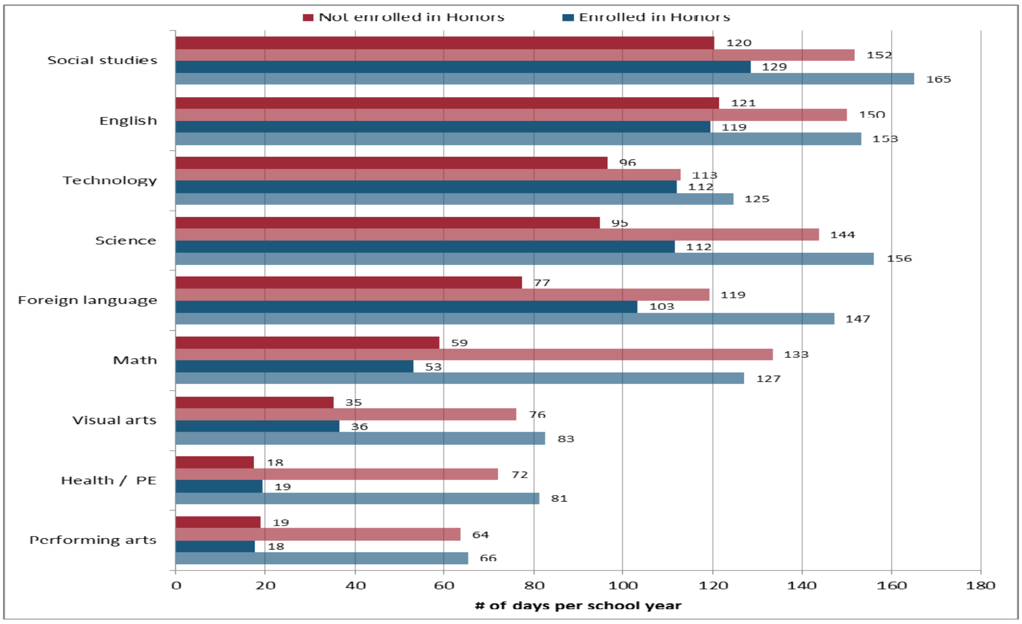

Figure 5. Differences in NHS students and teachers technology use across subjects for students enrolled in one or more honors course(s).

Figure 5 continues the exploration of student and teacher practices by plotting student use and estimated teacher use of technology during the first year of the 1:1 program. In the survey, students estimated not only their own use of technology (represented by darker shades) but that of their teachers (represented by lighter shades) using a 0-180 point scale roughly corresponding to the number of school days per year. Thus, Figure 5 provides our first examination of teacher practices during the first year of the 1:1 computing program. As frequently observed in the literature (Bebell & O'Dwyer, 2010), teachers own use of technology in the classroom (darker shades) occurs more frequently across the curriculum than student use (lighter shades). Figure 5 also portrays how much teacher and student practices were related to course level, specifically for students enrolled in honors level courses. In other words, is there any evidence that honors-level students are using the 1:1 resources differently than non-honors peers? Comparing the honors student averages (depicted in blue) to non-honors students (depicted in red), we observe that the frequency of student and teacher computer use was relatively similar in English classes across the two groups, but honors level students used more technology in science and foreign language courses. Such differences and their contextual relevance can be explored in future survey analyses, or substantiated through interviews, focus groups, classroom observations or other qualitative methodologies. For example, Figure 6, below, shows a more detailed examination of course-level differences in student practices as reported from the first year survey results.

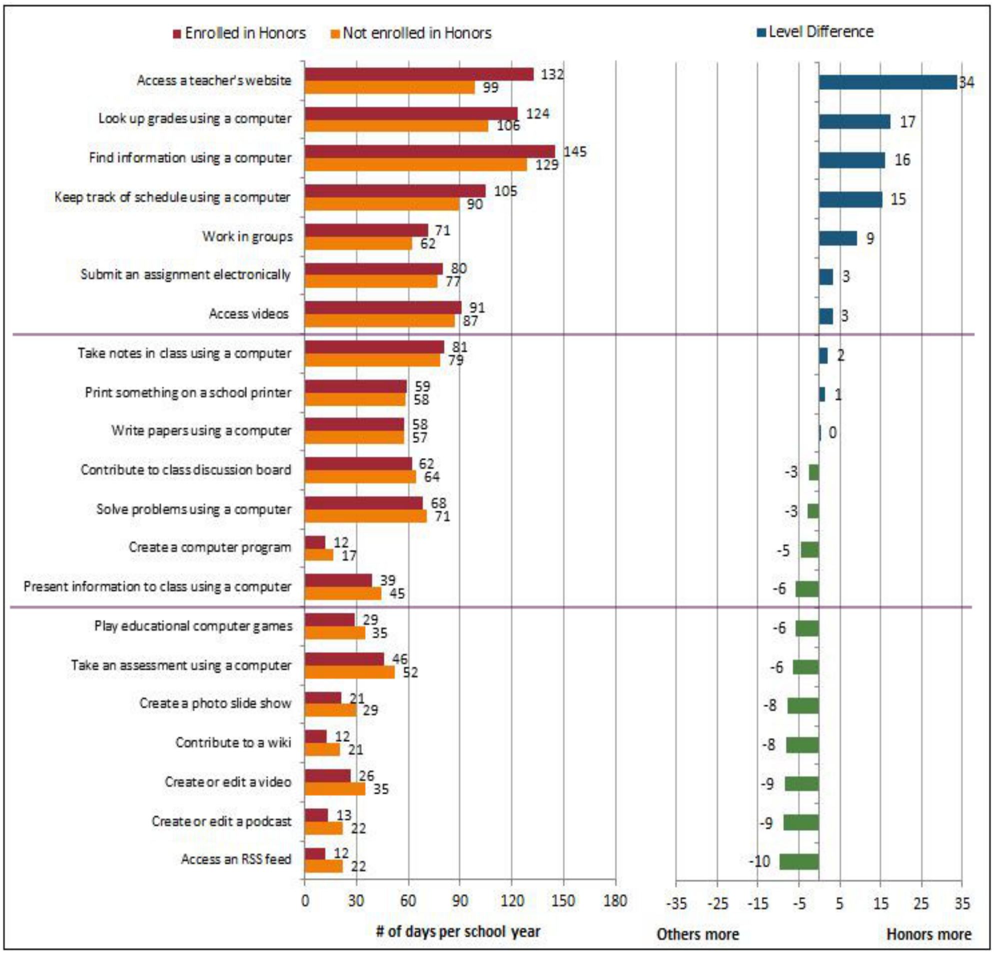

Figure 6. Comparison of honors-level students' frequency of various practices.

Figure 6 shows a more nuanced estimate of student practices across students in their first year of their 1:1 computing program. Specifically, Figure 6 reports the average frequency that students with different course backgrounds reported a range of different classroom activities. By merging the student survey results with school course records, we can explore differences in the classroom experiences of students who take honors courses and those who do not. Such exploratory analysis aims to provide school leadership with an opportunity to address the equity of implementation across different cohorts of students. In this example, the relationship between student practices in class and their past course levels suggested that honors-level students used computers in class for some purposes more frequently than students in non-honors courses. For example, accessing a teacher's website, looking up grades on a computer, finding information on a computer, and keeping track of schedules and assignments using a computer all were reported to occur more frequently by honors-level students during the first year of 1:1 implementation. Interestingly, honors-level students also reported somewhat more frequent class time working in groups while students taking no honors courses reported somewhat more use of computers in class to access a RSS feed and creating/editing podcasts, wikis, and videos.

The patterns between student practices and their course experience were found to be complex and deserving of greater scrutiny than typically afforded. Again, such results aim to serve school leadership an opportunity to consider new perspectives on their implementation efforts and highlight differences across teacher and student experiences. In general, we have observed that schools and other organizations implementing 1:1 programs use only a fraction of their available school records and data in their own research and evaluation efforts. Students' course history represents one such rarely examined data point as an independent/predictor variable or as a potential dependent/outcome variable. In the next example, we briefly explore the relationship between students' classroom practices and their socio-economic status at home. Figure7 compares the average frequency of classroom practices for low-income students during the first year of their 1:1 implementation.

Figure 7 shows another descriptive comparison of student experiences during the first year of Natick's 1:1 computing program. In this case, however, student practices are compared between students from low-income households (as measured by student eligibility in a state-run free and reduced lunch program) and students who were not. Because all students used school-purchased laptops, regardless of individual finances, we would not expect much of a relationship between student socio-economic status and their practices in the classroom. Indeed, Figure 7 shows that for the majority of surveyed classroom practices (both with and without technology), there was relatively little difference based on students' socio-economic status. However, a few of the classroom and computer practices that were explored here highlight differences in student experiences. For example, students from low-income households reported using technology in class more often for printing documents, accessing videos, and creating/editing videos during the first of the 1:1 program. Conversely, students not in the low-income cohort reported more frequent overall use of computers in class to find information.

Socio-economic status, gender, and course-taking patterns are also potential indicators that most schools have easy access to but rarely use in their research and evaluation efforts. The short-term challenges of merging survey results with existing school records (using a unique student-level identifier) can be easily overcome to provide rich opportunities for exploring a greater range of student experiences across an implementation.

Moreover, school records and data can also serve as the outcome/dependent variables in a summative research and evaluation study. For example, if a school is interested in measuring the impact of the student practices on math achievement, chances are that there is already an ample supply of student grades and test score data available in existent school records.

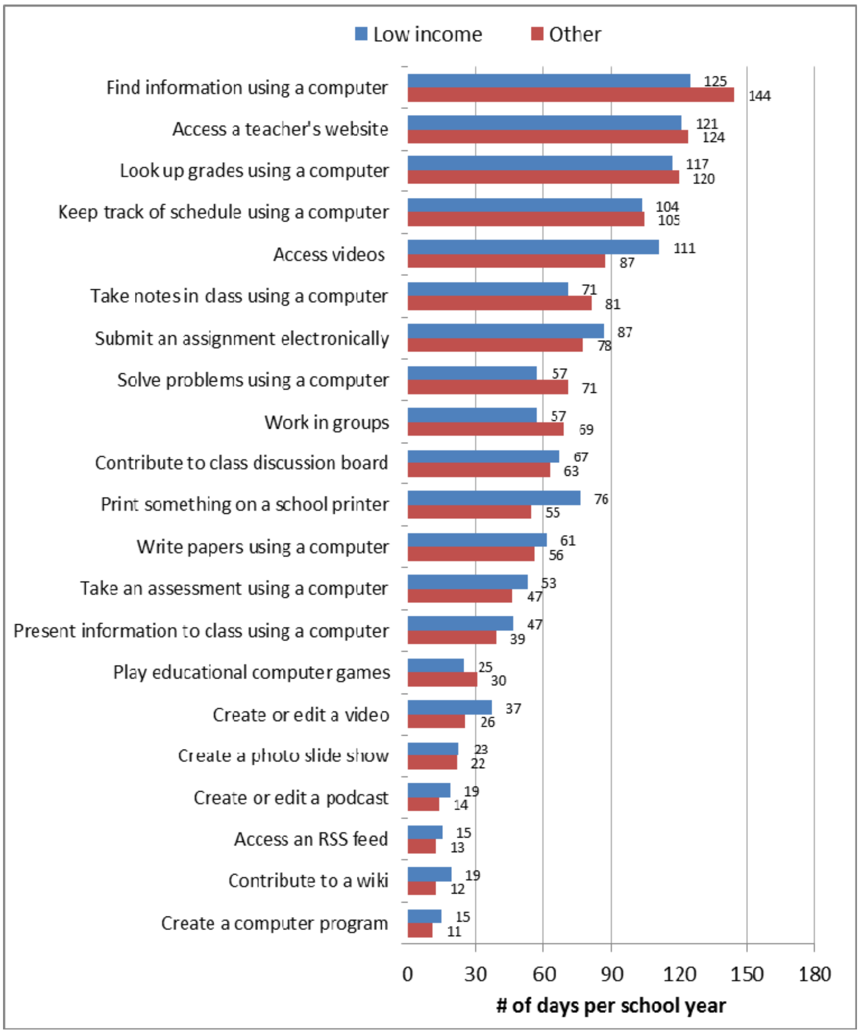

Figure 7. Examination of low-income students' specific uses for technology in school.

Before any exploration of student outcomes can be addressed in a 1:1 setting, there must first be fundamental agreement across stakeholders on what success looks like and how it will be measured. In other words, before you can measure the success or proof of any given program, the school leadership and policy makers must first articulate what success looks like and how it will be measured. Returning to the Natick example, a wide range of outcomes and success indicators were identified by the district and examined during the first two years of the 1:1 implementation. Specifically, the research and evaluation team worked with school leadership to access and explore student achievement, student attendance, special education enrollment, and behavior incidents. In the remaining pages we highlight a series of analyses exploring results and outcomes from the first year of Natick's 1:1 computing program. Given that one year is an extremely short implementation period, results are shared below in an effort to highlight how researchers and schools can examine impacts that are aligned with their program goals.

3.1. Student Achievement

In much of the world, the *de facto* measure of success for many policy makers and educational leaders is students' academic achievement as measured by standardized tests. Although educators and communities often espouse a broad range of educational aims and goals for their schools and programs, the familiarity and ease of using student test scores has ensconced their predominant role as the "proof" of a program's success. Exploratory data analyses were performed using the student data to investigate if the frequency of teachers' and students' various technology uses (as measured by the student survey) exhibited any notable relationship with the student achievement results. More simply put, did any of students' specific uses of technology during the first year of the 1:1 program relate to their test performance? Again, given just a single year of program implementation, we would not expect the results to be robust, but include these examples to highlight our approach and initial models. Figure 8 provides a summary of students English and Math performance for the first cohort of students using available achievement scores.

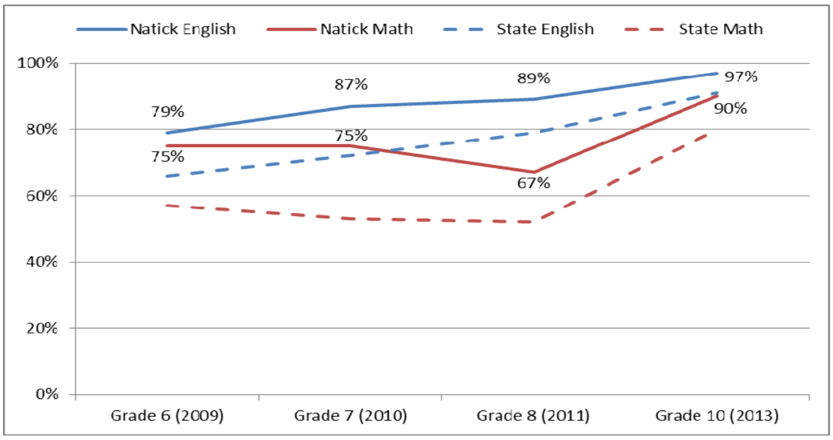

Figure 8. Percentage of students who scored as proficient or higher in state English and Math tests from 2009 to 2013.

Figure 8 examines students' English and Math proficiency from 2009 (when students were in sixth grade) to 2013(when students were in tenth grade and their first year of 1:1 computing). The state-mandated assessment schedule dictates what subject areas are measured each year, so the current analyses use tenth grade ELA and Math results as the best available indicators of students' academic performance during the first year of 1:1 computing. In this example, following this cohort of students over five years illustrates that student achievement was relatively unchanged as students matured from Grade 6 (2009) to Grade 7 (2010) and Grade 8 (2011). Since English and Math assessments are not offered in grade nine, 2013's grade ten results provide the first indication of student achievement in the 1:1 program. Indeed, the average scores were higher for tenth grade students in 2013 than previously recorded for this cohort of students. However, as Figure 8 shows, the 2013 gains were also found for the state averages. Although the average Natick score gains coincided with the first year of the 1:1 initiative, without a randomized experimental study it is impossible to discern if any portion of these test score gains can be attributed to the school initiative. Despite this, it is possible to more fully examine the potential of a "cohort effect" through further examination of how individual student performance changed over time.

Prior results showed that individual students had different experiences using the technology in class, despite similar technology access. With this variance, it is possible to explore the complex relationship between student and teacher practices and student achievement by examining the relationship between students' engagement in specific activities and the changes in their Massachusetts Comprehensive Assessment System (MCAS) scaled scores from 2011 to 2013. Beginning with Table 2, below, relationships between teachers' and students' use of technology and MCAS performance is demonstrated using Spearman's correlation coefficients *(ρ)* with all statistically significant relationships ($p < .05$, 2-tailed test) indicated. Again, these correlation results are not intended to determine the effectiveness of the student computing program or its various components, but rather to explore what student and teacher practices may be related to these common measures of student achievement.

Table 2

Correlation table examining2013 MCAS growth and proportion of class time students used technology.

	Change in MCAS Scores					
	ELA			Math		
% of time in	(n)	ρ	p-value	(n)	ρ	p-value
English	174	0.141	0.064	173	0.029	0.705
Social Studies	174	0.009	0.910	173	0.054	0.478
Math	163	0.088	0.264	162	0.221**	0.005
Science	172	0.013	0.868	171	0.147	0.055

Note: ρ = the Spearman's rho rank-order correlation coefficient.

**$p < .01$

Overall, there was little relationship between students' technology use in class and their MCAS gain scores, as evidenced by the correlation coefficients near zero. It is noteworthy that all of the correlations were positive, but the only relationship found to be statistically significant was between Math achievement and students' use of computers in their math classes. This finding from the first year of the 1:1 implementation suggests that students' use of technology in math class was positively related to their math achievement. Such a result makes intuitive sense given the notable increases reported in students' computer use in math. However, such results cannot be used to make causal inferences, but rather facilitate reflection and discussion about practices and outcomes. Table 3 shows the relationship between students' specific uses of technology during their first year of 1:1 computing, and their performance gains on the tenth grade MCAS.

Overall there was little observed relationship between students' technology use in class and their MCAS gain scores, as evidenced by the majority of correlation coefficients near zero. Improved math performance in 2013 was correlated with increased use of computers to solve problems and take assessments. Improved English scores in 2013 were most strongly correlated with students creating slide shows and giving presentations. Higher growth in English scores was positively correlated with students' use of computers to play educational games, solve problems, and access videos.

Table 3

Correlation table examining 2013 MCAS growth and a range of students' specific technology practices

	Change in MCAS Scores					
	ELA			Math		
Frequency of activity	(n)	ρ	p-value	(n)	ρ	p-value
Write papers	172	0.145	0.058	171	0.03	0.693
Find information	170	0.014	0.856	169	-0.042	0.591
Play educational games	171	0.183*	0.017	170	0.145	0.059
Solve problems	168	0.177*	0.021	167	0.168*	0.03
Take a test, or quiz	169	0.11	0.154	168	0.165*	0.032
Take notes in class	172	0.084	0.271	171	0.016	0.84
Present information to your class	171	0.216**	0.004	170	0.056	0.47
Work in groups with other students	171	0.044	0.567	170	-0.015	0.845
Look up your grades	173	0.077	0.312	172	0.083	0.277
Print something on a school printer	173	0.036	0.642	172	-0.013	0.867
Access a teacher's website	172	0.043	0.575	171	-0.065	0.4
Keep track of dates and schedule	170	-0.048	0.535	169	0.089	0.251
Access videos	171	0.165*	0.031	170	0.076	0.323
Create or edit a video	169	0.131	0.09	168	0.067	0.389
Create or contribute to a wiki	171	0.144	0.06	170	0.116	0.133
Access an RSS feed	168	0.066	0.396	167	0.067	0.39
Contribute to an online class discussion	170	0.081	0.296	169	0.151	0.051
Create photo slide shows	168	0.237**	0.002	167	0.141	0.069
Create or edit a podcast	167	0.086	0.271	166	0.097	0.216
Create a program, macro, or app	171	0.108	0.158	170	0.031	0.692
Submit an assignment	171	-0.053	0.487	170	-0.046	0.552

Note: ρ = the Spearman's rho rank-order correlation coefficient.
$^{*}p < .05$. $^{**}p < .01$.

3.2. Student Attendance

In addition to student achievement, schools and researchers can explore potential changes in student attendance related to increased technological resources and practices. In the current study, during Natick's first year of 1:1 implementation and new building facility, students' overall attendance decreased slightly compared to the previous year, as shown in Figure 9.

Comparing the two years of attendance data, we observed an increase of about two days on average and an increase of 5% in number of students with ten or more absences. Further examination of the student attendance distributions revealed that students who were only occasionally absent in 2011-2012 generally increased their number of absences in 2012-2013. Showing the efficacy of using multiple data sources, we employed student focus groups to learn that students were well aware of technology benefits when absent, but did not admit that this provided a greater inducement for them to miss school.

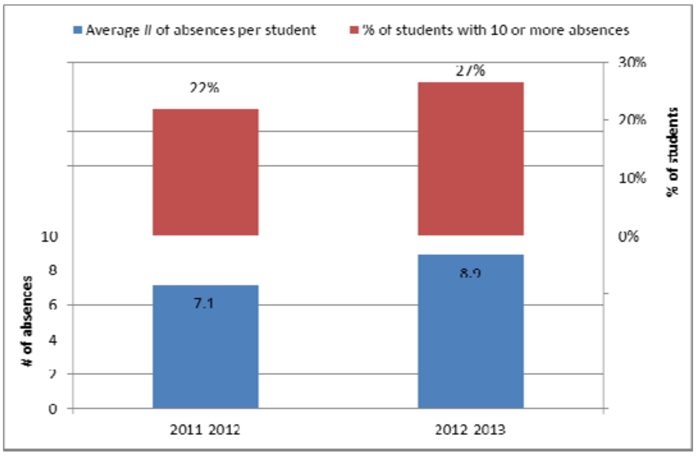

Figure 9. Student absences before and during the first year of the technology program.

To better understand potential relationships between student attendance and students' actual practices in school, correlations between student absences and the frequency of their technology use are also examined below in Table 4.

Table 4

Correlation table examining the relationship between student absences and technology related factors for 2012-2013.

	Student Absences		
	N	Pearson's *r*	*p* (2-tailed)
Gender (male)	640	-0.060	0.127
Honors class in 2011-2012	640	0.013	0.741
Honors class in 2012-2013	640	-0.025	0.527
How often do you use computers in school?			
	N	Pearson's *r*	*p* (2-tailed)
In your classroom	515	0.011	0.804
In the computer lab	466	-0.091	0.051
In the library	481	-0.031	0.493
In English / ELA	514	0.053	0.233
In Social Studies	512	0.018	0.686
In Math	508	0.058	0.195
In Science	510	0.040	0.366

Table 4 shows that there was no relationship observed between students' technology use during their first year of 1:1 computing and their attendance. It was not expected by Natick schools that first year technology practices would be related to student attendance, but it is again hoped this example illustrates the potential for examining student practices with a broad range of outcomes.

3.3. Student Behavior and Discipline

To explore the impacts of the 1:1 resources on student discipline, the research team accessed school detention records for those students enrolled at Natick High School both during the 2011-2012 and 2012-2013 school years. Compared to students pre-1:1 averages, the number of students who received detention decreased 6% during the initial year of the 1:1 computing program. A paired-samples t-test found this decrease to be statistically significant at the <.01 level. Further analyses within each grade level showed no significant changes. In an effort to more closely examine the nature of this change in frequency of detentions, similar paired-samples t-tests were used to examine changes in particular types of detentions, specifically detentions that were due to skipping class and misuse of electronic devices (phones, MP3 players, laptops, etc.).Table 5shows that the differences found for both of these infractions were significant, while detentions for electronic devices dropped off by about 9% and detentions for skipping school increased by about 6%.

Table 5

Paired-sample t-tests examining change in frequency of detentions from 2011-2012 to 2012-2013.

	(n)	Mean diff.	Pearson's r	t	p (two-tailed)
Students with detentions	524	-0.06	0.42	-3.20**	0.001
# of detentions per student	524	0.12	0.51	-1.79	0.075
Detentions for skipping school	524	0.06	0.10	2.01*	0.045
Detentions for electronic devices	524	-0.09	0.07	-4.22**	<0.001

$*p < .05$. $**p < .01$.

When students were asked about these outcomes during a focus group, they attributed the increase in detentions from skipping class to the greatly increased video surveillance at Natick High School.

3.4. Special education enrollment and referrals

Another potential outcome measure that is easily accessible considers the proportion of students who receive special education services. Although we would not expect such a far-reaching impact from a year-long implementation period, Figure 10 illustrates that the proportion of students receiving special education services did not change substantially during the first year of the 1:1 implementation (2012/2013).

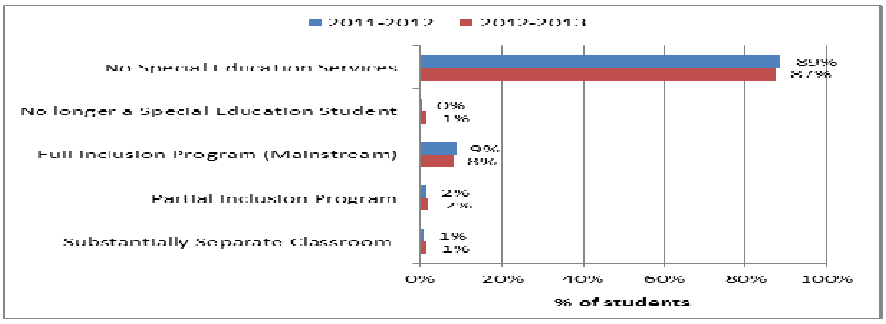

Figure 10. Percentage of Natick High School students that received various levels of special education services from 2011-2012 to 2012-2013.

4. Discussion

> "The entire point of all the examples I have given is that the computers serve best when they allow everything to change" (Seymour Papert, 1993, p. 149).

Over the past few decades, technological innovations have dramatically increased the opportunities for schools to collect, analyze, and communicate research and evaluation results. As schools experiment with new innovations and resources, the opportunities to leverage research and evaluation tools have become greater than ever. Research and evaluation efforts serve to compliment and inform large-scale student computing efforts. Formative data can inform the day-to-day implementation of a 1:1 program while summative results can address the long-term impacts and outcomes of the initiative. More specifically, evaluation and research serves to:

- Organize stakeholders and constituents around the goal(s) of a project
- Define success through the creation of project outcomes and indicators aligned to a project's goal(s)
- Provide data specifically targeted at measuring success relative to a project's goal(s)
- Provide feedback and recommendations for formative reflection, identification of best practices, course correction, and
- Provide your community with evidence and examples of what works (and perhaps what doesn't).

As researchers and schools plan to study 1:1 programs, or any educational initiative, it is imperative that they first consider what the goals and expected impacts of their program will be. What outcome measures do we select to demonstrate the success or failure of an initiative? It takes some thought and reflection to determine what the range of appropriate measures should be.

Too often, considerations for research and the identification of student outcomes are given too little attention or lack thorough consideration until the implementation is already well underway. In the example study presented here, the fortuitous availability of pre-1:1 student survey data was extremely beneficial for exploring changes in teaching and learning over the first year of the 1:1 student computing program. Although limited to just the initial year of a high school implementation, these working examples provide an opportunity to consider a range of different program outcomes. It is noteworthy that all of the outcomes explored in this paper (student achievement, attendance, discipline, etc.) were already available to the school and required only secondary analyses of existing data. Once schools have identified their outcomes they will find greater utility in measuring actual teaching and learning practices and not just access. The more detailed analyses examining the relationships between students' actual uses of technology, classroom practices, and outcome measures involved merging student survey data with existing school records, an accessible model for most schools. Such nuanced investigations into the implementation can be easily explored across grade levels, subject areas, and different student categorizations.

In the current study, teachers and students reported major increases in the frequency and variety of ways technology was leveraged across the curriculum. While practices were found to be relatively static for 7th grade students without 1:1 computing access between

2010 and 2012, the differences in teaching and learning practices experienced by the 1:1 students in 2012 were dramatic. As one of the most commonly discussed success indicators, it was encouraging that first year state test results looked so favorable for Natick's 1:1 students. Although most in-class uses of technology demonstrated no relationship to students' English and math score gains during the first year of the initiative, a few statistically significant positive relationships emerged of note. Students' use of technology in math increased exponentially during the first year of 1:1 computing, which was positively related to their math achievement gains. Improved math performance on the 2013 state assessment was correlated with increased use of computers to solve problems and take assessments. Students who reported creating slide shows and giving presentations more frequently showed somewhat improved English scores in 2013. Higher English score gains were also positively correlated with students use of computers to play educational games, solve problems, and access videos in class.

It is important to consider the limitations of the study design and data that were available for analyses. Given the illustrative and exploratory nature of the current analyses, study results presented here should also be interpreted with caution given the limited study context. A major intention of the Natick study was to strengthen the student computing initiative through the use of empirical formative data and eventually demonstrate long-term program impacts. Although only first year results were available at the time of this article, the methods, techniques and emerging results presented herein aim to serve future efforts by schools and researchers in other settings.

In the greater evaluation study from which these results were culled, additional qualitative methods complimented the teacher and student surveys and secondary analyses of school records. Although the survey results provided an economical and highly valuable tool for measuring practices and beliefs across large numbers of study participants, student and teacher focus groups, classroom observations, as well as teacher and administrator interviews provided additional context and depth. To better capture students' unique and personal perspectives on the 1:1 computing initiative, a student video competition was launched in Spring 2013 that asked students to submit an original short movie addressing: *How have computers and technology changed the way you learn new things and/or how your teachers teach?*.

A panel of reviewers juried the many submitted student videos and selected best examples for prizes, public screenings, etc. Like the classroom observations and focus groups, the student videos brought a complimentary and unfiltered perspective to the study: http://www.bc.edu/content/bc/research/csteep/natick21/natick-student-video-competition.html

In conclusion, these example methods and results provide considerations for schools and researchers leveraging research and evaluation in sustaining new educational initiatives. Not only does such empirically-based reflection provide insights into the educational technology initiative, but serves to demonstrate to the greater school community how data and research evidence can be incorporated into planning and decision making procedures on a larger scale. This latter impact is of special importance in light of the growing tsunami of learning analytics and other big data sources that will be available to educators and school leadership in the coming years. We believe those schools investing now in research and reflection will be preparing and developing their school cultures to best accommodate and capitalize on such data sources.

Similarly, the coming years will see continued advancement of data collection, analyses, and reporting from technological innovations in the research community. For these technical advancements to be of greatest utility, schools and leadership must address two important considerations. First, schools need to define what matters to them. Second, schools need to develop a culture to support the intelligent use of current and future data sources for all levels of educational stakeholders. Together, the research and school communities can evolve together to create the next generation of educational research, evaluation, and measurement to inform and sustain the next generation of teaching and learning practices.

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