

Portraits of One-To-One Learning Environments in a New Learning Ecology

John K. Lee, Hiller Spires, Eric Wiebe, Karen Hollebrands and Carl Young
North Carolina State University
Raleigh, North Carolina

Abstract: This research reports on four teachers in a new learning ecology prompted by one-to-one computing. The new learning ecology involves unique conditions for teaching and learning including: (a) immediate and constant access to information; (b) intensity, relevance and personalization of learning; (c) highly developed student dispositions; and (d) advanced teacher capacities. The study utilizes a multi-case method approach with four high school core subject classes, including data from classroom observations, interviews, and teacher materials. The findings suggest that teachers searched for ways to situate one-to-one computing in their teaching through a variety of negotiated actions: (a) using digital technologies as learning tools, (b) supporting existing pedagogical strategies, and (c) establishing the computer as a hub for learning activities. Additionally, important consistencies regarding the nature of the learning ecology emerged in the classrooms. These findings are an initial attempt to create a robust theoretical frame for one-to-one computing within a new learning ecology.

Keywords: One-to-one computing, learning ecology, technology, pedagogy

Introduction

"The digital age is creating an information and communications renaissance. But it is not serving all Americans and their local communities equally. It is not yet serving democracy fully. How we react, individually and collectively, to this democratic shortfall will affect the quality of our lives and the very nature of our communities."

-- Knight Commission, 2009

The Knight Commission (2009) suggests that we have entered an information and communications renaissance in the current digital age. One area that exemplifies this dynamic transformation has been the effort to put computers in the hands of every student in a school, which has become a reality for some communities across the nation. One-to-one laptop computing has emerged as one of

the most important contexts for educational innovation (Lei, Conway, & Zhao, 2007), with several states within the United States (i.e., Indiana, Maine, North Carolina, South Dakota, Texas, and Virginia) having implemented large-scale one-to-one computing initiatives. Research points to the impact of one-to-one learning environments and their potential learning benefits (Bebell, Clarkson, Burraston, 2014; Donovan, Green, & Hartley, 2010; Grimes & Warschauer, 2008; Mouza, 2008), technology literacy and writing (Penuel, 2006), and the advantages of cognitive tools (Weston & Bain, 2010). A recent study by Zheng, Arada, Nilya, & Warschauer (2014) provided the much needed perspective of student voices relative to personal computing in K-12 schools. Despite an abundance of activity, we still know very little about how the introduction of one-to-one student laptop computing impacts the classroom and the overall ecology of learning in schools, especially in terms of whether the initiative is affecting communities evenly as the Knight Commission warns.

Research presented herein sheds light on teaching and learning in one-to-one computing through an investigation of multiple classrooms in a single high school. Specifically, we investigated the practices of four academic teachers in a high school where every student was issued a computer and all teachers were expected to incorporate computer use in their instruction. The research reported here is an extension of a larger body of work in which we defined a *new learning ecology* (Spires, Wiebe, Young, Hollebrands, & Lee, 2012) related to one-to-one computing. The new learning ecology is a dynamic environment that extends learning contexts for students as they utilize technologies with the careful guidance of teachers.

Theoretical and Conceptual Underpinnings of the New Learning Ecology

Ecology as a metaphor for learning is widely used across a spectrum of disciplines, including but not limited to biology, psychology, linguistics, and education (Bronfenbrenner, 1986, 1989; Lier, 2004). Specifically related to the role of technologies and learning, John Seeley Brown (1999) defines knowledge ecology as “an open system, dynamic and interdependent, diverse, partially self-organizing, and adaptive” (p. 3). Barron (2006), in turn described the concept of a knowledge economy as a learning ecology as the “set of contexts found in physical or virtual spaces that provide opportunities for learning,” which may include formal and informal settings (p. 195).

Brown, Pendleton-Jullian, and Adler (2010) introduced the idea of “ecotones” to describe learning environments that possess a complex set of exchange dynamics. Ecotones is derived from the Greek word *oikos*, which means household, and *tones* from *tonos*, also Greek, which means tension or pressure. They contend that students are involved in “new combinations of education and research, classroom learning and learning in informal study groups, and learning that takes place in face-to-face and in online environments” (p.12). Gilbert (2013) describes an example of an ecotone in her work on civic education as providing an opportunity to “dismantle the boundaries between community and campus to create a highly interactive environment for civic engagement” (para. 3). Brown,

Pendleton-Jullian, and Adler (2010) applied the concept of ecotones to new “learningscapes” that they were seeing in higher education; however, the concept can be applied to K-12 learning environments as well. In both contexts, the tension of working with emerging technologies helps spark a creative dynamic in terms of teaching and learning.

Spires et al. (2012) defined a new learning ecology (Figure 1) as a new concept prompted by personal computing and learning environments. In a one-to-one ecology that has constant and immediate access to information, many influences are present in a partially chaotic (i.e., unpredictable) way – among complex interactions, new ways of teaching and learning may emerge. The new learning ecology provides new learning opportunities for students; greater understanding is possible as technologies are leveraged for ongoing learning actions. This view of situated learning (Lave & Wenger, 1991) is different from a scientific model in which every effect has a cause preceding it. The new learning ecology as we have defined it in relation to one-to-one computing environments is one such application, that includes four phases (Spires, et al, 2012,).

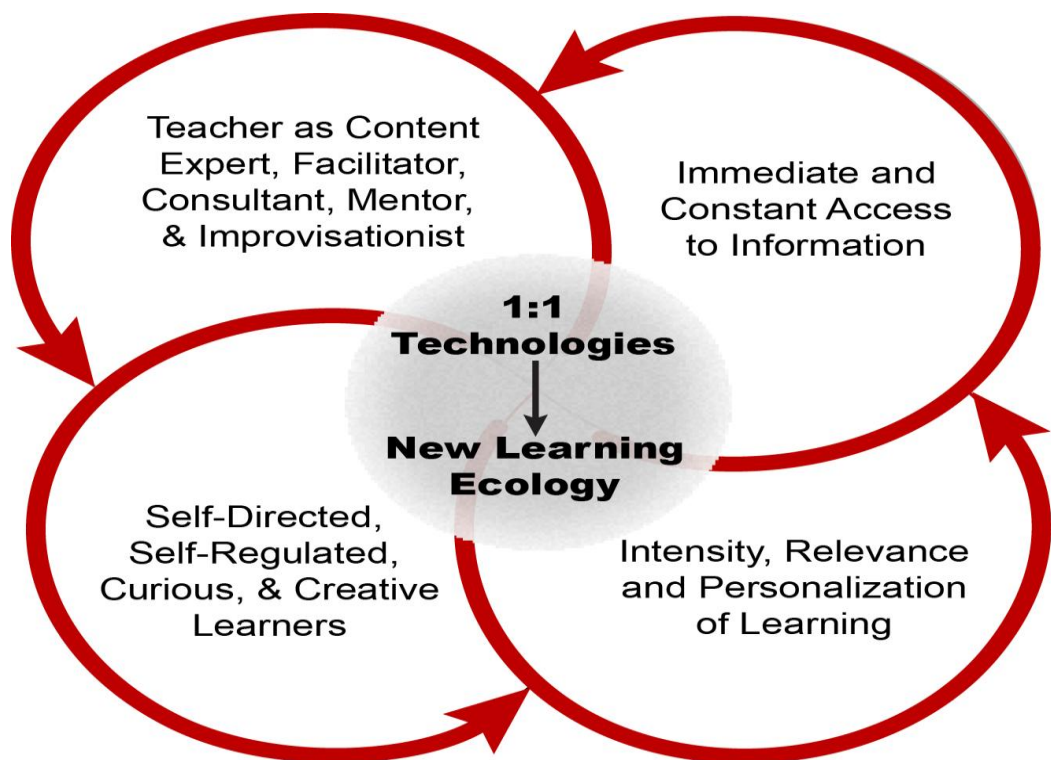


Figure 1. Four conditions of the new learning ecology.

One-to-One Computing in the Classroom

Policy-makers have championed one-to-one computing programs, in part, based on economic and equity concerns as well as a general interest in education reform (Zucker & Light, 2009). There is a belief that technology use by students and teachers is an essential component of developing future-ready, 21st century skills (Dede, 2009; National Research Council, 2008), and addressing the literacy challenges of the 21st century, more generally (Warschauer, 2006). Early one-to-

one laptop initiatives have been implemented at the statewide level in Maine and at a more regional level in New Hampshire (Bebell, 2005) and Virginia (HCPSTLI, 2008). Individual school districts in Texas, as well as states such as South Dakota, Massachusetts, and Florida, established programs ranging in size from 5 to 47 schools (Bebell & Kay, 2010; Cavanaugh, Dawson, & Ritzhaupt, 2008; Gorder, 2007). North Carolina also has an extensive and statewide one-to-one laptop computing program (NC1LC, 2008). Not surprisingly, schools in other countries are also establishing one-to-one programs—both industrialized nations such as Australia and emerging nations through the One Laptop per Child program (Derndorfer, 2011; Muir et al., 2006; OLPC, 2010).

This move to establish one-to-one computer (primarily laptop) programs has been supported by studies that have shown positive impact on the standard measures of student achievement (Gulek & Demirtas, 2005; Richardson, Mcleod, Flora, Sauers, Kannan, & Sincar, 2013). Penuel (2006) demonstrated in a meta-analysis that technology use may positively affect technological literacy and writing. Similarly, Sclater, Sicoly, Abrami, and Wade (2006) reported positive impacts on secondary reading and writing scores. The emergence of ubiquitous computing has also opened the door for new forms of instruction, especially individualized instruction driven by computer-based tutoring systems (Bebell & O'Dwyer, 2010; Mendicino, Razzaq, & Heffernan, 2009). From the researcher/practitioner view, however, there has been a desire to render a richer view of what is and what can be transpiring in the classroom (Spires et al., 2012; Weston & Bain, 2010) in the form of deep descriptions of transformative practice.

One-to-one laptop programs, in particular, and technology infusion programs, in general, are not without their critics. Numerous studies have found uneven implementation and varying levels of technology integration effectiveness when analyzed at the classroom, school and district level (Bebell & Kay, 2010; Shapley, Sheehan, Maloney, & Caranikas-Walker, 2009). The lack of strong implementation/integration plans and the resulting low-level or sporadic use that follows are problems that cross cultural and national boundaries (Derndorfer, 2011; Eteokleous, 2008). The reasons cited for these outcomes are many, including the slow response of curriculum development to match the potential held by new technologies (Johnson, Levine, & Smith, 2009). Researchers also have commented that technology implementation strategies in the classroom do not necessarily reflect how technology is used by students outside of the classroom (Ito et al., 2009). Cuban (2001) noted that initial technology integration designs often mimic their analog counterparts rather than facilitating transformative possibilities in teaching and learning. The result can be unstructured or poorly supported computer use that becomes a distraction to educational goals structured around traditional approaches and benchmarks (Clotfelter, Ladd, & Vigdor, 2009).

Christensen, Horn and Johnson (2008) concluded that one-to-one technologies act as a positive disruptive force to traditional approaches to instruction. However, the disruption must be followed by a development of new paradigms of teaching and learning (Weston & Bain, 2010). These changes are often seen first

in changes in teaching practices, if not in standard measures of student achievement (Cavanaugh et al., 2008). Instructors whose implementations have been deemed successful have understood the systemic nature of one-to-one environments, developing strategic plans to overcome both known and emerging barriers (Hew & Brush, 2007), especially as projects scale up (Dede & Rockman, 2007). Understanding the role that school leadership plays in one-to-one programs has been recognized as central to the success of projects (Ertmer et al., 2002). Student outcomes, in fact, is just one of many factors principals and other administrators take into account when deciding whether to commit resources to a technology project (Gerard, Bowyer, & Linn, 2008). Both researchers and policy makers also have concluded that research can play a role in building leadership and instructional capacity within school districts for the types of changes large-scale technology projects bring (Roderick, Easton, & Sebring, 2009; Zucker, 2004). Needless to say, at the classroom level, teachers have a key role in affecting how one-to-one technology is deployed and used in the classroom (Bebell & O'Dwyer, 2010). Teacher use of the technology affects the learning conditions in the classroom, while also providing a model for how students might make use of the technology.

Drawing from the theoretical and conceptual underpinnings of the new learning ecology and the literature highlighting the impact and support of one-to-one initiatives in the classroom, we conducted case studies of four one-to-one classrooms. With this understanding of the theoretical and conceptual underpinnings of the new learning ecology and research on one-to-one computing, our focus shifts to our own research initiative.

Research Context and Methodology

This research project emerged out of our work in a professional development network designed to support schools as they transitioned into a one-to-one computing program. After working with numerous teachers in one-to-one schools as part of this professional development project, we established a focused research relationship with a group of teachers at one school. Our research was guided by the following questions.

- What does teaching and learning in one-to-one environments look like?
- When and how were the conditions for the new learning ecology realized in four core academic one-to-one classrooms?

In addressing these questions, we wanted to describe the new learning ecology in one-to-one computing classrooms in terms of how teaching occurred in these environments. We purposively selected four teachers, one from each core content area, who had accepted the challenge of using technology in their teaching in the one-to-one computing environment that was new to their school. Following Yin's (2012) approach to multiple-case design, the selection of four teachers in four different content areas was an attempt to replicate the potential of a new learning ecology across four cases. The four cases were bounded by curriculum content, the teachers' pedagogies, and the uses of laptop computers in the classroom.

Yin (2012) also suggested that case selection is often theory-driven; therefore, we selected the cases based on the theoretical ideas featured in our early work on the new learning ecology (Spires et al., 2012). We were interested in determining the extent to which the teachers, who had all received previous training in one-to-one instruction, were facilitating a new learning ecology in their classrooms.

The research project was situated in a southern Atlantic coast state in the US in a rural high school with 1,044 students and 59 classroom teachers. Fifty-two percent of the students were African American, 46% were Caucasian, and 2% were Hispanic. Forty-five percent of the students enrolled were on free or reduced priced lunch, placing the school about 10% higher than the state average in terms of the number of students enrolled in the free or reduced lunch program. Students were each given a laptop computer. Faculty had completed two professional development sessions for one-to-one computing in the classroom. To get a fuller picture of one-to-one computing in the school, we chose a teacher in each of the four main content areas—English, social studies, math, and science—to observe and interview.

We collected data from observations of classroom activities, interviews with the teachers, and the analysis of teacher work materials. In total, we conducted 8 observations of the classrooms as well as 8 teacher interviews. All data were collected over a two-month period in early 2011. To ensure reliability, two observers completed observations. The observation instrument and interview protocol were developed from the Reformed Teaching Observation Protocol (Piburn, M., & Sawada, D., n.d.) and included a description of the classroom, descriptions of events, and related commentary. Interviews with all four teachers were conducted immediately following the observation sessions. The interviews included nine questions with follow up questions emerging during the interviews. Our data analysis consisted of scrutinizing our open-ended observations and resulting field notes as well as the data from the follow-up interview sessions. Analysis of teacher planning materials was also conducted as part of the process of confirming and disconfirming emerging findings.

We coded the data using a priori coding categories consisting of the four conditions of the new learning ecology. The general condition of student dispositions was comprised of four elements and the general condition of teacher capacities was comprised of five elements as noted below (Spires et al., 2012):

- Immediate and constant access to information and a global community
- Intensity, relevance and personalization of learning
- Self-directed, self-regulated, curious, and creative learners
- Teacher as content expert, facilitator, consultant, mentor, and improvisationist

We continued the analytical process using a method of selective coding which, according to Strauss and Corbin (1990), involves "selecting the core category, systematically relating it to other categories, validating those relationships, and filling in categories that need further refinement and development" (p. 116). In effect, we wanted to determine how teachers were meeting the conditions of the

new learning ecology as a way of making concrete the nature of learning in a one-to-one classroom. We identified themes that represented general trends or similarities among coded data. For example, we identified a tension between constant access to information and classroom management as we found multiple instances of observation and interview data describing classroom management activities that were coded for constant access to information.

From the coded data, Yin's (2012) method of pattern matching was used to determine the extent to which the new learning ecology was present in the four classrooms represented in the multiple cases. Additionally, a cross-case analysis was conducted in an effort to, as Yin (2012) describes, "apply a replication logic in interpreting the findings across the cases in a multiple case study" (p. 17). This analysis sought to determine the factors influencing the existence of a new learning ecology in the classrooms. After compiling a full list of these factors, we collapsed them into five assertions, which are presented following the four cases.

The Cases

This section presents cases of four teachers: Mrs. Perry, Mr. Thomas, Mr. Watson, and Ms. Austin. Each case describes how the teachers constructed learning experiences given the (a) one-to-one laptop computing activities present in the classrooms, and (b) potential of the new learning ecology as a theoretical framework for describing the interactions between teachers and students and their uses of laptops and information to achieve educational goals in the classroom.

Mrs. Perry, the Science Teacher

Mrs. Perry was an experienced science teacher. She had been teaching for 34 years, and although this was her first year using laptops in the classrooms, she had been using computers as part of her instruction for many years. During the semester in which this study was conducted, Mrs. Perry taught three classes of biology. Students engaged in a wide range of computer-based activities. They completed virtual labs and interactive activities from Public Broadcasting Services (PBS) as well as SAS Curriculum Pathways™. Several of Mrs. Perry's traditional hands-on dissection lab activities were being replaced with online virtual dissection.

In general, Mrs. Perry was very receptive to the school's one-to-one laptop program. She viewed the initiative as providing students with a unique opportunity to develop skills they would need for college and career. She valued the fact that the one-to-one laptop program gave her students access to information and saw that access as a way to encourage and motivate her students. In an interview, Mrs. Perry talked about access to information online as "something that will spark them a little bit because some of [it] might be a bit dry too. Some of them might find an interest and relate to it." However, Mrs. Perry also observed a difference in the way different students interacted with online information. In the same interview, Mrs. Perry described the unevenness of student experiences: "The good students like self-direction and are willing to take that extra step. The weaker students, I don't see doing anything better from using the computers."

Mrs. Perry sought to accommodate her students' deficiencies in technical skills by creating differentiated instructional plans. In her third period regular biology class, Mrs. Perry assigned students a project to research each stage in the cell cycle. Students were allowed to prepare their report using notecards or by creating a tri-fold brochure using Microsoft Publisher. Students used the Internet to gather information from various resources and find pictures and video links, and they also used their textbook as a resource. Six students used notecards and books while the remaining 15 students used computers and the Internet. While she identified a specific need for this instructional differentiation, Mrs. Perry also thought there were larger issues at work that limited some students as they worked in one-to-one computing learning environments. As she put it, "We've all been led to believe that all the students in this day and age are very technology savvy, but we have a lot of students that are not that savvy."

In another lesson, some students were having difficulty creating graphs with Excel so Mrs. Perry thought an online program would assist students with graphing. She quickly discovered that students were not able to adjust the scales on the axes in the program, and thus the online program was not helpful after all. Mrs. Perry's use of the online tool to replace Excel, which had been used to replace a paper and pencil graphing exercise, ended up being more of a distraction than an instructional benefit.

Despite the limitation, Mrs. Perry was often optimistic in her talk about using technology. In one interview, Mrs. Perry described an advantage of the computers is that they allow students to collect information about science-related topics on their own and provide a more efficient means to access resources:

Can we do this without computers? Yes, we can go to the library to look up the information. If they did find something that was interesting and they wanted to research further, it is much easier to do it on the computer. I like the computers. I think it is a great thing for the kids.

In one activity representative of Mrs. Perry's approach to research, she engaged the class in a lesson designed as a "seek and find" activity focused on health and disease. Students selected a particular disease and found out more about its causes and how the causes related to internal and external factors. Students engaged in animated discussions as they shared the video clips and images they had found with each other. Overall, the activity worked because the use of technology (online searching and retrieval of visual content) was limited and specifically aimed at supplementing other class activities. Mrs. Perry was able to work around constraints that limited her in other activities. In this activity, students were able to work together, thereby limiting the negative effects of some students not having computers. Students' analysis of the visual, the most important part of the exercise, was not dependent on a technical skill that had to be applied while using the computer. Connectivity remained a concern for this activity, but was not a limitation.

Essentially all of the one-to-one activities in Mrs. Perry's classroom involved moving existing classroom activities to use on computers with little if any change in learning objectives or pedagogy. In some cases, the moves brought little transformative value while introducing the downside of students needing to learn new technologies. More successful was leveraging the online information web and modeling and simulation tools that required little overhead in learning how to use. These web-based tools were still used to mimic activities that originally took place largely in the library or lab but expanded opportunities and resources with little logistical downside. Somewhere in between these two extremes were activities such as the "seek and find" activity that served as an effective replacement to off-line work, but required new skills and dispositions that students had not yet mastered. Mrs. Perry was able to use this activity and others like it as a context to support the development of her students' online literacy skills. The new teaching capabilities highlighted here did not involve new teaching approaches so much as an emerging improvisation around providing alternate lessons for the frequent Internet outages or students without computers.

Mr. Thomas, the Mathematics Teacher

Mr. Thomas was a young, energetic teacher who recently completed his undergraduate degree in mathematics education at a university not far from the rural county high school where he was employed as a full-time mathematics teacher. Mr. Thomas taught two sections of Geometry and one section of Algebra. During professional development workshops and as part of his undergraduate experience, Mr. Thomas was exposed to a variety of different content-specific technology tools, including The Geometer's Sketchpad, graphing calculators, clickers, and curricula for mathematics, such as SAS Curriculum Pathways.

In his teaching, Mr. Thomas regularly used wikis and a classroom management system called Schoolview to monitor what students were doing on their laptops during class. Mr. Thomas felt like his classes were, in some ways, positively affected by the introduction and integration of one-to-one laptop computing in his classroom. He pointed out that, after receiving their laptops, students appeared to be more engaged during class. He also noted that some students were taking the initiative to do research as well as looking online to find different methods for solving problems and to learn more about the mathematical ideas they were studying. However, Mr. Thomas mostly talked about access to online information in the classroom as an ancillary type of experience. "Having constant available Internet access does kind of help them out. There have been random days where I think okay." Mr. Thomas was not convinced that the one-to-one initiative was fundamentally altering his instruction given the content he taught. He described this in an interview: "I was so excited about doing all the WebQuests with them. But then again it's a math class, there's only so much you can do with it." Mr. Thomas saw himself as guiding students toward knowledge. He described this approach as such:

When I teach my kids I'm not like $2+2$ is... Some teachers I've had in the past just talk like that at you. So, I think I kind of coach them through the problem, and a good example of that is when

my kids go home and do homework. They say this was tough, but when I go over it, it seems so easy because you just go over and explain it.

Despite his reluctance to fully embrace technology in his teaching, Mr.

Thomas described himself as a “techie” and noted that he was using a tablet PC during his first year of teaching even before the school implemented one-to-one laptops in the classrooms. With the implementation of one-to-one laptops, he was beginning to seek creative ways to use technology to motivate and teach students. The most prominent shift for Mr. Thomas regarded the manner in which he supported students as they worked individually on math problems. Mr. Thomas said the biggest benefit of one-to-one computing was his “ability to walk around the classroom” where he could “focus on students one-on-one.” During one class, he created a review game for students using his own Microsoft Xbox gaming system. During another class, Mr. Thomas created a Geometer’s Sketchpad sketch that contained different polygons and a sequence of questions for students to answer related to finding the length of a side, the perimeter, and area of different polygons. Even with these in-class experiences, Mr. Thomas most often talked about the use of laptops outside of his classroom. “Some of them have taken the initiative [with laptops] when they go home or if they have a little free time they will go and find other ways of doing a math problem or research something.”

Mr. Thomas had a direct pedagogical stance that was not enabling of the sort of self-directed learning featured in the new learning ecology. He described the limitations of self-directed learning on laptops in terms of time and student knowledge. “In algebra I can’t afford to lose five minutes. I’m not going to lie and I’m not trying to talk bad about students but you have to spoon feed them.” He also saw limitations to technology integration in his discipline. “The quadratic formula is a long process. That’s just pencil and paper. Grind it out.”

The one-to-one laptop computing environment provided opportunities for Mr. Thomas to assess and monitor formatively what his students were learning. He used clickers to ask questions and immediately gather information about students’ understanding, used Schoolview to see what students were doing on their computers as they worked, and walked around the classroom and interact with students while using a wireless tablet PC to post problems, notes, and solutions on a screen. Mr. Thomas also posted notes and assignments on a class wiki to provide students immediate access to the information discussed in class. He also encouraged students to submit all of their work electronically. This requirement helped Mr. Thomas with the management of paperwork and reduced the use of paper and the need for copiers.

Mr. Thomas’ high comfort level with technology in his classroom helped empower him to investigate some new ways to use laptops, but he generally avoided the laptops in favor of more traditional paper and pencil or didactic pedagogies. While the mathematics content covered in the classroom stayed, out of necessity, close to the state-mandated course of study, his implementation of

some computer-based learning and assessment tools provided new approaches to teaching and learning this material. While Mr. Thomas did not draw widely from the information on the Web, he accessed tools and information specifically focused for the learning goals at hand, providing a more intense and personalized learning experience for his students. The use of technology-based formative assessment tools allowed him to improvise more strategically as he guided his students through the highly focused learning goals. When he did use the laptop technology, Mr. Thomas sought to use it in additive ways, demonstrating both creativity and adaptability in his pedagogy.

Mr. Watson, the Social Studies Teacher

In his third year of teaching, Mr. Watson taught three classes of United States history. He had recently completed an undergraduate teacher education program in social studies education. Mr. Watson was an engaged teacher who eagerly adopted his school's one-to-one laptop computing initiative. He viewed himself as a facilitator in the classroom, managing students' work and providing context and direction when appropriate. As a young teacher, Mr. Watson was still developing his teaching personality and pedagogical beliefs. He expressed an openness to change, but at times he projected a traditionalist view about teaching. Mr. Watson characterized his teaching approach prior to the implementation of one-to-one computing as traditional, saying about a particular activity that "it just would have been a lecture. Maybe an activity using the textbook."

As a one-to-one teacher, Mr. Watson was more expansive and inventive about his role in the one-to-one classroom. Mr. Watson described his teaching style as fluid, saying that he likes to "move around [to] make sure that I'm looking at every kid's computer so that I see they're progressing and they're not getting stuck, staying on one thing too long." Evidence of this facilitative stance emerged in the classroom as well. In an activity where students were researching various protest techniques used in the United States over the last century, Mr. Watson carved out 50 minutes from a 60-minute lesson for students to work in groups to locate and analyze relevant information online and then construct a product representing what they learned. Mr. Watson supported this work in two ways: he rotated among the groups using informal and formative assessment strategies to encourage students' progress, and he provided students with substantive content or clarifications about content.

Mr. Watson was committed to using one-to-one laptop computing throughout his teaching. Although, Mr. Watson was enthusiastic about his new one-to-one pedagogies, he also identified challenges. One challenge concerned the management of students and their on-task behavior. Mr. Watson indicated that larger classes were more difficult to manage if the activities required individual or paired work. He said that for classes over 20-25, he tended to group students into groups of three or four. This enabled him to manage interaction with groups better and to provide assistance for all students. A second challenge regarded online information access. Like Mrs. Perry, Mr. Watson was concerned about the reliability of the computer infrastructure and his classes' reliance on

network connections. He noted several times during the year when the network had been down or slow and how the resulting lack of access to information had limited the progress of students' work.

Even when the Internet connections were good, Mr. Watson was concerned about the quality of information his students accessed online. He attempted to manage his students' work by setting expectations about what resources they could use in research activities. For example, he only allowed students to use Wikipedia if they coupled the Wikipedia reference with a second reference that corroborated the original information. Mr. Watson did not seek to limit access – just manage the critical quality of the information used. As Mr. Watson put it, "There's no resource they can't access. Everything and anything they don't know is on the Internet somewhere, and they can find it as long as they search for it correctly. They now can find whatever it is we're working on and be much more creative."

Although Mr. Watson had a high level of acceptance for one-to-one laptop computing in his classes, some pedagogical conflicts emerged as a result of the school-wide shift to one-to-one computing. For one thing, Mr. Watson struggled with how to deliver lectures to students. He made use of a centralized system to control students' laptops, so as to keep them from browsing the Web while he delivered a lecture. He also was struggling to find a way for students to take notes while he lectured. His approach was to give students outline notes with blanks that they would fill in as he talked. Mr. Watson's use of one-to-one laptop computing to manage note-taking was at odds with his other more student-centered pedagogies. For example, Mr. Watson implemented an activity on the Cold War where students created video-based examples of propaganda. In the activity, he took the position of a facilitator, and in some ways, ceded content expertise to outside resources. Mr. Watson talked about how the one-to-one laptop environment had changed his responsibilities as a teacher. He saw the technology as enabling and expanding opportunities for students to be creative and inventive. "[One-to-one computing] definitely changed project-based learning. You give them a computer and it's easier to get materials together. There's no resource they can't access."

As with Mrs. Perry, Mr. Watson was able to use online information access to transform research projects that were previously completed in the library with limited resources. However, Mr. Watson struggled with both managing and empowering students' online research activities – both in terms of helping them to assess what constitutes appropriate, high-quality material to utilize and prompting them to stay on task. Mr. Watson's concern for management also extended to his use of the classroom management software, especially when he returned to a more teacher-centric lecturing approach. While the introduction of one-to-one computing forced a change in classroom pedagogy from a more teacher-centric lecture style to a more student-centric group project approach, it was unclear how much of this change was an existing desire by Mr. Watson facilitated by the technology or change imposed on him by the introduction of one-to-one computing. Mr. Watson made minor adjustments to existing activities

when leveraging computer technologies. As such, it was unclear whether enhanced student dispositions and teacher capacities were being fully realized through this transitional period. The change to one-to-one engendered some healthy reflective tension in Mr. Watson's teaching that led to continued creative problem solving on his part.

Ms. Austin, the English Language Arts Teacher

Ms. Austin was an ambitious and high-energy English language arts teacher. When this study was conducted, Ms. Austin taught 11th grade literature and AVID (Advancement Via Individual Achievement), where she consistently incorporated one-to-one laptop computing in her teaching. As an early adopter of one-to-one computing in her school and in the state where she teaches, Ms. Austin saw herself as being in a unique position to challenge some of the expected conventions about teaching her subject. She often took positions that were counter to the status-quo in favor of the use of computing in the classroom. Her views on social networking illustrated this forward and sometimes non-conventional thinking:

I think they make it seem as if social networking is this big be-all-end-all downfall of everybody. But I think that it doesn't necessarily have to be all bad and that connecting in here with my kids will be a positive thing, a learning experience for them and me, and that eventually we can communicate with other people that have different experiences than what we have here, and that social networking being a positive thing, that was something new.

Ms. Austin went on to describe how she had worked to overcome barriers to social networking in her school: "That was something that I had to explain to the tech people, because a month into this you created this great social networking site, and I get on it one morning trying to get some stuff added on, and it's blocked."

At the same time, Ms. Austin was often cautious and quick to point out potential pitfalls or limitations to using one-to-one laptop computing in her classes. She described immediate and constant access to information a double-edged sword: "It's good because we can use it for classroom instruction. It's negative in some ways because there's still some people around here that maybe aren't being monitored the way they should, that are using it for not the correct purposes and they're slowing down and bogging down the whole system." However, on balance, Ms. Austin seemed to value the access to information that one-to-one computing affords. "Before, we were very limited as to what we could do because we have very few resources that we all shared with two or three people, so now that's all right there. Also we can find out things that are very current. And that's important for the kids because they can find it out right then."

Ms. Austin sought out a middle ground between the transformative nature of one-to-one computing and the centrality of the teacher in the classroom. Ms. Austin was reluctant to argue that the laptop computer would alter the relationship between teacher and student. "From day one, my kids walked in the door

and because they knew me, it didn't matter that that computer was in their hand. They knew that they weren't going to touch that business until I said." Mr. Austin insisted that she would be in control of students' use of technology, both in terms of their physical access to the technology and in terms of how students' used online information and technology tools. In talking about how her teaching had changed with the introduction of one-to-one computing, Ms. Austin said, "So that stayed the same—the structure has stayed the same. I think that what has changed was that we have a lot more information at our fingertips."

In her teaching, Ms. Austin attempted to balance one-to-one laptop computing by maintaining control over the learning environment. One activity that reflected this careful balance was her focus on student writing. In one of these activities, students wrote a letter to Ms. Austin using a specific format and audience. She provided very specific guidance to students regarding how they would use computers. "So, today we're going to write a letter. On the board I have put some things that I would like you to include in this letter. So you may as well just spread your bodies out and type, type, type away." This activity and the introduction to the work provided by Ms. Austin were interesting because of the distance she put between the work and the technology. The laptops were background tools designed to support an activity that was decidedly removed from the specific forms and conventions of technology-enabled writing.

Ms. Austin seemed to be enthusiastic about one-to-one laptop computing and even aspirational regarding prospects of the technology, but she often took a decidedly traditionalist stance on instructional activities. Her position on a writing assignment highlighted this traditionalist stance. "I think because I am a little bit old-fashioned, I still want to see their handwriting. I still want to see that spell check is not what helped them write that word correctly." Ms. Austin was not willing to jettison traditional approaches to teaching reading and writing. "I think that some writing will still have to be done on paper. And even some of the kids have mentioned, why can't we do it the old fashioned way? What was wrong with that? If it wasn't broken, why do we have to fix it?"

Ms. Austin struggled with the changes that immediate and constant access to information through the one-to-one laptop environment brought to the classroom. Her concerns were related in part to classroom management, but more than some of the other teachers, she also struggled with how to leverage these new capabilities and tools into way that reflected less of a teacher-centered dynamic. This was reflected in her optimistic hope for social networking tools to help transform her classroom practice. However, this embracing of new technologies often came in conflict with deeply held beliefs about what constitutes appropriate instructional strategies in the classroom. In many ways, Ms. Austin's response to one-to-one computing centered more on ubiquitous access to information and the potential for students to develop their capacities with new tools, than on transforming her teaching.

Discussion

The cases reported here suggest that teachers engaged a range of negotiated actions as they searched for ways to situate one-to-one computing in their teaching. Although these teachers used computers differently in their classes, from the computer as a tool to support existing practice to using the computer as a hub for learning activities, there were important consistencies regarding the nature of the learning ecology that emerged in these classrooms. In this section, we highlight prominent themes from the new learning ecology framework that were represented in the data. Our analysis suggested that across the four classrooms, immediate and constant access to information was the most prevalent condition. The students and teachers had immediate and constant access to information since they all had Internet access and laptops; however, the four teachers leveraged that access in very different ways. The teachers in this study—Mrs. Austin (English), Mr. Thomas (math), Mr. Watson (social studies) and Mrs. Perry (science)—demonstrated their capacities as content experts, facilitators, consultants, mentors and improvisationists in different ways and in an uneven manner. The other two conditions, intensity, relevance, and personalization of learning as well as highly developed student dispositions (students as self-directed, self-regulated, curious, and creative) were less evident across the four teachers' classrooms, but important in unique ways. The following four assertions describe in more detail these findings as culled from data across the four cases.

Teachers Manipulated Immediate and Constant Access To Information Given Their Epistemological Stances

Internet-based access to information affected teaching and learning experiences in the four classrooms and in many ways reflected the teachers' beliefs about knowledge. The science teacher, Mrs. Perry, and social studies teacher, Mr. Watson, developed activities that involved students accessing information from the Internet to develop projects and conduct research. Both teachers were willing to facilitate their students' access to information even when that information included conflicting or even contradictory knowledge. These teachers enabled their students to construct knowledge using a wide range of acceptable sources. Their use of Internet resources was consistent, but not without problems. Both teachers worried about the reliability of their access to the Internet. They also confronted issues related to organizing students' work, insuring all students had laptops, and helping students make critical use of online information. Both teachers developed pedagogical approaches to accommodate for these issues so they were able to continue the use of online information in the classroom.

In contrast, the math teacher, Mr. Thomas and Ms. Austin, who taught English, were less likely to incorporate immediate and constant access to information in their classrooms. They tended to view online information as protean and a potential source of distraction from the fixed knowledge featured in their instruction. Both teachers saw Internet access as a way to extend the learning experience outside the classroom as opposed to inside the class. Mr. Thomas and Ms. Austin both developed class wikis and presented content online to facilitate homework assignments, but rarely incorporated such technology in class. Mr.

Thomas did use Geometry Sketchpad, a student-centered computer software program for learning mathematics, but only in situations that he considered low-stakes – i.e., classes with no mandated state end-of-course tests. Ms. Austin also leveraged social networking tools to facilitate and extend conversations with students, but limited the use of these tools to activities outside of class.

These two distinctly different approaches to accessing online information reflected the teachers' general pedagogical dispositions as well as their beliefs about knowledge. Mrs. Perry and Mr. Watson tended to provide their students with more project-based and personalized learning opportunities. Both teachers saw themselves as facilitators and were willing to cede some knowledge authority to outside resources and materials. However, both teachers were also concerned about how their students used critical skills when accessing online resources. Mrs. Perry worried about her ability to properly review materials that her students were accessing and used a system of informal and formative assessment to monitor students' online resource use. Mr. Watson developed specific rules for his students' use of online content from Wikipedia, requiring corroboration for any Wikipedia source. In both cases, the teachers were moderating their students' uses of materials, but were also recognizing multiple sources of information and to develop understandings from these materials. These teachers' epistemology was more flexible than traditional teacher stances on knowledge, which have viewed the teacher (or a teacher proxy in the textbook or other materials) as authoritative sources of knowledge.

Mr. Watson's use of questions signaled his epistemological beliefs. In one activity he used questions to open the door for students to develop knowledge about Soviet propaganda. "You've seen propaganda in photographs, and now you've just seen Soviet propaganda [films] about the Soviets and the Cold War. What did you notice about the film? What do you notice about the claims?" Mr. Watson did not answer his questions. Instead, he had students conduct research, viewing additional propaganda films and conducting analysis, and then producing their own propaganda films while applying what they had learned. Mrs. Perry took a similar approach toward knowledge. When working with students in online research projects, Mrs. Perry also posed questions and consistently emphasized the importance of students creating their own meaning and learning from these experiences. As she put it when talking about an activity focused on disease; "get them to figure out which [diseases] would be more likely to affect them in their lifetime and how they might change their lifestyle right now to prevent them from having problems later."

Mr. Thomas and Ms. Austin were not as willing to take the open epistemological stances that Mrs. Perry and Mr. Watson took. Mr. Thomas, who taught mathematics, had a direct pedagogical approach that was predicated on a more traditional epistemological stance. In his description of the differences between students' self-directed learning in mathematics and his guidance of student learning, Mr. Thomas argued, "when my kids go home and do homework they say this was tough, but when I go over it, it seems so easy because you just go over and explain it." Mr. Thomas saw himself as in possession of knowledge and his

teaching tasks as involving the communication of that knowledge to his students. These beliefs about knowledge seemed to limit Mr. Thomas' willingness to intercede the laptop computers between himself, as dispenser of knowledge, and the students as recipient of that knowledge. Ms. Austin took a similar stance on knowledge. Ms. Austin, when explaining her pedagogical beliefs, also took a traditional position on knowledge. She coupled a desire to guide students with firm beliefs about the forms within which students should express themselves. In commenting on writing, Ms. Austin called herself, "old fashioned." For example, with regard to writing Ms. Austin wanted to, as she put it, "see that spell check is not what helped them write that word correctly." Instead of viewing knowledge as fluid and subject to negotiation, Mr. Thomas and Ms. Austin had firm beliefs about not only what students should know, but also the shape that knowledge should take, and how students should learn these fixed bodies of knowledge. Laptop computers operated on the periphery of the learning activities where Mr. Thomas and Ms. Austin most carefully applied their traditional epistemological beliefs.

Highly Effective Teacher Dispositions Shifted Given Instructional Contexts

Of the five conditions for highly effective teaching theorized in the new learning ecology (content expert, facilitator, consultant, mentor, and improvisationist), none stood out as a prevalent method. Instead, specific dispositions were prevalent given specific conditions of the one-to-one computing environment in the classroom. Teacher dispositions were conceptualized in this research as holistic belief systems that would emerge in tandem with other conditions in the new learning ecology, and, in fact, we found evidence that these beliefs and dispositions took form unevenly among all four teachers. These dispositions were context driven, with teachers shifting very quickly along a range of dispositional attitudes. For example, Ms. Austin talked about being a facilitator, or as she put it a coach, and an improvisationist.

I still think my time in here is still divided 50/50 and with the computer time I'm a coach and I'm helping and I'll get on the same play or page, and then on the other side of it I'm an improvisational artist because I'm always dancing and singing and being on stage up here.

Ms. Austin wanted her dispositions to emerge in contexts. In the one-to-one context, she viewed herself as a helper and a motivator. In this context, the central classroom focus was on individual students, and Ms. Austin provided support or facilitation to get students to the same learning goal, or as she put it the same "page or play." In whole class settings, where Ms. Austin was the focus of attention, she saw her role shift to an improvisationist who was drawing on a wide range of personal skills to maintain students' focus. But, when she played the part of an improvisationist, Ms. Austin was less reliant on technology.

Mr. Thomas expressed similar shifting dispositions given the context. For example, his approach to teaching with Geometer's Sketchpad highlighted the way in which he moved back and forth across these dispositions. "With Sketchpad,

every kid can work at their own pace. A lot of them say I talk a lot and I do. I want to do it like they do in college and in college they give lecture. With Sketchpad I can walk around and help every student, which I haven't been able to do a lot of in the past."

Mr. Thomas deliberately shifted his teaching disposition to facilitator when teaching with Geometer's Sketchpad. These opportunities to facilitate his geometry students learning were mostly driven by the testing context for his geometry class. As Mr. Thomas explained, the lack of a test provided an opportunity to teach differently. When talking about how his teaching has changed since the start of the one-to-one laptop initiative, Mr. Thomas explained.

Algebra two has stayed a lot the same. I haven't changed my formal lecture but I've only been teaching two years. The geometry has changed a lot because of Sketchpad. I did Sketchpad in college and I was able to do that a lot with my regular geometry group and a lot with this group because they're in progressive geometry where I don't have the [End of Course Test].

The use of Geometer's Sketchpad in Mr. Thomas' class facilitated multiple approaches to solving geometry problems, meaning students needed to be more self-reflective as to the quality of the approach and solution they generated while attempted to demonstrate or prove properties of geometric forms such as triangles.

As with the personalization of learning, the teachers in this study sought to balance their role by maintaining some control over the instructional processes. Mrs. Perry and Mr. Watson tended to enable students' independent learning more through motivation, while also providing examples and direction toward attainable learning goals. The ubiquitous, constant access to information and a greatly expanded array of software tools enabled Mrs. Perry and Mr. Watson to carry on a parallel expansion of facets of instruction they could engage in. For example, Mrs. Perry faced challenges in supporting students on the use of sophisticated software tools, but found better luck in supporting more transparent software tools and information sources, where she could focus on supporting knowledge building around core science concepts. In sum, all four teachers strategically shifted their pedagogies between direct or teacher-centered approaches and student-centered approaches.

Teachers Used a Form of Pedagogical Triage in the One-To-One Classroom

In a new learning ecology, constant and immediate access to information as well as self-directed, curious, and creative learning, should in theory support increased relevance, personalization, and intensity in learning. Instead, the one-to-one environment in the four classrooms featured in this study encouraged teachers to personalize their instruction through the sorting and prioritizing of student's needs, something we viewed as a type of pedagogical triage as opposed to personalization as instructional transformation.

All four teachers expressed strategic tensions between the potential of the technology to individualize student instruction, while also “keeping them on track.” In contrast to relevance and intensity, which the teachers and learners were able to realize as a whole group, personalization required a distinction in individual learning that was difficult to attain. The teachers actually used technology tools to control individual departures from class norms. Teachers were interested in helping students, as Mrs. Perry put it, “find an interest and relate to it,” but specific adaptations at the individual level were rare.

Teachers tended to address issues and conditions at the class level as opposed to the personal level. For example, the uneven availability of computers caused teachers to differentiate instruction based on whether a student had a laptop to use. At other times, teachers developed alternative lesson plans based on whether the Internet would be working. The teachers also modified activities based on computing skills or the availability of specific resources online. In these instances, the teachers were presented with the challenge of flexible instruction as something to contend with rather than something they voluntarily embraced. Consequently, the teachers in this study were performing a sort of triage where student learning conditions that served as impediments to learning were assessed and teachers’ actions were meted out based on the teacher’s perceived priority of needs. Classroom management software provided by the district was one tool deployed by these teachers, as was the low-tech solution of walking around the room and observing what was on the students’ screens. When teachers identified students either off-task or in need, they provide personal assistance, but rarely enable personalized learning opportunities. Some of the teachers also realized that formative assessment would be a key tool to gauge the outcomes of these more individualized approaches to assignments, but instead used formative assessment in this process of triage and conditional pedagogical response.

Teachers Struggled to Manage Information Flow in the Classroom

The teachers in this study incorporated a variety of strategies when dealing with problems and opportunities that emerged from their constant and immediate access to information and the changing conditions for learning. Two of the teachers, Mrs. Perry and Mr. Watson, provided students opportunities to access information online during class, but used different strategies to manage students’ uses of that information. Mrs. Perry saw her efforts to provide students access to information as replacing existing analog approaches to using information in science classes. However, she struggled to provide students consistent experiences both as a result of students’ limited technology skills and due to hardware and technology infrastructure limitations. Mr. Watson took a more ambitious position. He created new learning experiences with online information for his students that were not possible offline and then tried to develop new instructional strategies for managing his students’ uses of online information. Mr. Watson created rules about what types of information could and could not be used (e.g. Wikipedia) and created research activities that necessitated stu-

dents' use of online information. However, Mr. Watson remained uncomfortable with his strategies.

Mr. Thomas and Ms. Austin did not regularly provide their students with opportunities to access online information in class. Both teachers thought that students accessing information during class would be a distraction, but for different reasons. Mr. Thomas saw student access to online information as disrupting his ability to maintain instructional control over the delivery of content. Ms. Austin was concerned about limited academic value of the information students would access, being mainly social constructed information. However, they both saw value in supporting students' uses of online information out of class. Mr. Thomas appropriated and adapted wikis to support his didactic teaching style, while Mrs. Austin used network tools to encourage traditional literacy skills. The uniqueness of the teachers' experiences given that the original notion of the new learning ecology emphasized personalization in learning points to the need for some clarification in the original ideas, specifically with regard to highly developed teacher capacities. Additional work should seek to determine how teachers personalize their pedagogies when the teaching and learning ecology shifts in order to gauge a variety of paths to transformational teaching and learning.

Conclusion, Limitations, and Future Research

Two general conclusions emerged from the analysis of data collected for the cases. First, the teachers appeared to mediate the new learning ecology given their beliefs about knowledge. Mr. Thomas and Ms. Austin believed that teachers should be the primary sources of authority of knowledge in the classroom. Mrs. Jones and Mr. Watson had more open epistemologies, valuing a wider range of sources for knowledge. The teachers' general pedagogical beliefs about managing the classroom framed a second general conclusion, which suggested that the extent to which the teachers were willing to provide some authority to students to regulate their learning influenced the ways in which the new learning ecology presented itself. Mr. Watson and Ms. Jones were willing to hand over more authority to students, both in terms of knowledge construction and in terms of how activities played out in their classroom. Given the nature of the new learning ecology as facilitating student learning that is self-directed, self-regulated, curious, and creative, Ms. Jones's and Mr. Watson's classrooms came closer to realizing the theorized new learning ecology.

This study made use of data collected within a small number of classrooms over a relatively short period of time. Future work will need to scale this investigation in both time and space—following a similar group of teachers longitudinally over a year or longer to see how their instructional practice and student behaviors continue to evolve (or not) and to expand the investigation to more schools and districts. Such work would help to generalize the findings of this multi-case study and further refine both the commonalities and differences in challenges faced by different disciplines as they grapple with the new learning ecology.

This study emerged from an ambitious idea that teaching and learning in the new learning ecology will enable constant and immediate access to information; personalized learning; advanced learner dispositions; and highly developed teacher capacities. This research responded to the need for establishing theoretically grounded practices within school-based one-to-one programs. Given the amount of resources (both time and money) that are being invested across the nation, as well as the hopes that are raised in terms of potential educational benefits of one-to-one environments, it is essential that we think deeply and strategically about one-to-one teaching and learning, including thoughtful considerations for theoretical grounding. The cases presented here suggest that although conditions of a new learning ecology are evident within one-to-one learning environments, they may be more nuanced and contextualized than we understood when theorizing our original idea (Spire et al., 2012). The Knight Commission (2009) report highlighted the dramatic changes in ways we use and share information in the current digital age. As school systems respond to these changes with one-to-one laptop computing initiatives, educators will need to carefully evaluate the contexts of these educational innovations. This research is one such effort toward better understanding of how one-to-one laptop computing can enhance teaching and learning in the 21st century.

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