A Year in the Life: Two Seventh Grade Teachers Implement One-to-One Computing

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Abstract

Maine was the first state to put laptops in the hands of an entire grade of students. This interpretive case study of two middle school science-math teachers was driven by the general question: Given ubiquitous computing, how do teachers use computers in constructing curriculum and delivering instruction? Specifically, the researchers sought to examine the facilitators and barriers for teachers in using laptops in the classroom. Using qualitative methods, the researchers collected data during the first year of the Maine Learning Technology Initiative (MLTI). Differential effects of one-to-one computing on each teacher were found along two dimensions: the effect of technical technological issues, and the educational effect of technology policies. For both teachers, the effects were deeply altered by the teachers' beliefs about teaching and learning, which in turn affected their ultimate choices of how their time (and their students' time) was spent. This empirical study offers a preliminary analysis and can be used both as a reflective mirror for practitioners and as a guide for administrators and teacher educators. (Keywords: middle schools, ubiquitous computing, one-to-one computing, laptops, qualitative research.)

INTRODUCTION AND PROBLEM STATEMENT

Over lunch one day, Seymour Papert convinced the then-governor of Maine, Angus King, that the best way to improve education was to put laptops in the hands of all students (Williams, 2000). King established a Task Force that made recommendations to the Legislature for the structure, oversight, and operation of the Maine Learning Technology Initiative (MLTI) (State of Maine, 2001, p. ii). In the fall of 2002, more than 17,000 seventh-graders and their teachers in 243 middle schools had their fingers on the keyboards of laptops. Each Apple iBook contained Appleworks word processing software, an Internet browser, First Class e-mail/bulletin board software, various helper applications, and *The World Book Encyclopedia.* In Maine, where local control of education is a fiercely held right, individual schools were expected to devise policies regarding acceptable use, insurance, and conditions for allowing laptops to go home. Schools could install other software if they chose. The state contract with Apple included wiring every school for wireless Internet access and providing how-to workshops for teachers. In addition, a position was created at the state level to oversee the provision of professional development with minimal funding.

The researchers recognized the unique opportunity of an entire state moving forward with middle school computing. As teacher educators, we wished to address the question: Given ubiquitous computing, how do teachers use laptop computers in constructing curriculum and delivering instruction? Specifically,

the researchers sought to examine the facilitators and barriers for teachers using laptops in the classroom. Because other researchers (Maine Education Policy Research Institute, 2003) were evaluating MLTI on a statewide scope, we aimed to construct a more finely grained picture by using ethnographic research techniques—that is, by posing a broad, open-ended question and seeking to discover emerging patterns (Patton, 1990). Specifically, our areas of inquiry included examining how one-to-one computing interacted with teaching styles as well as determining the barriers for teachers who were integrating the laptops into teaching and learning.

Based on the qualitative research paradigm we believe that this article contributes to the growing body of knowledge regarding teacher implementation of laptop computing through Glaser and Strauss's "grounded theory" (1967, p. 4, cited in Patton, 1990, p. 45). The ultimate goal was to illuminate the daily details in naturally existing classrooms. It is intended to draw a rich picture that will provide a companion to previously published, self-reported survey data about the MLTI project (Fairman, 2004). The results can be used both as a mirror for practitioners' self-reflection and as a guide for administrators and teacher educators.

REVIEW OF THE LITERATURE

From a theoretical perspective this research study draws upon Rogers' "diffusion of innovations" theory (1983). Diffusion involves the process through which the teachers progress from first hearing about the innovation, to forming an attitude, to deciding to reject or adopt it, to implementation of the innovation. Over time, actions, decisions, and choices are influenced by the contextual social system of interrelated units.

The literature on teachers' integration of laptop computing in instruction presents a complex picture (Bebell, Russell, & O'Dwyer, 2004), muddled by varying definitions of technology, a wide array of applications, and the rate of change in computers themselves. The difficulty of longitudinal studies can be epitomized by the comparison of the use of a lone classroom computer, with an operating system of 128K and monochrome monitor, with an entire classroom of students armed with laptops each using 1,000 times that memory. Teachers' integration of computer technology in their teaching is based on a number of factors, including access to *properly functioning* technology (Hill, Reeves, Wang, Han, & Mobley, 2003; Sandholtz & Reilly, 2004), level of professional development (Parr, 1999; Silvernail & Lane, 2004; Vannatta & Fordham, 2004), and teacher dispositions (Riel & Becker, 2000). A preliminary study examining general teacher attributes found that the best predictors of the use of classroom technology also included openness to unspecified change and a willingness to invest time and energy beyond contractual duties (Vannatta & Fordham, 2004).

Various studies sought to illuminate the influence of teachers' backgrounds on effective technology integration. Windschitl and Sahl (2002) conducted a two-year ethnographic study and concluded that the effects of one-to-one computing on instruction were mediated by teachers' "interconnected belief systems about learners in that particular school, about what constituted good teaching

within the context of institutional culture, and about the role of technology in lives of students" (p. 201). They also noted an additional factor influencing computer integration was the teacher's ability to see the potential for effective instructional use. Similarly, Russell, Bebell, Cowan, and Corbelli (2002) found in their case study of a fourth-grade class using one-to-one word processing devices that the greatest change in instruction occurred with the teachers who had already demonstrated a favorable disposition toward the use of computers in educational settings.

A growing body of literature based on cognitive science and technology suggests that a high ratio of computers to students may change the teaching and learning dynamics in the classroom. For example, Kozma's (2003) meta-analysis of 174 international case studies found clustering in the teacher behaviors that influence classroom technology practices.

A collaboration of public schools, universities, research agencies, and Apple Computer investigated the influence of routine and ubiquitous computing under the aegis of the ACOT (Apple Classrooms of Tomorrow) Project. After ten years of study, the researchers concluded that one-to-one computing *eventually* changed the roles of teachers (Sandholtz, Ringstaff, & Dwyer, 1997). At the project's outset, teachers structured their classrooms and organized their lessons in the same ways that they always had. However, the researchers witnessed the teachers moving along a continuum of instructional evolution over time, from *entry, adoption*, through *adaptation*, *appropriation* to *invention.*

Similarly, Rockman (2000) found in his three-year study that laptop-using teachers reported a statistically significant change in practice towards constructivist teaching as compared to matched non-laptop teachers. Among other findings, Henriquez and Riconscente (1998) also reported that 58.7% of the laptop-using teachers were more likely to act as coach or advisor than as instructor.

Fairman (2004) described the change of classroom dynamics in her state-wide MLTI study titled "Trading Roles: Teachers and Students Learn With Technology." Detecting "role reversal," Fairman reported teacher survey and interview comments that supported this concept, such as, "I think the biggest thing is teachers moving from being the keeper of knowledge to the facilitator of what's happening in the classroom" (p. 17). Furthermore, early in the implementation of MLTI, both principals and teachers reported an "increased use of an inquiry approach as opposed to memorization and practice; increased use of interdisciplinary or integrated approaches; increased use of cooperative or collaborative structures for learning and increased use of differentiated or individualized learning tasks" (p. 18).

Other researchers have been more cautious about the notion that computers may function as unintentional catalysts for instructional change. Mathiasen (2004) concluded a three-year study by saying, "From a pedagogical perspective, the question of whether teaching is enriched when all students have a laptop is front of them is debatable" in part due to educators' use of such vague terms as "effective" or "improves teaching" in their goals and objectives (p. 289). Schofield (1995) referred to Salomon's metaphor of the "Trojan Horse" Technology slipping under the eye of the gatekeepers (teachers and administra-

tors) to infiltrate and change our educational system. Schofield suggests that without purposeful planning and philosophical alignment, the "unanticipated" effects of educational shift from teacher-centered to student-centered cannot be taken as inevitable. In her study, she found that when teachers had goals and beliefs unaligned with supporting deep-seated change, any purported transformative effects of using technology were greatly hindered. Taken in sum, the history of research on ubiquitous computing provides a rather complex view, finding a multitude of factors influencing teacher infusion of technology in the classroom. We employed a qualitative research paradigm to profile the daily details of one-to-one computer use of two middle level teachers, with a view to discovering patterns that might reduce some of the complexity.

METHODOLOGY

The theoretical basis for this research is phenomenological inquiry, which uses a naturalistic approach to "inductively and holistically understand human experience in context-specific settings" (Patton, 1990, p. 36). As teacher educators, the researchers were most interested in the specifics of how classroom teachers implemented the MLTI project. While acknowledging the value of survey and interview data, we set out to verify these data with case study classroom observations. The research evolved in ways that uncovered and untangled the complex reality of two middle school teachers. (See Table 1.) Data included transcripts of teacher interviews and classroom observations as well as teaching artifacts such as e-mails from the teachers, handouts, Web pages, and news articles about MLTI. As in many qualitative studies, we began with a broad question and constructed finer foci as we analyzed the data (Patton, 1990). Concerns of validity in qualitative research are addressed in two ways: triangulation through multiple data-gathering techniques (Berg, 1989)—i.e., interviews, observations, and artifacts—and methodological integrity (Patton, 1990)—i.e., the participants read and authenticated early drafts of this manuscript.

Our criteria for selecting participant teachers were: they must be actively involved with the MLTI project, teach science, and be willing to be part of our research. In addition, the school itself had to fit two requirements: be within reasonable commuting distance due to the large amount of observation time,

Table 1. Data Collection Artifacts

	Susan *(Abigail)*	Rick *(Herman)*
Interviews	5	3
Observations	14	8
Artifacts		
E-mails (teachers)	8	14
Teacher produced handouts	11	6
Web page work	5	5
News articles	53	

and be a typical school—one that did not stand out in terms of extremely high or low achievement scores, socioeconomic base, or funding. Eventually we chose Hillside Middle School (pseudonyms are used throughout) whose average student standardized test scores were close to state averages across all subjects for at least the previous three years. The ethnic composition of the town is also similar to the state. Hillside's population is 95.6% White, 1.7% African-American, 1.2% Asian, 0.7% Native American, and 0.8% Hispanic. The state is 94.1% White, 1.7% African American, 1.4% Asian, 2.3% Native American, and 0.5% Hispanic.

Hillside Middle School, located in a rural community in the northeastern United States, contained approximately 380 students in grades six through eight. Seventh grade students were divided into two "houses," with each house having a social studies teacher, a language arts teacher, and a teacher who taught both math and science. This study began during the first year of MLTI with a November meeting with the principal, for the purpose of gaining access to the school and obtaining an underlying understanding of administrative support. The study ran through mid-June. In addition, our participants answered follow-up questions the following May. Although Rick and Susan, the paired participants, were "samples of convenience," they provided an intriguing view of how teachers cope with one-to-one computing.

Interviews with Rick and Susan were characterized as "guided semi-structured or semi-standardized" (Berg, 1989). Each researcher asked pre-determined questions and introduced special topics. We probed deeper as responses warranted, and the participants were encouraged to add additional reflections, comments or opinions that had not been formally posed. Field notes of classroom observations were expanded as soon as possible, and coded into emerging categories of interest. Inter-rater agreement between the researchers was reached.

The researchers used an iterative content analysis technique that involved transcribing audiotapes, and coding artifacts, observations, and interviews (Spradley, 1980). The unit of analysis was a single topic or a subject. After the first interview and first classroom observation, we came to an agreement on the selection criteria and the categories or domains for each subject topic. We disaggregated the data (separated transcriptions into single topic segments) and categorized them. Initially the categories were: Technical Skills Level, Modes of Instruction, Use of Computers in Classroom, Professional Development, Construction of Units/Curricular Planning, and Instruction. After our preliminary domain search (Spradley, 1980), we added the categories: Assessment of Student Work, Value of MLTI, School Policies, and Other (including affective comments.) We used inductive analysis as we read and discussed the data, always searching for underlying patterns.

RESULTS

Typical Lessons: Teaching Style

Both Rick and Susan held a positive vision of the educational potential of laptops. Rick had devoted several years to earning his recent Master's in Instructional Technology degree, evidence of his belief in the educational potential of computers, a prerequisite for effective integration according to Windschitl and

Sahl (2002). For similar reasons, Susan had enrolled in a graduate course on using laptops for middle school math prior to the implementation of MLTI. Although she had been teaching seventh grade science for only three years, Susan was not a recent graduate. Holding family life as a high priority, she had delayed her career until both her children were school-aged.

Susan could envision specific ways in which computers could support education. The shelves in her classroom were laden with multicolored clay cross-sections of Earth, each layer labeled "core," "mantle," and so forth. Ruefully, Susan explained that these items took considerable time, made a huge mess and now occupied important space. "Here," she said, "would be a perfect use of the laptops. Students could create a digital diagram in the beginning and add to it as they learned more." Susan believed the laptops could also redress issues with their science textbook, specifically that the publishers' apparent effort to be "friendlier" resulted in more pictures but less content. Not only could she see online resources replacing watered-down textbook content, but she also believed that high-quality Web resources could better target state learning standards and allow for the range of reading abilities in her class. Susan incorporated these two beliefs into an instructional strategy: as students accessed Web sites she had provided, she walked around the room pointing out more complex sites to the advanced students and easier sites to struggling readers. Subsequently, she evaluated their answers against the level of challenge she had given them. Susan noted that a problem with this technique was keeping track of the matches between sites and students.

During the first year of MLTI, Susan believed that one benefit to the laptops was enhanced motivation. Many students spontaneously used their laptop's *World Book Encyclopedia,* whereas in the past they would not have cracked a textbook or asked for a library pass. Furthermore, when Susan compared many students' reading and answering questions online to a similar activity with workbooks, she found that students appeared much less "needy" online. They complained less and appeared to think and work more independently. Halfway through the year, she pointed to one of her typical non-performers. "He was eight times more engaged [during the WebQuest]. He's pretty disinterested usually. Today he was really focused on his work, even though he didn't get it finished. Usually he doesn't do *anything*."

Susan used a critical eye when selecting online instructional resources. For example, she described the time-consuming search for a WebQuest on the human circulation system:

> There were about 8 or 10 out there that I didn't like for a variety of reasons. Many of them are poorly written, with misspellings and bad grammar; I hate to put *that* in front of the kids. A lot of them have expired links…. Some are too commercial. Sometimes, they don't have a whole lot of value.

Even after the significant time Susan spent finding a high-quality site, she still saw the circulation WebQuest as an extra—a supplement to the unit, not part of the core body of learning.

Regardless of her reservations about the planning required, Susan discovered that the technology provided an inherent benefit in the graphing component of the seventh grade's Invention Academy. In the past, if students made a conceptual error such as mislabeling the axes, they could choose to spend twice as much time re-doing the graph or give up and accept a lower grade. This year, Susan saw an enormous difference in students' willingness to think through conceptual mistakes and make the requisite changes on their laptops. The authors note that the laptops did not cause this deeper thinking; it appears to be the result of Susan's instructional technique coupled with one-to-one computing.

When teaching, Susan's typical communication dynamic was a hub-to-spoke pattern, with the teacher mediating the discussion and interactions. She typically began with lengthy and detailed explanations of the topic, interspersing question and answer time with generous portions of seatwork. Student learning primarily derived from listening and reading. Problems or questions were directed to Susan, and she usually responded by rewording the question in such a manner as to propel the student to access prior knowledge. Typically, Susan verified student understanding with the formative assessment technique of circulating around the room for individual conversations or checking of work.

Rick, on the other hand, tended toward presenting brief, clear introductions or reviews, so the students could quickly begin the active learning assignments—sometimes as individuals, sometimes in teams. During these activities, the students would often find answers to many of their questions by consulting the hard copy guidelines and rubrics, or on the Blue House Web site, a resource that Rick had spent many hours creating at home. Much of the students' learning came from collecting and interacting with their own data and in discussions with team members about processing this information. During the frequent student learning activities, Rick employed an efficient, effective helping pattern with an illusory ease.

Another difference in the teachers' styles was manifest in the general culture of the classrooms. Rick seemed uncomfortable without the hubbub of productive activity, and he used the radio to blend various noises into an amorphous background sound. Susan didn't insist on strict silence, but her room was much quieter. A more significant difference in their classrooms could be seen in the way they circulated around their rooms. Rick's "loop-back helping pattern" was typical of his classroom assistance whether the students were working individually or in groups. Rick's behavior seemed to allow the students to feel a certain amount of independence and discovery in solving problems, while it also enabled Rick to help many students one-on-one in a short period of time. He always seemed to have a calm, relaxed stride in this helping mode, but he covered a lot of ground in the classroom. Similarly, whether the students were on or off the laptops, Susan seemed to be performing a similar loop-back pattern. However, Susan employed this strategy in a calculated, albeit effortless, method of formative feedback, while Rick seemed to loop back as a way to provide just-in-time help.

Teaching styles emanate from multiple sources; one of these is a philosophical view of the teacher's role (Windschitl & Sahl, 2002). In her past, the teachers

who had most influenced Susan were those who were very precise in their expectations and who held extremely high academic standards—the type of teacher she strived to be. At many levels, Rick had a similar view of a teacher's role; he declared high standards for his students and the position of the teacher as a facilitator. Rick explained, "I agree with middle school philosophies and firmly believe that the teacher is a learning guide… Teachers must empower their students and allow them to make choices, and challenge them to follow through with dreams and ideas." However, he diverged from Susan's beliefs about the role of a teacher by the higher level of active learning in his lessons.

In contrast to Susan's view of technology as an extra, according to Rick laptops "totally changed my classroom." An example was Rick's "Mean Student" statistics unit, in which every student created a spreadsheet on his or her laptop. Rick found that the laptops have allowed him to be more easily adaptable in the classroom:

> One of the greatest changes I've experienced since the arrival of the laptops has been my increased opportunity to act spontaneously. Every educator realizes that when a teachable moment presents itself, one must act accordingly. Nevertheless, in most cases [before MLTI], if that moment involves the use of technology, one must make sure that the computer lab is free and, if it is not, beg for its use from another teacher. Having one lab for an entire school forces teachers to plan way in advance. From my experience, teaching this way tends to make me hurry through things in order to maximize the use of the lab when I want it. … I hate being the teacher that can sit down and state exactly what I am doing four months from now in my room.

Rick felt that

> …A quality teacher knows how to harness the energy of a roomful of kids and motivate them to learn. It is essential for students to know that learning really can be fun—this can easily be done through active learning (physically engaging activities), and games in the classroom.

Rick found on numerous occasions that many of his students were more creative when using computers as learning tools than they had been before computer technology was available. He observed that they tended to learn various uses of laptops that could help them with their content learning quickly. For example, during the previous year in a one-computer classroom during a science research project, an estimated 75% of his sixth graders had opted to use a spreadsheet to graph their data. Then as seventh graders in the first year of MLTI, spreadsheet use was simply a review. In addition, Rick's "most challenged students *loved* projects that involved the laptops versus pencil and paper projects. I believe this is because the laptops served as an equalizer."

From the beginning of the year to the end, there was a large difference in the time devoted to integrating the laptops in Rick and Susan's classes. Rick explained that students quickly learned how to be more efficient and to engage more easily in independent learning with the laptops. However, even near the end of the year, Susan still struggled to find appropriate laptop activities for math, citing similar difficulties encountered by the graduate class for laptop use in math she had taken. With a content-packed curriculum, she outlined the trade-offs as she described some new ideas she wanted to test: "They are essentially games but they are games that reinforce what we are doing. …The issue really is you've got to see if you can *replace* [an old math activity]. It can't be supplemental. It's got to replace." Even looking into an open-ended "future," Susan was ambivalent about use of the laptops. She understood that time is a precious commodity and if the laptops were going to be used, they must replace old "activities;" they must do what teachers are already doing, but better.

Technical Issues

Echoing the results of other computer integration studies, Susan's pedagogy was significantly influenced by technical problems (Hill, Reeves, Wang, Han, & Mobley, 2003; Sandholtz & Reilly, 2004). Because no other teacher volunteered, Susan had agreed to be the designated the MLTI "Lead Teacher (LT)." She had been bolstered by repeated reassurances from the state team that the associated stipend was intended to support teaching expertise, not to reward "technical savvy." As the year went along, her involvement in the MLTI training effort of the state tapered off because leaving her classes produced more work for her (crafting alternative lessons) than if she had not gone.

One of the first laptop activities Susan planned was for students to practice scientific note-taking and upload their work to the school server. She saw this as an effective way to assess students' ability to select key points and to paraphrase. Much to her distress, only half of the students had been taught how to access the server, so Susan had to rededicate time to teaching the others. Although she had success pairing students who knew how to access the server with those who didn't, this inefficiency was frustrating: "I can't lose four class days in terms of content, trying to successfully implement the use of the laptops." Another change in planning occurred when the teachers noticed that the Internet connections operated efficiently in the morning but not the afternoon. So as Susan planned for using the laptops, she had to recognize not only the best time of the day for students, but also the best time for optimum network connections.

In actuality, not only did she need to solve her own technological issues, but the LT role required her to assist other teachers. Before MLTI, Hillside had been a PC (Windows) school, so Susan first needed to learn how to use a Macintosh before she could help others. She quickly realized that if she didn't attempt to solve the technical glitches, the teachers on her team simply wouldn't use the laptops. Rick had the advantage of having used Macs throughout his master's degree program. (At the time the LT was chosen, Rick had been working at another grade level.)

A positive result of technical problems was that students enjoyed showing Susan tips and tricks on the laptops. She believed that one way her teaching had changed was that she had become better at modeling life-long learning. Eventually Susan became skilled at resolving glitches, but it came with the price of having less time for her to focus on instruction and curriculum building.

Before MLTI, Rick had eagerly awaited the opportunity to use his substantial technology preparation more extensively. "I have taken many courses in the University of Maine program and learned skills that had to sit on the shelf until MLTI laptops entered the picture. Integrating technology is easy for me because of this. It is also quite fun!" Grant projects further enabled his use of these skills. For example, the U.S. Department of Education's Preparing Tomorrow's Teachers to Use Technology grant program gave Rick access to technology that his school had formerly lacked.

Technological infrastructures also shaped laptop use. For example, the district purchased a single networked printer for the entire seventh grade without first consulting teachers. Susan found that placing the printer at the end of the hallway was a management nightmare: out-of-sight students would "congregate around the proverbial water cooler," and this wasted precious time. Printer policies caused other problems. The language arts teacher railed at the district policy of printing "final drafts" only as counter-productive to the writing process and she simply ignored it. Additionally, by spring the ink supplies ran out! Rick remembered that the teachers found an alternative strategy, "We sought out as many USB printers as we could and students that needed to print color plugged into the USB classroom printer, while students only needing B&W copies were instructed to print to the library and/or computer lab."

Whereas many of Susan's problems with laptop use were at the level of "seeking connection" with the technology, Rick's problems were along the lines of "seeking optimization" in interweaving technology with pedagogy. For example, during the first week of school, Rick encountered a problem during a math unit in which students measured their height, arm span, and foot size. The student whose dimensions closely match the mean is called the "Mean Student." During the year before MLTI, Rick had transformed the "Mean Student" activities to a single-computer unit using a spreadsheet program and having students enter their data individually. With MLTI, Rick's unit underwent even more transformation—to a multiple-computer unit.

> It kind of backfired on me—which was kind of neat… It was the first week of school and [I wanted] to get the kids to know each other and work together. So I had them working in smaller groups and getting everybody's data and then combining smaller groups and sharing data. And then combine to larger groups and share data. But in the sharing of data it turned into incorrect data entries. You know, 27.3 cm turned into 23.7 cm. So I don't think I have one data sheet that's totally accurate [laughs], which is too bad …

But Rick felt he profited from this technical problem:

> But it was a neat learning process for me on how to and how not to use the technology. And I know better how to not do it next time as a class. … I'll go back to my original design of having one central spreadsheet. But then I'm going to put it on the school's server, and have them download it into their own laptops, so that everybody will have the same data. And I'll teach them how to manipulate the data.

Rick did not appear to let glitches slow his teaching down. He tended to roll nimbly with whatever technical punches were dealt him, and to turn negatives into positives. For example, Rick steered students to a Web site ("Cell City") that compared a cell's organelles and their functions to those of a city. When students encountered broken links for some organelles, Rick simply referred students to their textbooks. The students' work on the unit culminated in designing and making physical models of human organizations to which a cell might be compared (e.g., a factory).

Effects of School and District Policy

Although "Policy Decisions" was not one of our original research categories, we found important interactions of policy with teaching and learning, and added it to our domain analysis. During the summer before MLTI, Hillside's laptop integration team drew up Technology Use Guidelines, which outlined decisions regarding when students would get e-mail and be allowed to take the laptops home. These decisions had unexpected negative effects on teaching and learning. Rick reflected a year later on the effect of a school policy decision concerning access to the statewide intranet:

> …The people responsible for MLTI in my school at that time chose not to give out student First Class accounts that were provided to them free of charge. Access to these would have solved any printer issues since students could e-mail assignments to teachers.

Rick remembered the school's stance on Web pages, "The only tech policy that forced me to alter my teaching was publication of student work on the Internet. I maintain several Web sites and love publishing student work. At that time, our school did not have the proper document needed for parents to sign." Thus, he was not able to showcase student work.

First Class accounts for students would have also opened up many doors for instruction and learning. The integration team decided that the laptops must work smoothly in school before they could be allowed to leave the building. This crimped pedagogy. For example, it was a school rule that if work weren't finished in class, students were expected to complete it at home. Without being able to take laptops home until February, Susan found she had to limit assignments and projects to those that could be finished during the school day.

The laptop integration team's policy decisions also enumerated rules about the care of the laptops: keeping them charged, when to print, and so forth. Each infraction, a "violation," was noted on a card kept in the laptop carrying case. After a specified number of violations students were disconnected from the network. This caused a significant problem with curriculum planning. Early in the year, one boy printed off "reams" of TV-related material, violating three rules. As the policy required, his Internet access was temporarily removed. The consequence was that Susan either had to allow him to view Web sites with another student or she had to acquire comparable information from the library. The former was not only antithetical to the concept of one-to-one computing, but it also hampered both students' interactivity with the Web site. Susan elaborated,

> I have to create equivalent material for this student to work on, and in some sense work up an entirely separate lesson plan if it's gone for several days in a row. … How do you do what's equitable? How do you pull a kid off the laptop and now, for essentially disciplinary purposes, you've restricted his or her learning. And you've taken on a burden for yourself as the teacher.

Parents were invited to a meeting to discuss the expectations involved in allowing laptops home and they were strongly encouraged to sign the permission form. Should a family not be able to afford the annual $30 insurance fee, they were informed that Hillside had funds to cover it. Susan offered to telephone reluctant parents to convince them of the importance of allowing the laptops to come home, and of her strong belief that seventh graders could be so trusted. Nevertheless, there were several parents who expressly said they did not want their children bringing home the laptops.

When reflecting on his curriculum planning with laptops, Rick estimated that:

> "Preparation time is most likely the same; however the exact nature of my planning has changed. I guess a better way of stating this would be that I am now using and thinking with technology as my presentation and instructional medium, instead of the traditional methods."

Ubiquitous computer access was significant:

> "I no longer had to worry about using the classroom computer during the school day to do my own research (*via* the Web). I had my own access point, as did all of my students. As a class, I no longer had to worry about planning science units weeks in advance to ensure that my students could have access to the library and/or computer lab."

We feel that our research points in the direction of illuminating the specifics around teaching in a ubiquitous computing environment.

DISCUSSION

This study examined the manner in which the introduction of one-to-one computing affected the planning and instruction of two teachers. We have laid out the facilitators and the barriers that two teachers faced as they implemented the MLTI ubiquitous computing project. Prior to the study, there were indications for the researchers that our participants would be at the high end of a technology integration continuum. Our initial expectations were that we would find creative and innovative ways in which the teachers used laptops in their classrooms. However, we documented the ways in which Susan and Rick experienced the advent of ubiquitous computing differently, especially demonstrating the interplay between their teaching and their technical knowledge, time constraints, and imposed technology policies. For both teachers, the effects of ubiquitous computing were strongly shaped by their beliefs about teaching and learning.

Although case study research does not necessarily generalize to the population of middle school teachers as a whole, we feel that it may provide a reflective opportunity for any teacher questioning the role of educational computing. More important, we hope that administrators will note that one-to-one computing does not easily or automatically cause a shift in the dynamics of the classroom. We note that contemporary research illuminated more specific associations of schools' organizational characteristics with teacher use of computers (O'Dwyer, Russell, & Bebell, 2004).

Our qualitative research attempted to answer in very specific ways how two teachers began to implement teaching with ubiquitous computing. We felt that this periscope into the teaching lives of Rick and Susan adds refinements to the survey and interview data on the MLTI project as well as supporting some previous research while contradicting other previous results. The announced leadership support from Hillside's principal was solidly in place for MLTI—a plus for laptop infusion (O'Dwyer et al., 2004)—yet technology problems surfaced that were clearly a result of school and district policies. Our year-long data collection indicated that having access to one-to-one computing did not automatically shift instructional styles from teacher-centered to student-centered.

Our case study strongly supports the concept that our participants interconnected beliefs about teaching and learning, and about their specific students with their technology use (Windschitl & Sahl, 2002). Rick and Susan are each exemplars of the Vannatta and Fordham (2004) study, though in different degrees. Both could visualize the educational potential of the laptops and both were willing to undertake technology professional development on their own. Both teachers committed extra time to their teaching, but as an unmarried man, Rick was able to devote significantly greater time than Susan, who held her family life as a high priority.

Susan spent a great deal of time resolving technical issues—time that could have been spent planning or teaching. Her need for increased technical knowl-

edge impeded the integration of the computer technology. This mirrors the results of other research (Hill, Reeves, Wang, Han, & Mobley, 2003; Sandholtz & Reilly, 2004). In contrast, Rick was very efficient in the use of laptops in his teaching. Rick's teaching with technology unhampered by inefficiency and distraction reached the level of style described by Whitehead (1949) as "an aesthetic sense, based on admiration for the direct attainment of a foreseen end, simply and without waste" (p. 153).

Susan pinpointed students' assistance and their patience as the best support she received. When commenting on her habit of asking for student help, Susan said that she had, "learned pride is not an issue" and acknowledged, "some of the students were light-years ahead of her." This echoes Fairman's (2004) finding that teachers are using more cooperative teaching structures with MLTI. However, Susan's requests for student technological help were at a low pedagogical level, such as accessing the school server, not reaching into such higher pedagogical levels as structuring lessons, formalizing classroom management, or granting greater agency to students.

Rick could bring all his Instructional Technology master's work to bear on his daily use of the laptops, from prior platform knowledge, to troubleshooting experience, to detailed curricular integration. Susan ruefully admitted that her teaching "really hadn't changed that much" because of the laptops. Even though she believed in the educational potential of laptops, she was disappointed in her first year with ubiquitous technology, wishing there had been more time to devise better lessons. To understand the MLTI effects on Susan, one must also grasp the educational backdrop of the concurrent initiatives for implementing the Maine Learning Results standards. In an interview at the end of her second laptop year, "time shortage" still surfaced as the most significant leitmotif. Although she could envision the laptops' learning potential, the time required for statewide curricular mandates trumped time spent on planning for laptops. Susan nicknamed the compound effect: "rush-rush-rush, push-push-push." Tensions between mandated content and teaching process can also be seen in the teachers' expectations for "change in the classroom." If we were to place our two teachers on the continuum proposed by Sandholtz et al. (1997), Susan would fit in the *adoption stage,* in which teachers demonstrate concern for technology integration but give a heftier time commitment to teaching students how to use it. Rick fits squarely in the *invention stage,* in which "teachers experimented with new instructional patterns and ways of relating to students and to other teachers" (p. 44).

It is tempting to suggest that Rick's computer integration stage was more advanced than Susan's only because of his graduate degree. However, their teaching philosophies sit on different foundations. Susan strongly believed that her greatest responsibility was that her students learned *science.* In this context, she perceived laptop use as a wonderful extra: assisting with organization and providing motivation. Conflicting with this notion of extra is her belief in the potential power of the tool. A teacher's planning time and class time *are* key factors, but neither is unlimited. They must be carved out of a finite school day based on priorities, and such priorities are a function of the teacher's intercon-

nected beliefs about the role of teaching and learning. "If beliefs govern behavior, the process of replacing old beliefs with new becomes critically important in changing educational practice in schools" (Sandholtz et al., 1997, p. 36). Like some of the teachers in Schofield's study (1995), Susan held an incrementalist view of the laptops' place in her classroom: their purpose was to perform traditional work better and more efficiently, not to change the nature of educational roles. Change takes time and deep change may take longer, but major shifts are unlikely without the concomitant efforts of teachers to understand and to share belief in transformational goals. To rely on the "unanticipated consequences" of laptops as Trojan Horses for educational change is not a realistic strategy. Without a school-wide common understanding of goals and purposes, typical barriers to technology use will remain barriers.

LIMITATIONS AND RECOMMENDATIONS FOR FUTURE RESEARCH

A perceived limitation of this study may be related to case study methodology in general and, specifically to the sampling of convenience. The individual character, circumstances, and other personal traits of the subjects may bias the results in unanticipated uncontrollable ways using samples of convenience.

Although we did not purposefully set out to select a teacher of each sex, gender differences in one-to-one computing implementation are an additional area for future research. Other potential topics include the ramifications of increased communication with students' families through e-mail and Web pages, and the possible interactions of such communication with teaching and learning.

Additional conversations with the teachers revealed that a district-level technician who came from a PC culture apparently would not support the Apple laptops at Hillside. Davidson, Schofield, and Stocks (1991) have proposed that the vastly different cultures, routines, and values of teachers and technicians create dramatic and debilitating undercurrents in schools. The potential effects of such a cultural mismatch warrant further research.

One of the primary purposes for MLTI was to provide technology equity for students. Governor King was adamant that all Maine students receive the same device, leveling the proverbial playing field. He wished to avoid placing sophisticated computers in the wealthier communities and low-end imitations in the poorer ones. Potential inequity of access to laptops was a frequent irritant to Susan, as some parents would not allow their children to bring the laptops home—even when the school was willing to pay for insurance. She saw a match between the students "who were falling behind anyway" and the parents who "for one reason or another didn't trust them to have a laptop." Ideally, Susan thought that laptops going home should be an unquestioned assumption. "After all," she said. "We don't hear parents saying, 'You can't bring your math book home.'" Further research is needed in the area of equity issues of ubiquitous computing.

The teachers at Hillside Middle School, like their peers around the state, had been accustomed to the flexibility and privileges of local educational control. With recent state and national trends towards continuous, rigorous assessment and mandated curriculum, Rick and Susan's laptop experiences were compli-

cated by external pressures. Additional research is needed in the interaction of technology with teaching and learning when teachers' philosophical beliefs are at odds with mandated expectations.

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