What Added Value Does a 1:1 Student to Laptop Ratio

Bring To Technology-Supported Teaching And Learning?

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Abstract

The purpose of this study was to document typical use and configuration of 1:1 computing in four schools focusing on the added value and unique challenges these uses present. A qualitative case study design was used in four middle schools (sixth, seventh, and eighth grade) in Virginia and California purposefully selected for their 1:1 computing programs. Data were collected through formal and informal interviews, direct observations, and site documents. Results indicated that online research, productivity tools, drill and practice, and eCommunications were the most frequent uses of computers in the 1:1 classroom. Moreover, the 1:1 classroom provided added value to these uses while simultaneously presenting unique management challenges to the teacher. However, researchers documented wide variation in implementation models and fidelity to 1:1 computing, which suggests the need for further research exploring the conditions under which this variation exists.

Keywords: Ubiquitous computing, 1:1 laptops, classroom technology practices

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Introduction

Beginning in 1985 with the Apple Classrooms of Tomorrow™ (ACOT) (Apple Computer, 1995) project, the last twenty years have seen a steady increase in the number, scope, and sophistication of 1:1 computer to student ratio initiatives that now stretch from Melbourne to Maine, ranging from programs with fewer than one hundred computers to over 36,000. In 2000, there were approximately 1,000 American schools using a 1:1 model, or ubiquitous computing as it is sometimes called, totaling over 150,000 laptops (Johnstone, 2003).

Advocates have hailed 1:1 programs as having the promise to transform education as we know it (Brown, 2003; Papert, 1980, 1993; Stager, 1995), while others see this promise as simply another "oversold" fad that is at best a drain on the perpetually limited education budget and at worst a distraction that is actually detrimental to the education of our children (Cuban, 2001; Oppenheimer, 2003).

Researchers and evaluators have been attempting to document what impact this influx of 1:1 technology is having on our students, teachers, schools, and communities. But the general consensus from reviews of the research to date is that additional detailed information is needed from 1:1 classrooms in order to describe the teacher and student practices and outcomes, and to identify the contributions the 1:1 access level makes to technology-supported teaching and learning (Lemke & Martin, 2003; Penuel, 2005; Zucker, 2004).

This paper contributes to this information need by disseminating typical classroom uses for 1:1 computing by 16 teachers of math, science, social studies and English across four middle

schools within rural, suburban, and urban districts. We discuss these uses in terms of the added value and unique challenges they present.

Literature Review

Much of the 1:1 laptop classroom research to date focuses on the ways teachers use the computers and the general benefits gained as a result. Teachers primarily use productivity and research applications, such as word processors, spreadsheets, presentation software, and Internet browsers on the laptops, employing it both for their instruction and for their and their students' research (Fouts & Stuen, 1997; Hill & Reeves, 2004; Lowther, Ross, & Morrison, 2003; Rockman, 1997, 1998, 1999; Ross, Lowther, Wilson-Relyea, & Wang, 2003; Russell, Bebell, Cowan, & Corbelli, 2003; Russell, Bebell, & Higgins, 2004; Silvernail & Lane, 2004). As a result of networked laptops teachers report greater access to "up-to-date instructional content" in the form of online and computer-based resources, and content that is available to them in a wider variety of modes (Zucker & McGhee, 2005, p. 17). Furthermore, they describe such resources as helping them to support students who learn in different ways by allowing them to present information in a variety of presentation styles and overall contributing to their increased instructional flexibility (Zucker & McGhee, 2005).

Teachers have also reported how their and their students' access to networked laptops leads to changes in their teaching. They report designing lessons that are more student-centered and constructivist, allowing for less lecturing and more facilitating or guiding students in the learning process (Apple Computer, 1995; Baker, Gearhart, & Herman, 1993; Sandholtz, Ringstaff, & Dwyer, 1997). Some teachers have also described how they increase the length of the instructional periods to better integrate the laptops into cross-curricular lessons (Johnstone, 2003). Other teachers have described how they use more inquiry-based and student-centered

activities and serve more of a facilitating role than before the laptop implementation (Hill &

Reeves, 2004; Jeroski, 2003; Ricci, 1999; Russell et al., 2004; Schaumburg, 2001). Additional

teachers report an increased ability to receive and give rapid feedback on class and student

progress allowing for more targeted remediation (Kerr, Pane, & Barney, 2003; Ricci, 1999;

Russell et al., 2004).

These studies allow us to recognize the general uses and benefits of laptops in the

classroom; however, further research is needed to provide detailed descriptions of teaching

practices within classrooms with a 1:1 student to networked laptop ratio. What practitioners and

policy makers need is knowledge about the teacher practices in classrooms with a 1:1 student to

laptop ratio that lead to these benefits and specifically how the 1:1 access contributes to these

benefits in such a way that would not otherwise be possible with a higher student to computer

ratio. Practitioners and policy makers also need to understand the possible problems and

drawbacks that might be caused by such a ubiquitous level of computers in classrooms as it has

implications for the sort of teacher training and support that should accompany laptop

implementations.

Researchers have described the findings reviewed above in terms of contributions,

capabilities, benefits, or advantages to teaching and learning that are provided by networked

technologies. In this paper, we use the phrase 'added value' to discuss what networked laptops

contribute to teaching and learning; by this we mean the capabilities provided by 1:1 student to

networked laptop ratio that otherwise would not be possible. Dexter (2002) elaborates about

added value in terms of the enhancements networked technologies provide when accessing data,

processing information, and communicating understandings (see Table 1). For example, in the

1:1 computing context, this added value might be represented by an enhanced ability to find and

retrieve relevant information via the web, an increased level of real-time formative assessment enabling individualized instruction, or the creation of virtual communities that allow students to communicate inside and outside of the classroom.

—Insert Table 1 here—

Another lens that can be used to describe the contributions that a 1:1 level of student access to networked laptops might provide comes from a summary of cognitive science research over the last forty years. In the research examining the development of understanding in learners, many studies emphasize the importance of building upon learners' prior knowledge about a topic and of learners' active involvement in their learning. In summarizing the implications of these findings for educators, Bransford, Brown, and Cocking (1999) identify four essential design principles of effective learning environments. According to this research, effective learning environments should be learner-centered, knowledge-centered, assessment-centered, and community-centered. That is they should, respectively, support making connections between the students' existing knowledge, skills, attitudes, and beliefs and the current learning situation; provide explicit and implicit guidance and clarification on what is taught, why it is taught, and what represents mastery of this knowledge or skill; provide learners with insight into their own progress and allow for revising and refining their knowledge representations; and establish classroom norms and connections that support the desired learning values (Bransford, Brown, and Cocking, 1999).

It is important to acknowledge that the mere presence of a technology-rich environment is not sufficient for enhanced teaching and learning or added value. In fact, the 1:1 computing classroom frequently presents unique challenges and barriers to successful instruction such as an increase in management problems (Hill, Reeves, Grant, Wang, & Han, 2002; Kerr et al., 2003;

Newhouse, 2001; Turnbull & Gilmour, 1991; Zucker & McGhee, 2005), an increase in teacher

workload (Kerr *et al.*, 2003; Zucker & McGhee, 2005), and difficultly linking laptop use to

learning outcomes and standards (Newhouse, 2001), among others. Researchers have also

documented fragile or excessively heavy machines, limited desk space, inadequate battery life,

software deficiencies, data loss, scheduling problems, unreliable Internet access, and

infrastructure inadequacies accompanying 1:1 laptop programs (Bartels, 2002; Efaw, Hampton,

Martinez, & Smith, 2004; Garas, Davis, Hopstock, Kellum, & Stephenson, 2005; Hill & Reeves,

2004; Kerr *et al.*, 2003; Lowther *et al.*, 2003; Rockman, 1997).

Together, the elaboration about added value and the four learning environment design

principles provide specific language and outcomes that we can use to investigate and describe the

contributions to teacher practices and classroom learning environments made by a 1:1 student to

networked laptop ratio. In addition, we document the challenges presented to teachers in this

environment providing a critical counterpoint against which such contributions can be weighed.

Methods

Methodology

The purpose of this study was to understand how middle school teachers used laptops at a 1:1

student to laptop ratio in the context of curriculum and instruction; hence, a multiple case study

design was employed (Stake, 2005; Miles & Huberman, 1984; Yin, 2003). The research aimed

at understanding how teachers made sense of and used the laptops in the process of instruction.

Four case study sites were chosen for in-depth examination of this variable. At the four case

study sties, we sampled a total of 16 teachers from the core subject areas of math, science, social

studies, and English in order to understand generally the phenomenon of laptop uses within

varied school contexts and content areas. As the research progressed, the design was formalized

so that attention was focused on selected variables in each case derived from the conceptual

framework (Stake, 2005). We triangulated the data through the use of multiple types of data

(observations, interviews, documents), multiple sources (teachers, students, administrators), and

multiple researchers.

Sites and Participants

The participants in this study were students, teachers, and administrators in four middle schools

(6th, 7th, and 8th grade) in Virginia and California. Researchers identified these schools primarily

through purposive sampling. The principal selection criteria of schools were the presence of 1:1

student to computer ratios in their classrooms as well as a history of integrating technology into

the curriculum. Secondary selection criteria included (a) nature of 1:1 computing initiative; (b)

duration of implementation 2 years or more; and (c) willingness to participate. Table 2 presents

demographic information on the sample school sites analyzed for this paper.

—Insert Table 2 here—

Configuration

At the sites there were different implementation patterns for the laptops that resulted in variations

in how often students had access to the laptops. Table 3 summarizes the variations among the

four sites in the study.

—Insert Table 3 here—

Data Collection

A team of four researchers spent approximately 2 days collecting data at each school site. The

data sources were formal and informal interviews, direct observations, and site documents.

Interviews and/or focus groups were conducted with: 1) four to eight teachers; 2) a sample of

students from each school; 3) the technology coordinators or resource/media specialist for each school and 4) the principals from each school. The interviews and focus groups were structured around a set of questions derived from the conceptual framework and research questions. The researchers systematically observed each teacher 1-2 hours over the course of the site visit for a total of 32 observation hours. Observations were conducted using an observation protocol congruent with the conceptual framework and research questions. Observation notes, field notes, and audio data were compiled for within-site analysis.

Data Analysis

Within-Site Data Analysis

Using NUD*IST NVIVO, a qualitative analysis program, the researchers analyzed the observation field notes and interview transcripts using a structured coding scheme based on the conceptual framework of the study. The first level of coding used five major coding areas: 1) 1:1 Role & configuration of in school; 2) Students Practices in 1:1 project; 3) Students Outcomes and impact of 1:1 project; 4) Teacher Practices in 1:1 project; and 5) Teacher Outcomes and impact of 1:1 project.

Using the data gleaned with this first level coding process, the researchers coded typical uses according to the NCREL Range of Use chart (NCREL, 2000). This second level of coding used eight major coding areas: 1) Drill & Practice; 2) Integrated Learning Systems; 3) Productivity Tools; 4) Expression/Visualization; 5) Online Research; 6) eCommunications Video/Audio/Data Online Environments; 7) Simulations; and 8) Problem Solving with Real Data Sets. The resulting code reports were used to analyze the possible linkages to the effective learning environments and added value theoretical frameworks (Bransford *et al.*, 2000b; Dexter, 2002).

Cross-Site Data Analysis

The individual case studies were used for the cross-case analysis. The focus of the cross-site analysis was on various factors identified from the conceptual framework (see above), hence emphasis was placed on the similarities across the cases with regards to the phenomenon and factors of interest (Stake, 2005). Variations in the phenomenon of use and causal explanations of those variations were not the focus of this study. Returning to the theoretical and organizational conceptual framework, the authors created a case ordered cross-site data matrix categorizing the data accordingly. Pattern-matching analysis, in which each case served as a comparative context for the other, was used to determine if there were significant patterns of use that capitalized on the unique capabilities of the 1:1 student to networked laptop ratio across sites as well a significant patterns of challenges across sites. Tactics used for the pattern matching were making comparisons and contrasts among cases as well as counting the frequency of a use or challenge across cases.

Findings

<u>Online Research & Productivity Tools</u>

The most frequent use by teachers and students of the laptops in the 16 observed classrooms at the four schools was online research used in conjunction with productivity tools. At each of the four schools, we noted, in our observations and interviews, extensive use of the laptops in these two capacities, as well as a wide range in the instructional approach used, and the resulting complexity of learning task assigned. Overall, the use of the 1:1 laptops appeared to contribute generally to the effectiveness of the learning environments per the design criteria of being more learner-, assessment-, community-, and knowledge-centered. However, online research presented unique challenges for the teachers and there were some examples of the

networked laptops actually detracting from effective teaching and learning, which was further exacerbated by the 1:1 student to networked laptop ratio.

Across sites the teachers and students readily and effectively used search engines to access data on a variety of topics. The students used simple Google searches most frequently, but were also observed using other search engines such as Yahoo, Ask Jeeves, and Dogpile with advanced search techniques such as placing the search phrase in quotations or searching for images only. Invariably, productivity tools such as the Microsoft Office suite components Word, Excel, or PowerPoint were used to record and communicate the results of these searches in notes, papers, and presentations. This varied from creating web pages on India, to illustrating plate tectonics and earthquakes, to defining vocabulary words, to seeing what the weather was supposed to be for an upcoming field trip. Other examples included exploring poetry analysis, finding examples of Venn diagrams, and collecting and categorizing biographical information on Edgar Allen Poe. In addition, certain classes also used AppleWorks, FrontPage, and Publisher to create web pages and newsletters. Once again, a wide range of students' skills and capabilities in the use of these tools were recorded.

One example comes from an 8th grade language arts class. After explaining the objectives of the lesson, the teacher used a video projector connected to her laptop to walk the students through a research project that involved creating data sets from information collected on the Internet to write a biography paper on Edgar Allen Poe. As she modeled the navigational steps of searching on the Internet and utilizing a database to record what she found on her laptop, the students kept pace and executed the same procedures on their own laptops. Following her demonstration, the students worked independently using the search engine Google to locate pertinent Web sites, collect biographical data on Poe, and then organize it into a database the

teacher created using AppleWorks 6. To support the students in organizing the facts in a way that would later support their writing a paper, the database categories were related to the paper outline. During the demonstration the teacher modeled how to decide what facts went into which categories. During the post-observation interview, the teacher explained how the students would then use their own database of facts to write the biographical paper using the AppleWorks word processor.

In this example the networked laptops allowed for the students to access information and to process it in an organized fashion, but what was the added value of the 1:1 student to networked laptop ratio? Further, did this ubiquity provide any drawbacks or hindrances? The teacher's use of the projected image of some Web sites and the database let her model and thus make very clear how students were to collect, categorize, and organize the facts they found. Because it was a 1:1 environment the students were able to execute the actions in real time and ask any questions they had immediately. This supported the teacher in spending minimal time on helping them learn the basic, discrete skills of guided searching, selecting, and cutting and pasting pieces of data and instead emphasize to them the point of their search, which was the more complex, higher order thinking activity of autonomous research and the production of a research paper. While the laptops networked to the Internet provided the added value of a large amount of a variety of data at fingertip access through which they could search quickly with keywords, the 1:1 ratio allowed each student to work independently and pursue the facts about Poe that were of greatest interest to him or her. Further, since each student's database reflected the facts he or she located, its contents provided the teacher with a sense of the student's approach and perspective on the topic, his or her understanding of the guiding questions and how

to categorize facts, and, in general, if he or she knew how to carry out high-quality Internet searches.

A second example from a language arts class illustrates the range in teachers' instructional uses of online research and productivity tools that we encountered throughout the four schools. In this observed lesson the students were assigned to answer reading comprehension questions on a worksheet using an online version of the text *Treasure Island*. The teacher provided the students with the web address (http://www.kellscraft.com/treasureislandcontent.html) that contained the complete text as well as supporting materials such as the author's biographical information. The students were instructed to read the question and then look in the corresponding online section (i.e., chapter) for the answer. After relating these instructions the teacher provided no additional coaching or instruction and spent the remainder of the class sitting at her desk completing other tasks.

In this example, the networked laptops provided free access to the book, and allowed the students to employ key word searching to search for the answer. Since the students had individual access through the 1:1 ratio, they could proceed at their own pace and devise their own search strategies to seek the answers. However, the emphasis in this lesson was on completing the worksheet and providing the one correct answer for each question. Thus, it seems that if the school had this text on hand, the same activity could have been accomplished with a paper copy of the book. While online research and productivity tool use were the most frequently recorded uses of the networked laptops across all four school sites, the examples above illustrate how differently these tools might be employed.

The teachers reported that online research offered instructional challenges for them because of concerns that students might access inappropriate materials (i.e., games, pornography,

etc.), or waste time with inefficient or ineffective searches. While all the teachers across the four sites used online research in their classrooms, the approach each teacher used to address these challenges was different. In some classrooms, the students were given directions and a few suggested Web sites to begin their research, but were also encouraged to explore on their own using various search engines such as Google, Yahoo, and Ask Jeeves. A different teacher at the same site completely circumscribed her students' Internet access by filtering and presenting acceptable Web sites via a third party Web site called Nicenet (http://www.nicenet.org/). When one student inquired about using Google to search for something, the teacher responded with, "You are not searching the Internet, not ever." While the 1:1 student to networked laptop ratio doesn't create this challenge, it does intensify it; the teachers have a whole class full of students who simultaneously need to be directed and monitored regarding their use of Internet resources. Further, the presence of the laptops on a regular basis leads teachers to utilize the Internet regularly, as is borne out by our observations that this is the most frequent category of use, and so this too increases the frequency with which teachers need to meet this challenge.

Drill and Practice

The second most frequent laptop use among teachers and students across the sites was drill and practice exercises. The 1:1 student to networked laptop ratio provided unique and powerful capabilities to provide self-paced, individualized instruction with embedded feedback loops, scaffolds, and other tools embedded in the software that enhanced learning. The authors observed multiple examples of this added value when students were conducting drill & practice exercises. As observed in the online research and productivity tools uses, the drill and practice exercises generally enhanced the effective learning environment design principles. While there were isolated examples of the 1:1 laptops being used for low level drill and practice, the majority

of the observations recorded high level, individualized exercises that were learner-, assessment-, knowledge-, and community- centered.

Across sites, teachers used drill and practice exercises for instruction, remediation, reinforcement, and assessment of concepts. In observed math and science classes, teachers often used the laptops to conduct drill and practice exercises while they circulated throughout the room providing individual instruction. The students worked individually to solve math problems and games on Web sites such as Algebra Notes (www.algebranotes.com), Math Forum (www.mathforum.org), and AAA Math (www.aaamth.com). Language arts and Social Studies teachers used drill and practice programs such as Scholastic Reading Inventory, SuccessMaker®, Accelerated Reader, and Discourse to instruct and asses various topics ranging from Indian culture to reading comprehension. The majority of these websites and programs had unique features, which scaffolded tasks, explained concepts, and provided relevant and timely feedback.

For example, a 6th grade social studies teachers used Discourse to create a scaffolded series of tests that enabled the students to practice and demonstrate their knowledge of Indian culture until mastery had been achieved. Discourse is Internet-based software that allows teachers to monitor the responses students make on their laptops keystroke by keystroke. The first iteration of the test was taken online at home using class notes and books. In addition, the teacher had constructed the test with hints and prompts embedded into individual items. The second iteration of the test was taken online in class without the hints and prompts, but with the teacher observing each response of each student on his laptop at the front of the room. When the teacher saw that a student was not answering or answering incorrectly, he would intervene with a written prompt or hint. The final iteration of the test was for a grade and was taken in class independent of any help from the program or the teacher.

The 1:1 student to networked laptop ratio provided numerous levels of added value in this observed lesson. One of the strengths of this particular program used in conjunction with a 1:1 student to networked laptop ratio is that it allowed the teacher to view the answers of the students in real-time so that he could intervene with a written prompt, correction, or encouragement that only that individual students could view. The student could then revise immediately before the test was complete. The use of the laptops in this way makes the students thinking visible to the teacher and the student, thereby empowering the teacher and the student to detect and confront problematic or incomplete understandings. This ability to provide explicit guidance on what mastery looks like and to provide opportunities for the students to refine their understandings in real time at the individual level would be impossible save for the 1:1 networked laptops and is the essence of a learner-, knowledge-, and assessment-centered learning environment. Furthermore, by working individually on a laptop the students had a certain amount of privacy that possibly encouraged them to ask questions that they would not ask in front of their peers. Another added value of the 1:1 ratio of laptops to students is the automatic grading and reporting feature that enables the teacher to immediately begin remediation at the class or individual level. The combination of the Discourse software and the 1:1 networked laptops allowed the teacher to better ascertain the "knowledge state" of each student as well as the entire class (Bransford, Brophy, & Williams, 2000, p. 63). This added value gives the teacher a better understanding of how much time he or she needs to spend on certain areas of knowledge that may be isolated to an individual student or representative of the entire class.

A second example of drill and practice use emphasizes the role of feedback and individualized instruction in 1:1 student to networked laptop classroom. After instructing the students on how to 'play' a monomial exercise found on a website, an algebra teacher circulated

amongst the students providing individual coaching and direction as needed. The laptops were used primarily to complete learning exercises that drilled the students on previously covered concepts and to assess student comprehension. The websites used had 'hint,' 'help, ' and 'show me' buttons to assist students. In addition, the programs provided immediate visual and audio ("Wonderful," "Perfect," "Way to go," "Fantastic," etc.) feedback to the students regarding their performance. During this observation the teacher told the class, "I should hear 'Perfect' and 'Good Job' all the time." There was a significant amount of peer-assistance regarding the computer games and the students were obviously aware of their performance versus their peers. At the end of the individual exercises, the students brought their laptops up to the teacher's desk in order to confirm completion and understanding before going on to the next exercise.

The 1:1 student to networked laptop ratio in this drill and practice example provided added value in five main ways: 1) an increased ability to formatively assess; 2) an increased ability to individualize instruction and pacing; 3) an increased ability to provide timely feedback; 4) an increase in the student interaction and collaboration; and 5) an increase in student engagement. Similar to the example above, the multi-sensory visual and audio feedback enabled the teacher to quickly assess the knowledge state of the class and individual students. Using the audio and visual cues, the teacher circulated providing individualized instruction to students who were having problems. At the same time, the laptop-based program also provided individual coaching. For example when one student was having trouble she asked the teacher "How do I do this one?" and the teacher responded, "Click 'Show me' down at the bottom… and it tells your right here." The student followed the teacher's directions and was satisfied with the help she got from the 'Show Me' feature. This is an added value of the 1:1 student to networked laptop instruction because it frees the teacher from having to answer every question, which also results

in students waiting for help. Instead the students are empowered to use the 'Show me' feature to answer their own questions and the teacher has more flexibility to target instruction. As a result, the students were able to practice to the point of fluency in a self-paced manner thereby creating a learning environment that was centered on and congruent with their cognitive ability.

The 1:1 student to networked laptop ratio also allowed the students to proceed at their own pace while supporting peer collaboration and feedback. Students frequently asked each other how to solve problems or offered assistance to peers who were struggling. The 1:1 student to networked laptop ratio facilitated this interactive and social environment. Finally, the majority of the students observed across sites were highly engaged in these computer-based drill and practice games and exercise. It was obvious that the students enjoyed the feedback capability of the games, which encouraged and empowered students to practice a discrete skill set until mastery or fluency was achieved. Several teachers interviewed individually and in focus groups also reported a significant increase in student engagement and willingness to work.

Teachers reported few challenges in the use of the laptops for drill and practice beyond the previously mentioned concern of accessing inappropriate websites. However, observations revealed that drill and practice websites ranged widely in instructional quality and rigor. On several occasions, teachers used websites as a reward and playtime rather than an opportunity to learn. This challenge is increased with the 1:1 networked laptops as there are many content-based websites that can provided engaging distraction, but may not deliver challenging curricula-aligned exercises. Furthermore, the use of the laptops to assess certain concepts is limited. For example, computer-based math games or exercises use a multiple-choice format to assess comprehension. In observed lessons, the students would work the problems out on a piece of paper next to the computer, but then select one of the multiple choice answers provided to check

their work. However, there was no place or capacity for the machines to incorporate the students'

work into the assessment. In other words, the student could have worked a 5-step problem

correctly for 4 of the 5 steps only to make a mistake on the last step. But the laptops will not be

able to differentiate and therefore the student will not know which step he or she made a mistake.

This is a significant weakness of the laptops versus a teacher and presents a challenge to the

teacher that is easily remedied once he or she is aware of the problem. In addition, the downside

of the audio feedback is a cacophony of "Good Job" which is potentially distracting and/or

embarrassing for students who are not doing well.

eCommunications Video/Audio/Data Online Environments

The third most frequent use by teachers and students of the laptops in the observed

classrooms was online environments, such as classroom Web sites and video to disseminate

information, facilitate communication, and enhance instruction. Collectively, we'll refer to the

categories as eCommunications (NCREL, 2000). The 1:1 student to networked laptop ratio

provided added value in all of the observations within this category and in some cases it would

have been impossible to conduct the lesson save for the 1:1 networked environment. As seen in

the previous examples, the eCommunications uses present unique management challenges for the

teacher that could possibly detract from effective instruction.

Across sites, teachers used classroom Web sites such as School Notes

(www.schoolnotes.com), Nicenet (www.nicenet.org), and k12Planet (www.k12planet.com) to

disseminate information, synchronously and asynchronously communicate, and build local

communities within and among different classes. A typical Web site would contain the

classroom mission statement, rules, goals, objectives, assignments, homework, calendar, research

web links, and the individual day's agenda. Teachers would also personalize the pages with

interesting quotations, community news, exemplary student work, and class photographs. Often

these web pages were hyperlinked in a way that lets the students and parents receive more

detailed information as they clicked through the site. In addition, these Web sites were used as

mediums for publishing work and grades, turning in assignments, soliciting feedback on written

work from peers or teachers, and other forms of communication.

For example, in an observed 7th grade science class, the teacher used the class webpage

throughout the class for multiple purposes. The teacher began the class by instructing the

students to open their tablet-style laptops and to retrieve the day's agenda from the class website.

The website contained the class calendar, links to websites used for class research, alternative

assignments for absences, vocabulary lists, homework, due dates, resources, the state standards,

archived videos, archived lesson plans, and numerous other resources. The day's agenda

provided the goals of the lesson, the instructions for getting started, and a list of the programs

that would be needed to accomplish the task. The majority of the students immediately began to

work on an exercise comparing and contrasting infectious diseases using the Internet for research

and Inspiration or Kidspiration for presentation. While the teacher circulated answering

clarifying questions, the students were primarily self-guided throughout the lesson. At the close

of the lesson, the teacher directed the students back to the class web page and instructed the

students to record the due date for an upcoming assignment in their calendars

The 1:1 student to networked laptop ratio in this eCommunications example provided

added value in two ways. First, the teacher used the website to communicate what she wanted the

students to know, what she wanted the students to complete, and what she wanted the students to

be able to do by the end of the lesson as well as by the end of the year. Communications such as

these can contribute to the development of the deep understanding associated with knowledge-centered environments. Because students were able to access these e-communications as they worked through the assignment they could reference and proceed with them at their own pace, and follow links to additional information or directions more seamlessly. Second, because these class materials are online, students and parents alike can access the class information outside of class using the laptops. This supports student autonomy and independence as well as parental awareness. This latter point was reiterated in a post-observation interview in which the same teacher explained how the laptops have resulted in greater parent awareness and participation in their child's schoolwork: "I get less phone calls from parents because they are very aware of where their students are because they can check their grades and their missing assignments."

A second example exemplifies the added value of the 1:1 student to networked laptop ratio in facilitating synchronous and asynchronous communication among students. The lesson observed was a collaborative poetry writing exercise using an Internet-based website called NiceNet, (see http://www.nicenet.org), to compose and share poetry in an iterative, accretive process. The teacher informed the students that they were going to use the threaded discussion section of the website for a collaborative poetry writing exercise. The teacher first instructed the students to write a short, 5-10 line, poem in the threaded discussion area and post it so that the class could view it. She then asked each student to read the poem of the person on their immediate left, choose a word, phrase, or line from the poem, and copy and paste it into a new message window. The teacher then instructed the students to write a new poem incorporating the chosen phrase of their neighbor. The teacher gave the students approximately 8 minutes for each poem writing session and then had the student repeat the process 3 times. The teacher circulated throughout the exercise facilitating and coaching as needed. Each student produced an original poem and 3 additional poems that incorporated pieces of their peers' poetry. The entire lesson

used the threaded discussion interface to write and share the poetry. At the end of the lesson, the students copies and pasted the collection of written poems into a Word document and turned it in via a shared server.

While this lesson could have been accomplished with paper and pencil, the 1:1 student to networked laptop ratio added value in several ways. First, the use of the laptops to exchange the poems removed the shuffling and passing of papers thereby minimizing wasted time and management problems while making the transition from writing to reading and writing to rewriting seamless. In addition, the students did not have to decipher each other's handwriting, which can often be a problem. Second, the students were able to see each other's poems, incorporate portions of their peers' poems into their own poetry, and determine how their individual poems blended or fit into the overall theme that was chosen for their table in a virtual environment. This allowed for "opportunities to revise and improve thinking, help students see their own progress over the course of" the class (Bransford, Brown, and Cocking, 2000, p. 25). Third, according the observed teacher, when teaching this lesson with paper, the student writing degenerates after the second round because the students are tired of writing and passing papers back and forth. When using the laptops, the student writing did not deteriorate in quality and the students maintained a relatively higher level of engagement with the exercise. Finally, the use of the shared server saved time and paper, provided a permanent record, and made the process easier and more efficient.

The use of eCommunications in a classroom with a 1:1 student to networked laptop ratio presents several management and procedural challenges to the teacher. As documented in the drill and practice section, the use of video in the classroom can lead to a high level of distracting noise as 15-30 individual laptops begin playing videos at different intervals. Some students used

this as an opportunity to disrupt the class by intentionally restarting the video or turning up the volume beyond the necessary level. While this audio problem can be partially remedied with headphones for each student, this in itself presents possible management issues of which teachers needs to be aware. A second potential challenged for teachers is the complexity of the activities, which required multiple explanations of the steps necessary to complete a task. The poetry writing exercise, which had multiple steps, necessitated clearly presented directions. The teacher in this observation posted step-by-step directions on the classroom wall and, when presented with a procedural questions, referred the student to the posted directions. If this had not been done, the lesson may have become bogged down in procedural explanations.

Challenges

In addition to the specific challenges presented by the 1:1 student to networked laptop ratio detailed above, more general challenges unique to 1:1 environments were documented as well. The challenges fall generally into two categories: 1) classroom management and 2) hardware issues.

Teachers across sites reported that classroom management had become more problematic. One teacher explained, "It makes classroom management--it raises the management to a whole other level, if you let it." While the computers are powerful tools, they can also serve as a competitive or disruptive distraction. Across sites, the authors observed teachers having to repeatedly instruct the students to close their laptops when not using them for the lesson and to navigate to the appropriate page. The also recorded isolated, but significant examples of teachers unable to successfully manage the 1:1 student to networked laptop ratio. In this environment, if the teacher does not have strong class management skills, the computers simply add another layer of management complexity that is possibly overwhelming.

Hardware problems present another challenge with a 1:1 student to networked laptop ratio. These challenges consist of students forgetting to bring their machines to class, students not having machines due to repair issues, and students arriving to class without a fully charged battery. The most frequently observed challenge was the battery issue. Invariably 1-3 students arrive to class without a functional computer due to a lack of charge. In the worst-case scenario, if the classrooms do not have well-positioned outlets, extra computers, and/or a flexible teacher these students are essentially locked out of the planned lesson and consequently often create a disturbance.

Previous research on 1:1 classrooms support our findings that the 1:1 computing classroom frequently presents unique challenges and barriers to successful instruction (Hill et al., 2002; Kerr et al., 2003; Newhouse, 2001; Turnbull & Gilmour, 1991; Zucker & McGhee, 2005).

Discussion

In our observations the 1:1 student to networked laptop ratio added value to the teaching and learning process by providing an increased: 1) ability to formatively assess learning; 2) ability to individualize instruction; 3) capacity for self-guided pacing; 4) ability to access online resources; 5) capacity for student interaction and collaboration; and 6) capacity for networked communication and materials management. Each of these added value categories is congruent with one or more of the four interrelated design principles of effective learning environments, as we discuss below.

Ongoing assessments that make whole class and individual student understandings visible are essential to an assessment-centered environment (Bransford, Brown, & Cocking, 1999). As evidenced in this study, a 1: 1 student to networked laptop ratio provides added value to formative assessments by increasing the frequency and quality of the assessments while

decreasing the time and labor required for such intensive assessments. These assessments are fast, efficient, and greatly facilitate the teacher's ability to target remediation and to meet lesson objectives. The real-time monitoring of students' understanding represented in observations of this study would be impossible without a 1:1 environment. Furthermore, the combination of 1:1 computers with the embedded scaffolding and coaching features found within many of the computer applications has the potential to shift our current understanding of drill and practice from a low level didactic learning approach to a high level constructivist approach.

The increased abilities to individualize instruction and provide self-paced instruction are critical qualities for a learner-centered environment. Across sites, the 1:1 student to networked laptop ratio empowered teachers to cultivate these principles within their classrooms. By capitalizing on the greater frequency and higher quality formative assessments, teachers were better able to ascertain each student's level of understanding and design learning tasks that were individualized. This is one of ways that technology has been seen to create an effective learning environment effectively "increasing opportunities for learners to receive feedback from software tutors, teachers, and peers; to engage in reflection on their own learning processes; and to receive guidance toward progressive revision that improve their learning and reasoning" (Bransford, Brown, & Cocking, 2000, p. 243). Perhaps more significant and indicative of the future, each student had the ability to proceed through a series of learning tasks at his or her own pace in an engaging, but challenging laptop or web-based program.

The increased capacities for student interaction, collaboration, communication and materials management as well as the ability to access online resources via the networked laptops are critical qualities for community-centered and knowledge-centered environments.

The added value that the 1:1 student to laptop ratio brings to these capacities was clearly exemplified across sites. While different teachers used the laptops to reinforce or support divergent norms, e.g., competitive versus collaborative, the laptops brought added value to each. The drill and practice findings clearly represent the use of the laptops to reinforce a competitive classroom norm while the poetry writing exercise emphasized collaboration. In the latter example, the 1:1 ratio allowed the teacher and students to create virtual communities that communicated synchronously and asynchronously to share ideas, solicit writing feedback, or ask relevant questions about the learning task. One of the more surprising findings from this particular case was the continuation of asynchronous student communication concerning poetry via a class-based website for two weeks after the last day of school. The added value the laptops created in building these virtual communities warrants further research.

Another practical aspect of our findings is the efficiency and speed of materials management that is possible within the 1:1 environment. The shared server is a powerful tool and it could be hypothesized that in the future it will be the main medium by which students and teachers exchange work (i.e., quizzes, homework, assignments, etc). In addition, classroom websites are used as mediums for publishing work and grades, turning in assignments, soliciting feedback on written work from peers or teachers, and other forms of communication. While not explicitly pedagogically driven, the use of these tools to manage class assignments and activities is an important component of a fully functional 1:1 environment and worth further investigation and documentation.

The challenges of teaching in a 1:1 environment can be substantial. The findings from this study revealed the unique hardware issues, the complexity of the learning tasks, and the potentially distracting characteristics of laptop instruction (i.e. video, audio, unlimited Internet

access) intensify the need for effective classroom management skills. In addition, the observation that certain teachers interacted less with their students or taught less in the 1:1 classroom is significant. In these cases, we hypothesize that the teachers mistakenly viewed the laptops as proxy instructors relieving them of their teaching responsibilities.

Implications and Conclusion

Laptops can add value to the teaching and learning process but can also contribute to classroom management problems. In addition, the presence of 1:1 laptops does not automatically add value and their high financial costs underscore the need to provide teachers with high-quality professional development to ensure effective teaching. In order to create effective learning environments, teachers need opportunities to learn what instruction and assessment practices, curricular resources, and classroom management skills work best in a 1:1 student to networked laptop classroom setting.

The documentation of both high and low-end laptop uses within this study supports the assertion that teachers would benefit from explicit instruction about an evaluative framework to apply to potential curricular resources and software applications. If combined with district-level or school-level support for locating and acquiring these resources, such a framework would focus teachers' instructional decision making on the integration of high-quality resources that provide documented added value to teaching and learning, A large number of such resources must be located and aligned to the desired student outcomes in order to use laptops in the classroom on a regular basis in meaningful ways.

In addition to professional development that helps teachers adapt their instruction to leverage unique pedagogical capabilities within a 1:1 environment, these findings suggest special attention should be paid to help teachers realize how laptops can support assessment-centered

learning environments. Formative assessments are a powerful support for learning yet many teachers do not regularly employ them. Further, the drill and practice-oriented software that can be used to support formative assessment if often considered a low-level use of computers and one that many technology enthusiasts dismiss. Yet when every student has a laptop, drill and practice programs embedded within digital textbooks have the potential to increase the frequency, quality, and speed of whole class and individual student formative assessment. This suggests the need for professional development for this pedagogy in general as well as support in locating assessment tools and aligning them to key student learning outcomes.

Technology specialists and other technology leaders at schools with laptop programs will need opportunities to learn about and plan for the challenges of managing ubiquitous laptops in the K-12 environment. It is critical that the leadership implement policies and routines that allow teachers to focus on the significant tasks of integration, rather than distracting management issues such as charging the laptops' batteries or preventing students from accessing inappropriate Internet sites. Associated with this management might be additional costs for carts, electrical work, insurance policies, and loaner laptops, parent education programs, and school board approval of new policies. This suggests a need for careful "What if?" planning that brainstorms all the things that could go wrong when several hundred adolescents are simultaneously given delicate and expensive machinery that is vulnerable to viruses and other malfunctions.

The implications of the above for policy makers is that alongside the costs of purchasing hardware, the costs of well thought out professional development and management programs must be budgeted for as well. If the teachers and the technology specialists do not have opportunities to learn about and plan for meaningful and well-managed 1:1 uses, it is less likely that the laptop programs' goals will be reached, and the related investments warranted.

The instructional uses of laptop computers detailed above warrant further investigation into the relationship among instructional approaches to learning, the complexity of learning attempted, and the authenticity of learning (NCREL, 2000). It's really not about the laptops. It is about what the 1:1 laptops enable in terms of new ways of teaching and learning. Our results indicate that the 1:1 student to networked laptop ratio contributes generally and significantly to the effectiveness of the learning environments per the design criteria of being more learner-, assessment-, community-, and knowledge-centered. However, without a congruent professional development program and clear definition in program objectives certain uses of the technology for effective teaching may be ignored or overlooked. Further research is needed to answer questions such as: What are the conditional variables that influence the uses recorded? How does high-stakes testing influence the uses of technology in the 1:1 classroom? How do expert teachers use technology when given 1:1 computer resources? From the teachers' perspective, what are the conditions that facilitate or hinder successful integration of computers in the 1:1 classroom? Do ethnic, economic, or gender-based subgroups benefit more or less with the introduction of 1:1 computing? These and other questions need to be fully explored in future research studies to fully leverage the power and potential of 1:1 computing in the k-12 environment.

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Table 1.

Added Value Summary for Accessing Data, Processing Information, and Communicating

Knowledge

Task	Added Value
Accessing Data	• Multi-sensory • Greater amounts of data • Searching and "mining" capabilities • Timeliness of the information • Relevance of the information
Processing Information	• Self-paced • Individual attention • Remediation • Practice to the point of fluency • Visualizing information • Develop process or skill capabilities • Organize and categorize information
Communicating Knowledge	• Publish information to an audience • Communicate in an authentic format and style • Communicate findings and understanding to others

Table 2

Demographic Information for School Sites

School Name	Level	Grades Served	Enrollment	District Type	Percentage Poverty[a]	Percentage Minority[b]
Fulton Middle School	Middle	6-8	1,017	Suburban	47.15	24
Jackson Middle School	Middle	6-8	551	Urban	21.9	54.7
Lewis Middle School	Middle	6-8	890	Urban	62.3	76.3
Lincoln Middle School	Middle	6-8	972	Urban	59.67	87.2

[a] Free and reduced lunch percentage
[b] African American, Hispanic, Asian, Pacific Islander, American Indian, Filipino

Table 3

Implementation Models

School Name	Implementation Model	Access level and Ratio Achieved
Fulton Middle School	Laptops Carts	Periodic 1:1
Lewis Middle School	A combination of 1:1 Tablet-style laptops and desktops	24/7 1:1 for tablets: 2:1 thin client
Lincoln Middle School	Teams of 1:1 laptops classrooms within 6th, 7th, & 8th Grade	24/5 1:1
Jackson Middle School	All 7th & 8th Grade students have laptops	24/7 1:1