JRTE | Vol. 44, No. 4, pp. 335–356 | ©2012 ISTE | iste.org/jrte

Activity Theory as a Framework for Investigating District-Classroom System Interactions and Their Influences on Technology Integration

Anika Ball Anthony
The Ohio State University

Abstract

Technology implementation research indicates that teachers' beliefs and knowledge, as well as a host of institutional factors, can influence technology integration. Drawing on third-generation activity theory, this article conceptualizes technology implementation as a network of planning and integration activities carried out by technology specialists, teachers, and administrators. The researcher conducted a case study of a school district's laptop program to examine how district and classroom systems interacted to influence teachers' technology use. Findings suggest that continuous improvement efforts aimed at aligning intersystem linkages can support technology integration. The article discusses implications for technology leadership and technology implementation research. (Keywords: technology integration, technology leadership, activity theory, case studies)

For more than three decades, researchers, policymakers, and industry leaders have promoted computer technology use within and across learning environments to enhance teaching and learning (CEO Forum, 1997; Culp, Honey, & Mandinach, 2003; Papert, 1980; U.S. Department of Education, 2010). Isolated studies have documented the promise of well-designed instructional software to support learning (Bransford, 2000; Dede, Salzman, Loftin, & Ash, 2000) and increase academic performance (Cuban & Kirkpatrick, 1998; Hannafin & Foshay, 2008; Wenglinsky, 2005). However, technology integration in actual classrooms remains a perplexing challenge (Barron, Kemker, Harmes, & Kalaydjian, 2003; Becker, 2001; Cuban, 1986; Wenglinsky, 2005). Despite access to funding and equipment, a recent study found that less than 35% of teachers in U.S. districts that received funding through the Enhancing Education Through Technology program have integrated technology in their instruction on at least a weekly basis (U.S. Department of Education, 2008). Such limited use, coupled with a lack of documented effect, has led to questions about the value of continued investments in educational technology (Christensen & Horn, 2008; Trotter, 2007).

Educational research offers insights into why technology integration efforts have not had a greater impact on teaching practice and student achievement. One strand of research has emphasized teachers' individual characteristics, such as technological literacy, constructivist beliefs, and perceived usefulness of technology, as essential factors that influence technology use (Becker, 1994; Franklin, 2007; Myhre, 1998; Windschitl & Sahl, 2002). A second strand of research has focused on institutional conditions, such as school and district settings, as factors supporting or constraining technology use (Anderson & Dexter, 2005; Bauer & Kenton, 2005; Schofield & Davidson, 2002; Songer, Lee, & Kam, 2002). However, a third strand of research has emphasized the influence of a combination of individual and institutional factors (Bauer & Kenton, 2005; Baylor & Ritchie, 2002; Dwyer, 1994; Ertmer & Ottenbreit-Leftwich, 2010; Honey & Henriquez, 1996; Inan & Lowther, 2010). Collectively, this research, along with technology leadership standards and reports (Consortium for School Networking, 2009; International Society for Technology in Education, 2009), suggests that effective school leaders work to influence individual and institutional factors to support classroom technology use.

This article presents findings from a study on the first 3 years of one school district's laptop learning program to examine what changes, if any, took place over time to lead to improved technology implementation. Building on the educational technology implementation literature and third-generation activity theory, technology implementation was conceptualized as a network of interactive and dynamic systems of activity (Engeström, 1987; Weick, 1976). Systems examined include technology planning and technology integration. The study focused on two teachers who participated in the laptop program. In particular, it examined how the activities of technology planning and continuous improvement mediated teachers' classroom-based technology use.

Study findings reveal that contradictory linkages between the district's technology planning system and teachers' systems of technology integration initially impeded technology use, whereas subsequent complementary linkages supported technology use. Findings suggest that effective technology leadership extends beyond separate efforts to influence individual and institutional factors, and also entails the work of continuous improvement to detect and address the fit between technology implementation systems, which in this case were the systems of district technology planning and classroom technology integration. Although ongoing evaluation and continuous improvement have been described as vital to technology implementation (Keane, Gersick, Kim, & Honey, 2003; Yasemin, 2007), limited research examines this process in practice. This study contributes to the literature by providing insight into one district's continuous improvement efforts. This article begins with a discussion of how technology leadership can support technology implementation. Then it discusses activity theory and the conceptual framework that informed research questions and methods.

The Role of Technology Leadership in Supporting Technology Integration

Technology leadership is an emerging role for fostering school conditions that support technology integration. Associated roles and responsibilities often include providing visionary leadership, promoting a school culture for digital learning (International Society for Technology in Education, 2009), budgeting, selecting and working with vendors (McNabb, Valdez, Nowakowski, & Hawkes, 1999), organizing technology professional development, and collecting data on how technology supports school restructuring efforts (Dexter, 2008).

Although the literature has described technology leadership as a schoolwide characteristic that is shared among principals, technology specialists, and teachers (Dexter, 2008), there are variations in how this function is distributed in practice. It has been suggested that many principals and district leaders lack the technological knowledge and skills to make informed decisions about program goals, equipment, technological infrastructure, and teachers' technology professional development (Davis, 2008; Flanagan & Jacobsen, 2003). Although technology specialists often have such knowledge, because their organizational roles tend to focus on providing instructional and technical support, they (unlike principals and superintendents) are limited in their authority to mandate teachers' technology use. Thus, they often resign to working through power resources, organizational structure, and culture to influence administrators' and teachers' commitment to technology initiatives (Bennett, 2008).

Depending on how a district values and distributes technology leadership, parallel processes can emerge in which technology planning occurs in isolation of district- or school-wide improvement efforts. This condition has potential to give rise to a host of contradictions, not only regarding how technology and district plans align, but also for whether technology integration efforts supplement or complicate teaching practice overall. It is the surfacing of these very contradictions that potentially limit teachers' classroom-based technology use.

Activity Theory

Activity theory offers a conceptual framework for studying human behavior (Engeström, 1987; Leont'ev, 1978) and a lens for examining how district and classroom systems interact to mediate teachers' technology integration practices. An activity system is a means for conceptually bounding social and material resources that interact to enable and constrain what individuals and social groups are able to accomplish (Engeström, 1999a). Figure 1 (p. 338) offers a representation of activity that mediates interaction between individuals, groups, and collective motives.

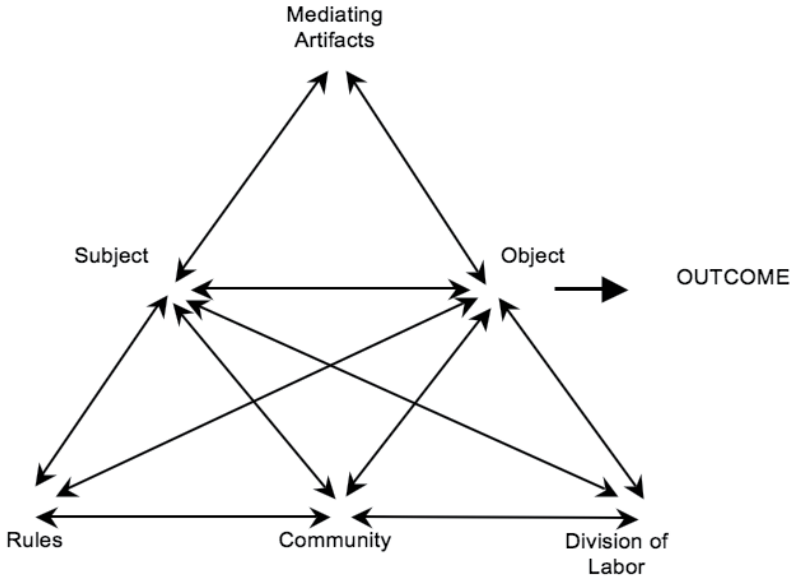

Figure 1. Representation of an activity system (Engeström, 1987).

Basic elements of an activity system include subject, object, mediating artifacts or tools, rules, community, and division of labor (Engeström, 1987). The subject is the individual or groups of individuals involved in the activity. The object is the motivating influence behind subjects' participation in the activity. Mediating artifacts or tools are symbols, signs, and conceptual understandings that serve as physical and psychological tools, mediating activity between the subject and the object. A community is the social and cultural group that subjects are a part of, with explicit rules or social norms that regulate and influence behavior. The division of labor defines how tasks and responsibilities are shared among system participants as they engage in activity (Cole & Engeström, 1993). In the course of activity, the system can change in response to changes in driving needs and underlying motives (Engeström, 1999a).

Activity theory has been described as a flexible and evolving theoretical approach (Kaptelinin, 2005) and has informed educational research because of its ability to address divides between individual and collective action (Roth & Lee, 2007). This framework has informed research on mediation. When studying tool mediation, researchers in human-computer interaction (HCI) have used activity theory to extend analysis beyond interactions between the computer and a user to also consider the use of computers in social, organizational, and cultural contexts (Kaptelinin, 1996). Activity theory has enabled HCI researchers to design solutions that support computer-mediated activity (Gay & Hembrooke, 2004; Hardman, 2007). For example, the framework has informed the design of educational software intended to mediate learning by providing students access to tools and practices that resemble the adult world (Bellamy, 1996). Beyond software design, activity theory has helped explain how teachers use pedagogy and classroom discourse such as discussion, argumentation, and clarification to support student learning (Walshaw & Anthony, 2008).

One of Engeström's contributions to the representation and analysis of human activity is third-generation activity theory, which offers conceptualizations of interconnected activity systems that can be arranged as networks for studying micro- or macro-level clusters of activity, such as instances of teamwork, an organizational system, or human society (Engeström, 1987; Roth & Lee, 2007). Third-generation activity theory extends the second-generation notion of mediation of system components (i.e., mediating artifacts or rules) to how neighboring systems mediate one another. Third-generation activity theory endorses that during social development, an activity system unfolds over time into a group of interconnected systems (Engeström, 1987). According to third-generation activity theory, the components of an activity system, as well as surrounding systems, shape humans' interaction with their environment. Applications of third-generation activity theory include redesigning preservice education to improve teachers' technology use in classrooms (Blanton, Moorman, & Trathen, 1998) and conceptualizing educational change as dynamic intersystem interactions (Engeström, 2008; Sannino, 2008).

Conceptual Framework

Building on third-generation activity theory, the work of implementing technology in schools is achieved through teachers' and leaders' involvement in at least two activity systems: (a) the system of technology planning that district administrators and technology leaders typically carry out and (b) the system of technology integration that teachers enact in their classrooms. These two systems connect in ways that can mediate teachers' ability to integrate technology. Figure 2 (p. 340) illustrates how outcomes of a district-level technology planning activity can affect aspects of a classroom-level technology integration system by shaping who the subjects are (e.g., schools, teachers, students), mediating artifacts (e.g., software, curricular resources, hardware), rules (e.g., acceptable use policies, blocked websites), community (e.g., teacher meetings for collaboration and subject-specific technology integration lesson planning), division of labor (e.g., technology integration support), and object (e.g., the underlying need that technology integration is intended to address or a vision for technology use).

When technology planning and integration systems are complementary, they can lead to collective implementation success. In similar fashion, when planning and integration systems are contradictory, program implementation might be impeded. An example of a contradiction between the

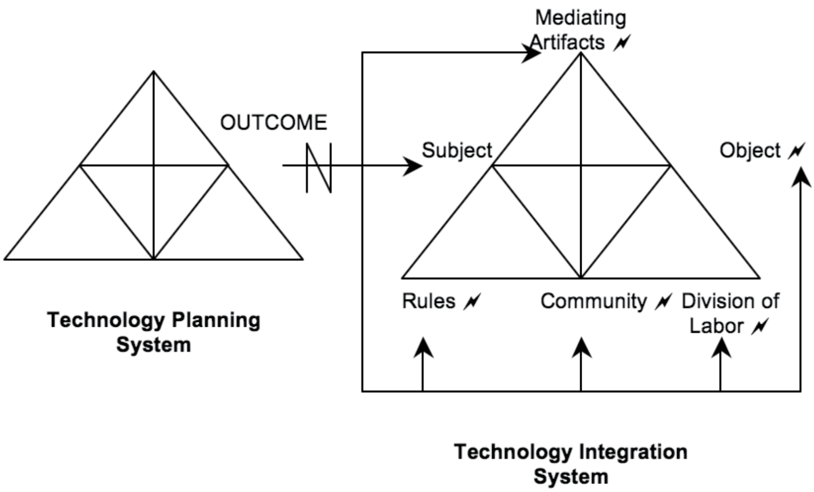

Figure 2. Potential contradictions between a district's technology planning and technology integration systems.

technology planning system and teachers' technology integration systems would be technology planners unintentionally purchasing hardware that cannot withstand the wear and tear of heavy classroom use. If the unreliable hardware cannot facilitate frequent and educative uses of technology in the classroom, then a contradiction would exist not only within a teacher's technology integration system between mediating artifacts and the object of activity, but also between the technology integration and technology planning systems.

The purpose of this study was to investigate whether district-classroom system interaction changes occurred over time to contribute to increased technology implementation across two classrooms located within the same district. The research addressed two questions:

1. Did district-classroom system interactions account for differences in teachers' technology integration experiences?
2. In what ways, if any, did administrators, technology specialists, and teachers work to align district-classroom system linkages associated with the laptop program?

Method

I conducted a longitudinal case study to examine one school district's efforts to plan and implement a one-to-one student laptop program. Qualitative inquiry methods enabled an in-depth investigation of influences on teachers' technology integration practices in an authentic setting (Marshall & Rossman, 1999). As several scholars have indicated, limited research has studied processes of teaching and learning with technology in practice (Cilesiz, 2011; Roblyer & Knezek, 2003; Thomas, 2005).

Activity Theory Methodology

The unit of analysis of activity theory research is object-oriented, collective, and culturally mediated human activity (Engeström, 1999b). When building on this framework, researchers are advised to consider what is taking place in a larger system of activity and how system components relate with one another to shape activity (Nardi, 1996; Roth & Lee, 2007). I drew on aspects of Engeström's (1987) expansive developmental research methodology to inform research methods. Although the methodology has been used to guide organization intervention efforts, it was appropriated to gain a phenomenological insight into teachers' technology integration challenges and to analyze successive developmental phases of the technology planning and technology integration activity systems.

Context

The study site was a middle school in the Westwood School District*, located in a rural area of a U.S. Midwestern state. At the start of this study, there were approximately 2,900 students enrolled in the district's six schools. According to district data, at the time of study, 96% of the student body was white, and a majority of students performed at proficient and advanced levels as measured by the state's standardized achievement test. With an 8-year history of district-led technology initiatives, in fall 2003, the district embarked on an effort to plan and implement a pilot laptop program for 115 sixth grade students. By fall 2010, the district's laptop program expanded to include all fifth, sixth, and seventh grade students. According to district documents, the local press, and articles in technology leadership trade publications, the program has been viewed as successful at supporting teaching and learning and continues to receive board support despite recent economic challenges that have led to budget cutbacks and a reduction in central office staff.

Participants

Participants included the district's laptop program planners (the assistant superintendent, technology director, technology integration specialist, and the sixth grade principal) and two of the four classroom teachers who program planners asked to participate in the district's program: Cindy, a science teacher, and Ann, a teacher who taught a block-period language arts and social studies class. Of the four teachers who were a part of the district's pilot laptop program, Cindy and Ann participated in this study over the 3-year period.

Data Collection

I collected data on how the outcomes of the technology planning system connected with teachers' technology integration activities. The technology

* The author uses pseudonyms in place of actual district and school names.

planning system was defined as activities involved in planning for the laptop initiative. Teachers' technology integration practices were defined as teachers' and students' use of computer-based resources to carry out classroom routines in pursuit of teaching and learning goals (National Center for Education Statistics, 2002; Sun, Heath, Byrom, Phlegar, & Dimock, 2000).

To gather information about the technology planning and integration systems, I conducted semistructured interviews with participating teachers and administrators during the first 3 years of the laptop program (2004–2005, 2005–2006, 2006–2007) to obtain rich descriptions of professional development (Guskey, 2000) and to gather information about teaching practice rationale and approach. Teachers' reflective accounts were a vehicle for understanding their shared and divergent experiences as participants in the program, whereas administrators' interviews focused on program planning decisions that helped explain differences in teachers' experiences. Although interviews were the primary means of data collection, I used observational data to supplement self-reports of teaching practice (Hew & Brush, 2007; Schrum et al., 2005). I conducted four classroom observations with each teacher to document technology integration practices. I also observed five district-led teacher professional development workshops, as well as three district laptop meetings. I video-recorded observations and took field notes for subsequent analysis. I obtained program planning and teaching documents, such as newspaper articles, school board materials, parent newsletters, lesson plans, and samples of student work to gather information about the program plan, professional development, and how technology supported teaching and learning.

Data Analysis

I analyzed data to examine whether changes occurred across two dimensions of technology integration: (a) the frequency of technology use, and (b) the centrality of technology use to classroom routines. The centrality of technology use to classroom routines was coded as either seamlessly embedded or peripheral to classroom routines. I grouped the frequency of technology use into two categories ranging from daily to less than once a month. Table 1 displays the coding scheme used to investigate changes in teachers' technology integration practices over time.

After investigating similarities and differences in teachers' experiences as participants in the laptop program, I triangulated teacher, classroom, and district data sources to identify historical roots of components of teachers' technology integration activity systems. I used interviews, observations, and documents to identify subjects, objects, mediating artifacts, rules, community, and division of labor to construct activity systems for each teacher and document contradictions that occurred between Years 1 and 3. I drew on interviews to signal contradictions in teachers' activity systems. Although teachers may have been aware of tensions, they did not always know to whom or what

Table 1. Dimensions of Technology Integration and Corresponding Codes and Descriptions

Dimension	Code	Description
Technology Use Frequency	Infrequent	Classroom technology used several times a month or less
	Frequent	Classroom technology used weekly or daily
Centrality of Technology Use	Peripheral	Technology use peripheral to a majority of classroom routines; technology used as an add-on resource for remediation or enrichment
	Seamless	Technology use integral to a majority of classroom routines; technology used as an essential teaching and learning tool

to attribute root causes. Through analysis, I traced many contradictions to the technology planning system. I analyzed differences in Cindy's and Ann's contradictions of activity and summarized it in a table. Finally, drawing primarily on interviews, I examined what changes, if any, occurred between Years 1 and 3 of the program that contributed to reductions in intersystem contradictions overtime.

Results

Changes in Teachers' Technology Integration

Cindy and Ann's technology integration practices over the 3-year study period are summarized below. The next section details how interactions between the technology planning and technology integration systems changed over time to further support teachers' technology use.

Experiences of Cindy, the science teacher. Cindy described her teaching style as "experience-oriented." Cindy explained that she valued hands-on approaches to teaching yet also incorporated strategies such as lecture and note taking, providing classroom demonstrations, and assigning worksheets to encourage reflection and reinforce concepts. During each visit to Cindy's classroom, I observed students conducting a laboratory experiment or discussing a project they had recently completed. I interviewed Cindy again during Year 3 to investigate whether she perceived any changes in her beliefs or practices due to her participation in Westwood's laptop program. Cindy reported that her views about teaching and learning had not changed over the years.

During the first year of Westwood's laptop program, Cindy and district personnel reported that she used technology with her students on only a few occasions. In general, Cindy's practices without technology were intended to encourage active manipulation of objects or parameters, observation, collaboration, reflection, and memorization. However, during Year 1, her practices with technology were peripheral to regular classroom routines. For example, during Year 1, Cindy directed students to complete an interactive virtual lab to predict an object's buoyancy based on its density. However, because the virtual lab did not foster as much interaction, manipulation, and observation as the physical lab, she decided to reinforce the virtual lab with a physical, hands-on density lab.

Cindy reported that she was interested in using technology with students in an interactive manner, yet she doubted whether Web-based activities contributed to student learning.

The extent to which Cindy integrated technology into her instructional program increased over the 3-year study period from several uses a year to weekly. She reported using a combination of software, interactive websites, online videos and animated visualizations, and Web links on her classroom Web site. Instead of stating that technology added little value, during Year 3, Cindy offered several examples of how her technology use had changed to better support student learning. The interview excerpt below offers one example of how Cindy directed students to work in small groups to visit Web sites that enabled them to observe phenomena that could not be easily visualized without technology. She stated:

> [In the past], when we looked at static electricity, one of the things that we always discussed was the movement of electrons. And this is very difficult for the students to understand because they can't see the electrons moving … and this Web site, which was a physics Web site that we went to, actually showed positive and negative charges being repelled and attracted within the balloon and on the surface of the wall so [students] could visually see what was happening. And that was much better than the pictures that we had drawn because there was motion that was occurring as they brought the balloon to the wall. They could see, "Oh, this is what is happening to the charged particles that are in the wall."

In addition to computer-supported visualizations, Cindy reported that students used laptops to conduct Internet research, complete worksheets that encouraged reflection as they visited Web sites, and prepare for unit exams.

Experiences of Ann, the social studies and language arts teacher. Similar to Cindy, Ann reported that project-based learning was the dominant teaching and learning activity in her classroom. I observed Ann's students completing projects while working in groups to gather information, construct physical artifacts, and create multimedia products. Ann reported in Year 3 that she continued to direct students to complete projects and assignments that linked students' learning to real-world activities and also supported mastery of academic content.

During the first year of the program, Ann's students used laptops daily to write journal entries in response to prompts for expository and persuasive writing. Ann's students also used laptops to conduct Internet research and complete social studies and language arts projects. During each class observed, without Ann's prompting, students took their laptops out of their backpacks upon entering the classroom for writing journal entries and would keep laptops nearby for subsequent use during the 2-hour block period.

Table 2. Changes in Teachers' Technology Integration Practices Over 3 Years

	Cindy (Science)		Ann (Language Arts)	
	Year 1	Year 3	Year 1	Year 3
Centrality of Technology Use	Peripherally integrated in classroom routines	Further integrated in classroom routines	Seamlessly integrated in classroom routines	Seamlessly integrated in classroom routines
Technology Use Frequency	Infrequent	Frequent	Frequent	Frequent

The frequency of Ann's technology use remained unchanged over the 3-year study period as students maintained daily laptop use. By Year 3, Ann continued to direct students to use laptops to complete assignments and projects. She also reported that students used laptops to research authors, reflect on samples of exemplar writing, draft papers, and provide one another feedback.

Table 2 summarizes the extent to which teachers' technology integration practices shifted over the 3-year study. As displayed in Table 2, Cindy further integrated technology into her instructional routines, while Ann's technology use remained unchanged.

Cindy and Ann taught in the same building and at the same grade level. They both participated in the same district laptop program. Yet they had very different experiences as participating teachers in the laptop program: Cindy's use of technology increased, and Ann's remained unchanged. Because both teachers' beliefs about teaching and learning, as well as their general practices, were consistent over the study period, I conducted activity systems analyses to examine whether changes in their context of technology use accounted for differences in the two teachers' technology integration experiences.

System Interactions and Technology Integration

Analysis of linkages between the school district's system of technology planning and teachers' classroom systems of technology integration revealed differential interactions among the two teachers. Table 3 (p. 346) displays how the outcome of the technology planning system was linked with the rules, community, mediating artifacts, and division-of-labor components of teachers' technology integration activity systems.

Table 3 displays contradictions teachers experienced as tildes and displays complementary interactions as plus signs. As indicated in Table 3, Cindy encountered numerous intersystem contradictions during Year 1. Although Cindy's beliefs about teaching and learning did not change over time, modifications program planners made to the technology planning system appeared to result in more complementary system linkages by Year 3, which fostered Cindy's more frequent and integrated classroom technology use. Contrary to Cindy's experience, linkages between the district's technology planning system and Ann's classroom-level technology integration system

Table 3. Interactions Between the Technology Planning System and Teachers' Classroom Systems During Year 1 and Year 3

	Cindy (Science)		Ann (Language Arts)	
	Year 1	Year 3	Year 1	Year 3
Rules				
Locate online resources	~	+	+	+
Simultaneous initiatives	~	+	+	+
Technology policies	~	+	+	+
Community				
Social pressure and expectations	~	+	+	+
Subject-specific collaboration	~	+	+	+
Mediating artifacts				
Equipment reliability	~	+	~	+
Professional development	+/~	+	+/~	+
Division of labor				
Technology and integration support	+	+	+	+
Provide program planning input	~	+	+	+

Note: ~ = contradictory intersystem interaction; + = complementary intersystem interaction; +/~ = complementary and contradictory interactions

remained mostly complementary over time, which helps account for her technology integration success during Years 1 and 3.

The next section presents evidence that describes the extent to which system linkages were complementary or contradictory during Year 1 as well as changes program planners made between Years 1 and 3 to identify and address contradictory linkages.

System linkages during Year 1. Outcomes of the technology planning system led to conditions for technology use that mediated teachers' technology integration efforts.

Use of online resources. Policies implemented at the school and district levels are structural considerations that can influence meaningful classroom technology use (Anderson & Dexter, 2005; Fitzgerald, 2003; O'Dwyer, Russell, & Bebell, 2004).

Planners sought and obtained funding for hardware, infrastructure, productivity software, and an online video streaming subscription. However, because software did not directly address curricular goals, teachers resorted to locating Web sites they could use with students. Cindy indicated during interviews that her efforts to locate educational Web sites extended past the summer professional development workshop into the school year. Whereas Cindy expressed frustration with the time required to locate quality online resources, Ann was not as negatively affected by the program's expectation that teachers use Web-based resources with students. Instead of locating and screening all Web sites, Ann taught students how to use search engines to conduct Internet research. This decision not only reduced the amount of time Ann spent locating resources, but it also enabled students to develop online research skills.

Simultaneous initiatives. It has been suggested that teachers use computers less when asked to simultaneously implement other initiatives (Zhao & Frank, 2001). During the first year of the laptop program, Cindy also piloted new science curriculum adopted by the district. She described the new curriculum as prescriptive and less inquiry oriented than the curriculum she had previously designed and used for 9 years. During an interview, Cindy stated, "The first year [of the laptop program] … I felt overwhelmed because … I was so busy just implementing the new curriculum." Unlike Cindy, Ann was not asked to enact new curriculum while participating in the laptop program.

Technology policies. Westwood's technology policies consisted of an acceptable use policy for staff, families and students and a Web publishing policy. For Cindy, the policies occasionally restricted her ability to meaningfully integrate technology into classroom routines. For example, in an effort to limit online gaming, students were prohibited from downloading and installing a multimedia platform that supported animation and Web page interactivity. This policy, in turn, limited Cindy's attempts during the first year of the laptop program to direct students to complete virtual labs. During one lesson, Cindy learned that students could not access the virtual lab on their laptops. In response, she made an impromptu change to the lesson by making the lab a whole-class, as opposed to a small-group, activity, which she felt compromised the virtual lab's effectiveness. However, unlike Cindy, Ann did not attempt to make use of interactive Web sites. Instead her students used laptops for word processing, desktop publishing, and Internet research.

Social influences. There is evidence that professional community and subject-specific inquiry groups contribute to teachers' computer use (Becker, 1994; Ertmer, 2005; Glazer, Hannafin, & Song, 2006; Hughes, 2005; Schrum, 1999; Zhao & Frank, 2003). Social aspects of Westwood's program included pressure for teachers to integrate technology and teachers' access to a professional community.

Parents and students had expectations for extensive classroom technology use. Cindy stated during Year 1 that students would often ask her why the laptops were used less often in science than in social studies and language arts. In addition to students' inquiries, I observed a Year 1 school-wide meeting, during which parents publically voiced frustration over Cindy's infrequent technology use.

There were also differences in Cindy and Ann's technology integration professional communities. The program design called for two language arts and social studies teachers, one math teacher, and one science teacher. Cindy collaborated with other science teachers to prepare lessons; however, because her departmental peers did not teach in a one-to-one environment, they were limited in their ability to share ideas about how to frequently and seamlessly integrate technology. However, Ann and the other social studies/language arts teacher not only co-planned technology-rich lessons, but also taught in neighboring classrooms and frequently discussed lesson modification ideas.

Professional development. Professional development was distributed across multiple contexts, including in-class support, asynchronous discussion boards, and face-to-face workshops held during the summer and monthly during the school year. Teachers reported an appreciation for professional development. However, professional development design and delivery also appeared to limit teachers' technology integration attempts. In particular, the workshops lacked specificity to transform teaching. The technology integration specialist expressed a desire that teaching practices become more constructivist, and he stated that teachers needed to integrate technology into "their existing lesson" plans. Yet Cindy reported that because many of her lesson plans were already hands-on and effective, she did not perceive a need for technology integration. Workshops did not emphasize ways in which technology-supported, constructivist-oriented teaching might differ from teachers' existing practice.

Another aspect of the laptop program design that resulted in an uneven development of teachers' technology integration skills is that the technology integration specialist requested that Ann and the other social studies and language arts teacher assist with testing the laptops, server, and wireless Internet connection during the spring prior to the start of the pilot program. Although this decision was intended to help avoid Year 1 technical issues, daily exposure to laptops prior to the start of the program offered Ann additional experience with technology, an advantage prior to the start of the program that Cindy did not receive.

Reliability of technology. When purchasing technology, schools must look beyond hardware (O'Dwyer et al., 2004) to consider appropriate infrastructure (Keane et al., 2003) and whether technology is rigorous enough for regular classroom use (Honey et al., 1999). Year 1 of the laptop program was plagued with technical issues that occurred on a nearly daily basis. Most issues concerned server accessibility and wireless networking. It was not until 4 months into the program that technology personnel and vendors successfully addressed the issues and improved equipment reliability. During interviews in Years 2 and 3, Cindy and Ann did not mention equipment reliability as a constraint on their technology use.

In summary, Year 1 system linkages converged to support Ann's technology use while simultaneously limiting Cindy's technology use. The next section describes ways that system linkages changed over time to provide more uniform support for technology integration.

System changes made between Years 1 and 3. Westwood adhered to many recommended guidelines for technology planning. For example, to reduce the risk of negatively impacting the district, the program began as a pilot (Keane, et al., 2003). There was a technology director and technology committee in place to lead planning efforts (McNabb, et al., 1999). Planners selected teacher participants they believed would be willing to integrate technology (Baylor & Ritchie, 2002). The district secured external funding for equipment purchases (Anderson & Dexter, 2005; Fitzgerald, 2003) and made sustained professional development available to teachers (Cobb, McClain, Lamberg, & Dean, 2003; McNamara, Grant, & Wasser, 1998). However, as previously reported, during Year 1, outcomes of Westwood's technology planning system both supported and hindered teachers' technology integration efforts, but subsequent iterations of the technology planning system further mediated technology integration.

Between Years 1 and 3, program planners worked to modify program plans, which in turn changed components of teachers' technology integration systems. As Table 3 (p. 346) indicates, component changes had a marked effect on the linkages between the planning system and Cindy's technology integration system, which corresponded with her improved technology use. Input program planners sought from teachers prompted many planning changes. Surveys and conversations were primary means for obtaining teachers' input in preparation for Years 2 and 3. During an interview, the technology director stated:

> The technology integration specialist is always trying to get feedback from [teachers]. We've just put surveys out to all the teachers to get more feedback on more changes we might be able to implement for next year—things we might be able to do differently.

Planners relied on teachers' feedback to expand participation to all students and teachers in a grade level, modify policies, improve technology reliability, and change the professional development model. These changes are described below.

Expand participation. Program planners reported that following Year 1, teachers requested that the laptop program be expanded to include all sixth grade students and teachers. Teachers were concerned that unintended consequences of the pilot program were student isolation and inequitable distribution of technology resources. To address concerns, planners expanded Year 2 of the program to include all fifth and sixth grade teachers and students at a 2:1 student-to-computer ratio. The technology director explained how teachers' feedback during Year 2 influenced decisions to acquire additional funding and to return to a 1:1 student-to-computer ratio. The technology director stated:

> Going back and talking with the teachers … the first thing they said was, "It's not the same … because I'm not guaranteed I can use [the laptops]." … And, they said if they had their choice, it has to be one to one, and [the program] has to go in that direction.

As a result of teachers' feedback, the Year 3 program had a 1:1 student-to-laptop ratio for fifth and sixth grade. Following 2007, it was further expanded to a one-to-one program for fifth through seventh grade.

Policy changes. Between Years 1 and 3, two district policies were changed in ways that further supported Cindy's technology use. First, the district lifted the ban on downloading a multimedia platform for animation and Web page interactivity. Instead of focusing on preventing students' online gaming, planners focused on how interactive Web sites could enhance teaching and learning, particularly in science and mathematics. The second policy change was that, by Year 2, the district fulfilled its obligation to pilot the new science curriculum. During Years 2 and 3, Cindy was once again permitted to enact some of the lessons she had previously developed. The greater curricular flexibility provided more time and space for technology integration.

Fostered professional community. During Year 1, teachers were not offered equal access to social capital that could support their technology integration efforts due to program structure, which enabled only the social studies and language arts teachers to engage in content-specific conversations about technology integration. The program expansion during Years 2 and 3 granted all teachers access to colleagues with whom they could discuss subject-specific applications of technology.

Improved technology reliability. During Year 1, the technology director worked with technology staff and vendors to improve technology reliability. They achieved improvements by refining the division of labor among technology support team members. Although the technology director worked closely with vendors, technicians were assigned to two schools to maintain repairs and to address warranty issues, and the technology integration specialist who was charged with leading professional development efforts provided more troubleshooting assistance. Additionally, a bond initiative and state grant helped fund new hardware purchases.

Changed professional development model. Following Year 1, professional development was changed for several reasons. The technology director explained that, first, program planners recognized that teachers had different interests in and frequencies of technology integration, thus teaching everyone the same content was inefficient. He stated, "We discovered along the way that every teacher's at a different level in technology.… So why are we forcing upon them this cookie-cutter approach?" Second, planners reasoned that each teacher had unique professional goals for technology integration that could change over the course of the year, so they developed a framework intended to enable each teacher to

Table 4. Guiding Questions to Inform Investigation of Intersystem Linkages

Activity System Element	Possible Question
Object	Is the object of the technology initiative aligned with objects of teachers' classroom practices?
Mediating artifacts	To what extent do computer technology and professional development support or hinder teaching practice?
Rules	How do district policies support or hinder technology integration?
Community	Do teachers have opportunities to work with and learn from colleagues to support technology integration?
Division of labor	Would teachers benefit from additional technology integration support (e.g., co-teaching, locating instructional resources, in-class professional development, data collection or analysis)?
	Do teachers have opportunities to provide suggestions for program improvement?

pursue individual professional learning goals. Third, planners encouraged greater teacher ownership over professional development by providing additional time for locating and exploring subject-specific and grade-level online resources. Finally, planners coordinated opportunities for teachers to discuss technology integration ideas with subject-matter colleagues.

Conclusion and Implications

This study indicates that technology implementation can be conceptualized as a network of district systems associated with technology planning and classroom systems related to technology integration. Furthermore, the ways these district-classroom systems interact can have profound influences on the nature and frequency of teachers' technology use. The effects of intersystem linkages were readily seen in Cindy's practice, which changed to further integrate technology as intersystem contradictions were reduced to become more complementary when the district engaged in efforts to continuously improve the laptop program. Thus, teachers who are linked with district systems in complementary ways may receive more positive support for technology integration than those who are linked in contradictory ways.

The integral role continuous improvement served in this case study through fostering a more supportive and equitable environment for teachers' classroom technology use has important implications for how technology leadership is understood and practiced in school settings. First, effective technology leadership extends beyond the work of vision setting, developing strategic plans, purchasing equipment, and coordinating professional development but may also call for collective attempts by technology specialists, teachers, and administrators to identify and address differences in how intersystem linkages converge to affect teachers' ability to integrate technology. This study documented first-order changes (Argyris & Schön, 1978), such as equipment improvements, redesigned professional development, and modified policies that were made to improve technology implementation. However, continuous improvement might also necessitate second-order changes, such as a re-evaluation of program motives and goals. Drawing on study findings and the activity theory framework, Table 4 poses a set of questions technology leaders can raise in their efforts to uncover instances of contradictory intersystem linkages and how they work to shape teachers' technology integration experiences.

Study findings confirm the importance of distributed technology leadership (Dexter, 2008) to the design and delivery of technology programs in general and teachers' professional development experiences in particular. As indicated in this study, technology specialists and administrators sought input from teachers to identify challenges and work toward program improvements through valuing collective effort reflective of shared instructional leadership (Marks & Printy, 2003) and organizational learning (Argyris & Schön, 1978). Findings imply that leadership preparation programs can serve a critical role in preparing administrators and technology directors who are equipped to design and lead technology initiatives that are not only intended to help address the teaching and learning challenges of tomorrow's schools, but that are also careful to not further complicate teachers' existing complex and multifaceted work.

Research is needed that further examines the effect of complementary and contradictory system linkages on technology integration on a larger scale. Although this study demonstrated how activity theory could be used to investigate district-classroom interactions and their differential effects on teaching practice, other system models may be better suited for less contextualized, large-scale investigations. Future research can also examine the utility of the activity framework in informing the work of planning and continuously improving technology initiatives in practice.

Author Note

Anika Ball Anthony is an assistant professor in the School of Educational Policy and Leadership at The Ohio State University. Her research interests include the systemic nature of school organizations, technology integration, and technology leadership. Please address correspondence regarding this article to Anika Ball Anthony, PhD, The Ohio State University, School of Educational Policy and Leadership, 325A Ramseyer Hall, 29 W. Woodruff Ave., Columbus, OH 43210. Email: aanthony@ehe.osu.edu

References

Anderson, R. E., & Dexter, S. L. (2005). Technology leadership: An empirical investigation of prevalence and effect. *Educational Administration Quarterly, 41*(1), 49–82.

Argyris, C., & Schön, D. A. (1978). *Organizational learning.* Reading, MA: Addison-Wesley.

Barron, A. E., Kemker, K., Harmes, C., & Kalaydjian, K. (2003). Large-scale research study on technology in K–12 schools: Technology integration as it relates to the national technology standards. *Journal of Research on Technology in Education, 35*(4), 489–507.

Bauer, J., & Kenton, J. (2005). Toward technology integration in the schools: Why it isn't happening. *Journal of Technology and Teacher Education, 13*(4), 519–546.

Baylor, A. L., & Ritchie, D. (2002). What factors facilitate teacher skill, teacher morale, and perceived student learning in technology-using classrooms? *Computers and Education, 29*, 395–414.

Becker, H. J. (1994). How exemplary computer-using teachers differ from other teachers: Implications for realizing the potential of computers in schools. *Journal of Research on Computing in Education, 26*(3), 291–321.

Becker, H. J. (2001). *How are teachers using computers in instruction?* Retrieved from http://www.crito.uci.edu/tlc/FINDINGS/special3

Bellamy, R. K. E. (1996). Designing educational technology: Computer-mediated change. In B. A. Nardi (Ed.), *Context and consciousness: Activity theory and human-computer interaction* (pp. 123–146). Cambridge, MA: MIT Press.

Bennett, N. (2008). Distributed leadership and IT. In J. Voogt & G. Knezek (Eds.), *International handbook of information technology in primary and secondary education* (pp. 597–613). New York: Springer Science+Business Media, LLC.

Blanton, W. E., Moorman, G., & Trathen, W. (1998). Telecommunications and teacher education: A social constructivist review. *Review of Research in Education, 23*, 235–275.

Bransford, J. D., Brown, A. L., Cocking, R. R. (Ed.). (2000). *How people learn: Brain, mind, experience, and school.* Washington, DC: National Academy Press.

CEO Forum. (1997). *School technology and readiness report: From pillars to progress, year one* (pp. 220). Washington, DC.

Christensen, C. M., & Horn, M. B. (2008). How do we transform our schools? Use technologies that compete against nothing. *Education Next, 8*(3), 12–19.

Cilesiz, S. (2011). A phenomenological approach to experiences with technology: Current state, promise, and future directions for research. *Educational Technology Research and Development, 59*(4), 487–510.

Cobb, P., McClain, K., Lamberg, T., & Dean, C. (2003). Situating teachers' instructional practices in the institutional setting of the school and district. *Educational Researcher, 32*(6), 13–24.

Cole, M., & Engeström, Y. (1993). A cultural-historical approach to distributed cognition. In G. Salomon (Ed.), *Distributed cognitions: Psychological and educational considerations* (pp. 1–46). New York: Cambridge University Press.

Consortium for School Networking. (2009). *Framework of essential skills of the K–12 chief technology officer.* Retrieved from http://www.cosn.org/Resources/CTOCouncil/EssentialSkillsoftheK12CTO/tabid/4489/Default.aspx

Cuban, L. (1986). *Teachers and machines: The classroom use of technology since 1920.* New York: Teachers College Press.

Cuban, L., & Kirkpatrick, H. (1998). Computers make kids smarter—right? *TECHNOS, 7*(2), 26–31.

Culp, K. M., Honey, M., & Mandinach, E. (2003). *A retrospective on twenty years of education technology policy.* Washington, DC: U.S. Department of Education, Office of Educational Technology.

Davis, M. R. (2008). The knowledge gap. *Education Week.* Retrieved from http://www.edweek.org/dd/articles/2008/01/23/3leadership.h01.html

Dede, C., Salzman, M., Loftin, R. B., & Ash, K. (2000). The design of immersive virtual environments: Fostering deep understandings of complex scientific knowledge. In M. J. Jacobson & R. B. Kozma (Eds.), *Innovations in science and mathematics education: Advanced designs for technologies of learning* (pp. 361–414). Mawah, NJ: Lawrence Erlbaum.

Dexter, S. (2008). Leadership for IT in schools. In J. Voogt & G. Knezek (Eds.), *International handbook of information technology in primary and secondary education* (pp. 543–554). New York: Springer Science+Business Media, LLC.

Dwyer, D. (1994). Apple classrooms of tomorrow. *Educational Leadership, 51*(7), 4–10.

Engeström, Y. (1987). *Learning by expanding: An activity-theoretical approach to developmental research.* Retrieved from http://lchc.ucsd.edu/MCA/Paper/Engestrom/expanding/toc.htm

Engeström, Y. (1999a). Activity theory and individual and social transformation. In Y. Engeström, R. Miettinen, & R.-L. Punamaki (Eds.), *Perspectives on activity theory* (pp. 19–38). New York: Cambridge University Press.

Engeström, Y. (1999b). Introduction. In Y. Engeström, R. Miettinen & R.-L. Punamaki (Eds.), *Perspectives on activity theory* (pp. 1–18). New York: Cambridge University Press.

Engeström, Y. (2008). Weaving the texture of school change. *Journal of Educational Change, 9*, 379–383.

Ertmer, P. A. (2005). Teacher pedagogical beliefs: The final frontier in our quest for technology integration? *Educational Technology Research and Development, 53*(4), 25–39.

Ertmer, P. A., & Ottenbreit-Leftwich, A. T. (2010). Teacher technology change: How knowledge, confidence, beliefs, and culture intersect. *Journal of Research on Technology in Education, 42*(3), 225–284.

Fitzgerald, S. (2003). Back to the future: total cost of ownership and other ed tech sustainability models. In N. Dickard (Ed.), *The sustainability challenge: Taking ed tech to the next level* (pp. 74): Benton Foundation with EDC Center for Children and Technology.

Flanagan, L., & Jacobsen, M. (2003). Technology leadership for the twenty-first century principal. *Journal of Educational Administration, 41*(2), 124–142.

Franklin, C. (2007). Factors that influence elementary teachers use of computers. *Journal of Technology and Teacher Education, 15*(2), 267–293.

Gay, G., & Hembrooke, H. (2004). *Activity-centered design: An ecological approach to designing smart tools and usable systems.* Cambridge, MA: MIT Press.

Glazer, E. M., Hannafin, M. J., & Song, L. (2006). Promoting technology integration through collaborative apprenticeship. *Educational Technology Research and Development, 53*(4), 57–67.

Guskey, T. R. (2000). *Evaluating professional development.* Thousand Oaks, CA: Corwin Press.

Hannafin, R. D., & Foshay, W. R. (2008). Computer-based instruction's (CBI) rediscovered role in K–12: An evaluation case study of one high school's use of CBI to improve pass rates on high-stakes tests. *Educational Technology Research and Development, 56*(2), 147–160.

Hardman, J. (2007). Making sense of the meaning maker: Tracking the object of activity in a computer-based mathematics lesson using activity theory. *International Journal of Education and Development using Information and Communication Technology, 3*(4), 110–130.

Hew, K. F., & Brush, T. (2007). Integrating technology into K–12 teaching and learning: Current knowledge gaps and recommendations for future research. *Educational Technology Research and Development, 55*(3), 223–252.

Honey, M., & Henriquez, A. (1996). Lessons from Union City: Six replicable factors from a unique success story in school reform. *Electronic Learning, 16*(1), 58–59.

Hughes, J. E. (2005). The role of teacher knowledge and learning experiences in forming technology-integrated pedagogy. *Journal of Technology and Teacher Education, 13*(2), 277–302.

Inan, F. A., & Lowther, D. L. (2010). Factors affecting technology integration in K–12 classrooms: A path model. *Educational Technology Research and Development, 58,* 137–154.

International Society for Technology in Education. (2009). *National Educational Technology Standards for Administrators (NETS-A).* Retrieved from http://www.iste.org/standards/nets-for-administrators.aspx

Kaptelinin, V. (1996). Activity theory: Implications for human-computer interaction. In B. A. Nardi (Ed.), *Context and consciousness: Activity theory and human-computer interaction* (pp. 103–116). Cambridge, MA: MIT Press.

Kaptelinin, V. (2005). The object of activity: Making sense of the sense-maker. *Mind, Culture, and Activity, 12*(1), 4–18.

Keane, J. T., Gersick, A., Kim, C., & Honey, M. (2003). Toward a sustainability framework: Lessons from the literature and the field. In N. Dickard (Ed.), *The sustainability challenge: Taking edtech to the next level* (pp. 27–46). Washington, DC: Benton Foundation with EDC Center for Children and Technology.

Leont'ev, A. N. (1978). *Activity, consciousness, and personality.* Englewood Cliffs, NJ: Prentice-Hall, Inc.

Marks, H. M., & Printy, S. M. (2003). Principal leadership and school performance: an integration of transformational and instructional leadership. *Educational Administration Quarterly, 39*(3), 370–397.

Marshall, C., & Rossman, G. B. (1999). *Designing qualitative research* (3rd ed.). Thousand Oaks, CA: Sage Publications.

McNabb, M. L., Valdez, G., Nowakowski, J., & Hawkes, M. (1999). *Technology connections for school improvement: Planners' handbook* (pp. 153): U.S. Department of Education and North Central Regional Educational Laboratory.

McNamara, E., Grant, C. M., & Wasser, J. D. (1998). *Using technology to support systemic education reform.* Hanau Model School Partnership project description research monograph. Cambridge, MA: TERC.

Myhre, O. R. (1998). I think this will keep them busy: Computers in a teacher's thought and practice. *Journal of Technology and Teacher Education, 6*, 93–103.

Nardi, B. A. (1996). Studying context: A comparison of activity theory, situated action models, and distributed cognition. In B. A. Nardi (Ed.), *Context and consciousness: Activity theory and human-computer interaction* (pp. 69–102). Cambridge, MA: MIT Press.

National Center for Education Statistics. (2002). *Technology in schools: Suggestions, tools, and guidelines for assessing technology in elementary and secondary education.* Retrieved from http://nces.ed.gov/pubs2003/2003313.pdf

O'Dwyer, L., Russell, M., & Bebell, D. (2004). *Elementary teachers' use of technology: Characteristics of teachers, schools, and districts associated with technology use* (pp. 33). Boston, MA: Technology and Assessment study Collaborative, Boston College.

Papert, S. (1980). *Mindstorms: Children, computers, and powerful ideas.* New York: Basic Books.

Roblyer, M. D., & Knezek, G. A. (2003). New millennium research for educational technology: A call for a national research agenda. *Journal of Research on Technology in Education, 36*(1), 60–71.

Roth, W.-M., & Lee, Y.-J. (2007). "Vygotsky's neglected legacy": Cultural-historical activity theory. *Review of Educational Research, 77*(2), 186–232.

Sannino, A. (2008). Sustaining a non-dominant activity in school: Only a utopia? *Journal of Educational Change, 9*, 329–338.

Schofield, J. W., & Davidson, A. L. (2002). *Bringing the internet to school: Lessons from an urban district.* San Francisco, CA: Jossey-Bass.

Schrum, L. (1999). Technology professional development for teachers. *Educational Technology Research and Development, 47*(4), 83–90.

Schrum, L., Thompson, A., Sprague, D., Maddux, C., McAnear, A., Bell, L., & Bull, G. (2005). Advancing the field: Considering acceptable evidence in educational technology research. *Contemporary Issues in Technology and Teacher Education, 5*(3/4). Retrieved from http://www.citejournal.org/vol5/iss3/editorial/article1.cfm

Songer, N. B., Lee, H., & Kam, R. (2002). Technology-rich inquiry science in urban classrooms: What are the barriers to inquiry pedagogy? *Journal of Research in Science Teaching, 39*(2), 128–150.

Sun, J., Heath, M., Byrom, E., Phlegar, J., & Dimock, K. V. (2000). *Planning into practice: Resources for planning, implementing, and integrating instructional technology.* Greensboro, NC: Southeast Initiatives Regional Technology in Education Consortium (SEIR*TEC).

Thomas, A. D. (2005). Scientifically based research: Establishing a research agenda for the technology in teacher education community. *Journal of Research on Technology in Education, 37*(4), 331–337.

Trotter, A. (2007). Getting up to speed. *Technology Counts '07: A Digital Decade, 26*(30), 10–16. Retrieved from http://www.edweek.org/ew/articles/2007/03/29/30tcpolicy.h26.html

U.S. Department of Education. (2008). *National educational technology trend study: Local-level data summary.* Washington, DC: Office of Planning, Evaluation and Policy Development, Policy and Program Studies Service.

U.S. Department of Education. (2010). *Transforming American education: Learning powered by technology: National Educational Technology Plan 2010.* Washington, DC: Office of Educational Technology.

Walshaw, M., & Anthony, G. (2008). The teacher's role in classroom discourse: A review of recent research into mathematics classrooms. *Review of Educational Research, 78*(3), 516–551.

Weick, K. E. (1976). Educational organizations as loosely coupled systems. *Administrative Science Quarterly, 21*, 1–19.

Wenglinsky, H. (2005). *Using technology wisely: The keys to success in schools.* New York: Teachers College Press.

Windschitl, M., & Sahl, K. (2002). Tracing teachers' use of technology in a laptop computer school: The interplay of teacher beliefs, social dynamics, and institutional culture. *American Educational Research Journal, 39*(1), 165–205.

Yasemin, G. l. (2007). Technology planning: A roadmap to successful technology integration in schools. *Computers and Education, 49*(4), 943–956.

Zhao, Y., & Frank, K. (2001). *Technology uses in Michigan schools: An empirical study.* East Lansing, MI: Center for Information Development at Michigan State University College of Education.

Zhao, Y., & Frank, K. A. (2003). An ecological analysis of factors affecting technology use in schools. *American Educational Research Journal, 40*(4), 807–840.

Manuscript received May 17, 2011 | Revisions received February 23, 2012 | Accepted February 27, 2012