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ABSTRACT

This study examined how the teacher's role is dependent on what they know and how what they know is affected by how they learn, focusing on the acquisition of knowledge regarding educational technology by student teachers and their mentors. The study emphasized three types of educational technology knowledge: content knowledge, pedagogical knowledge, and pedagogical content knowledge. Participants were three experienced middle school classroom teachers and their three student teachers. They worked in a school that had reasonable amounts of technological equipment. Data sources included field notes from classroom observations and teacher conversations and transcripts from semi-structured interviews. Data analysis indicated that while university coursework was useful for acquiring content knowledge, pedagogical knowledge and pedagogical content knowledge were more readily acquired within the teaching context. Student teachers brought with them current content knowledge of technology. Mentor teachers served as pedagogical guides in the process of acquiring educational technology pedagogical and pedagogical content knowledge. Lack of time and difficulty with classroom management were obstacles to acquiring educational technology knowledge. (Contains 41 references.) (SM)

Teacher Knowledge of Educational Technology: A Study of Student Teacher/Mentor Teacher Pairs

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Introduction

This study lies at the intersection of two critical currents in American education: A growing sense of the importance of the role of the teacher in the implementation of educational technology and the need to successfully prepare literally millions of new teachers in the coming decade. In this study, we argue that the role that teachers play is dependant in part on what they know and that in turn, what teachers know is impacted by how they learn. As part of a dissertation study, this paper reports partial results of the larger work; interested readers can contact the authors for more complete results.

The acquisition of knowledge regarding educational technology by student teachers and their mentors is the focus of this study. In general, computer-based technology is a major object of thought and action in the K-12 educational community (President's committee of advisors on science and technology, 1997). Technology use in education holds the promise of increased student performance (Wenglinsky, 1998), support of reform-oriented curriculum interventions (Means & Olson, 1995), and improved teacher professional communication (Gibson & King, 1997), among other educational benefits. Recent research has established a number of requirements that need to be addressed in order for the promise of technology to be realized (e.g., Krajcik, Soloway, Blumenfeld & Marx, 1998); prominent among these is adequate preparation for and support of teachers (Willis & Mehlinger, 1996). Despite the recognized importance of teacher preparation and development in technology use, little is known about how and what teachers learn through traditional professional development efforts (Wilson & Berne, 1999); in this study, we identify student teachers as a potential source of educational technology knowledge, exploring knowledge acquisition in ways which we believe can inform professional development as well as teacher preparation.

Intersecting the new opportunities offered by technology is a demand for a large number of new teachers; American schools will encounter a vast infusion of new teachers as tens of thousands of teachers retire and as new opportunities are created through forces such as larger student populations and legislation mandating smaller class sizes. If teacher education is equal to the challenge of meeting the demand for new teachers, these changes promise—among many other things—the opportunity to rapidly bring increased technological understanding to the classroom. Teachers entering the field of education have a responsibility to acquire the knowledge needed to be effective technology-using educators (CEO Forum, 1997), just as teacher educators have a responsibility to give these teachers the means to do so (Handler, 1993).

A central component of teacher preparation programs is the student teaching experience. Because learning to teach is in large measure a professional enterprise, it is essential that theoretical and practical knowledge develop in concert. Thus student teaching is seen by many (e.g., Borko & Putnam, 1996; Carter, 1990; Cochran-Smith, Garfield & Greenberger, 1992) as a site where such integrative learning can take place. The student teaching experience also is a place where teacher education students can influence the practice of experienced teachers. After all, student teachers come to their placements with their own knowledge and experience and potentially have something to teach their supervising teachers. In other words, learning in and from student teaching can be bi-directional (Tatel, 1996).

The set of case studies of which this paper is a part are being written to describe knowledge of educational technology as it is acquired, used and shared between student teachers and the experienced teachers with whom they work during their student teaching experience. The central question addressed is: "How is knowledge about teaching with technology acquired, used, and shared by pairs of student teachers and the experienced teachers with whom they student teach?" By understanding knowledge of educational technology and its development in classroom teaching and learning contexts, the authors hope to speak to issues of teacher preparation and development as they relate to the use of educational technology.

What is Teacher Knowledge?

Fenstermacher (1994) has noted that knowledge is a complex and often ill-defined construct in educational research. In defining "knowledge" for the purposes of this paper, we hold that teacher knowledge of educational technology is complex (Carter, 1990; Clandinin & Connelly, 1996; Cochran-Smith & Lytle, 1999; Connelly & Clandinin, 1995; Fenstermacher, 1994), situated (Greeno, 1998; Putnam & Borko, 2000) and multi-faceted (Shulman, 1987).

A goal of this study is to describe the knowledge held by the participants in a way which addresses the inherent complexity and situate nature of knowledge. To do this, we frame our conception around Shulman's (1987) general framework for teacher knowledge. Previous scholarship (Margerum-Leys, 1999), has described this framework as potentially useful for describing teachers' knowledge of educational technology . When teachers' knowledge from all sources is considered as a whole, Shulman writes that it has the following components: Content knowledge, general pedagogical knowledge, curriculum knowledge, pedagogical content knowledge, knowledge of learners and their characteristics, knowledge of educational contexts, knowledge of educational ends, purposes, and values (Shulman, 1987, p. 8). For purposes of this study, we distinguish between three types of educational technology knowledge:

- **Content knowledge** of educational technology refers to knowledge of the existence, components and capabilities of various technologies as they are used in teaching and learning settings. This might include an understanding that a range of tools exist for a particular task, the ability to choose a tool based on its fitness, and knowledge of strategies for using the tools' affordances.
- **Pedagogical knowledge** as we use the term here refers to knowledge of general pedagogical strategies and the ability to apply those strategies to the use of technology. Later in the paper, we describe a teacher's ability to use her attendance-taking system to manage a set of word processors as evidence of pedagogical knowledge.
- **Pedagogical content knowledge** of educational technology is an emerging construct. As used in this paper, it is knowledge which arises from experience with using technology for teaching and learning and which in turn applies to the use of technology for teaching and learning. Such knowledge is specialized; it does not come from nor does it necessarily apply to other areas of teaching and learning.

Methods

The methods section which follows is divided into six sections. In the first, we consider methods used in other studies of educational technology and teachers and comment on their utility as well as how this study differs in method. This introductory section is followed by descriptive sections in which we characterize the study participants and setting. We follow the descriptions of the participants and setting with a depiction of the field-based teacher preparation program in which the student teachers were enrolled and in which the mentor teachers play a key role. To close the methods section, we discuss the data types and their analysis.

Methods Used in Recent Research

In terms of scale, the largest of current studies on educational technology are the survey-based studies conducted by researchers such as Becker (1994; 1998) and Wenglinsky (1998). These studies serve a vital role: They inform the field as to what conditions are "normal" for teaching and learning with technology. How often do teachers use technology in their teaching? What software do they use? Which equipment is available to them at their schools? These kinds of questions can be answered by large-scale surveys. Where these studies are limited is in their ability to provide detailed portrayals of what goes on in individual classrooms. In turn, it can be difficult to apply the results of these large-scale studies to teacher education or professional development programs. For instance, Wenglinsky's research indicates that higher student test scores in mathematics are correlated with teachers who have had professional development in the use of technology. But "professional development" in this research refers to any experience ranging from a one-time workshop to a semester-long course. Which professional development efforts are most appropriate? How do they help? Large scale studies do not capture results in a fine enough grain to address these questions.

Another major trend in research on educational technology are the family of studies which can loosely be called design studies (Brown, 1992). Such studies (i.e., Bell, Davis & Linn, 1995; Cognition and Technology Group at Vanderbilt, 1992; Davis, 1998; Edelson, Gordin & Pea, 1997; Gomez, Fishman & Pea, In Press; Scardamalia, Bereiter & Lamon, 1994; Songer, 1996) instantiate a particular instructional design in a classroom setting and study its effects. The research effort consists of both the development of a reform-oriented curriculum innovation and the study of its implementation. Such studies do much to inform the field as to the role and impact of change. The late Stephen Marcus defined the three great research questions as "What?", "So What?", and "Now What?". Unlike large-scale surveys, design experiments are very informative in answering the question "Now What?" . A drawback to design studies as they are currently conducted is that they often take place under conditions which cannot be approximated in traditional K-12 settings. The researchers may supply extra computers, technology support, or instructional support; by definition, design experiment researchers furnish some or all of the curriculum to be studied.

Methods Employed in This Study

The current study differs from these two types in research in several important ways. First, our research is deeply contextualized. The conclusions we draw are based on months of daily contact with practicing teachers in the midst of their teaching settings. While there are studies which examine educational technology use in particular settings over time (i.e., Schofield, 1995; Van Haneghan & Stofflett, 1995), no studies of which we are aware explore both teacher knowledge and educational technology, are conducted over extended time, and have classroom observations as a major source of data.

Second, the present study is naturalistic along lines which are unusual in educational technology research (Wallace, 2000). The authors were not invested in any particular form of technology use. While we have definite ideas about the role of technology in teaching and learning, our role was not tied to any explicit tools or pedagogy.

In designing the study, we have drawn on case study methods suggested by Yin (1984/1989;1993) and data collection methods advocated by Emerson, Fretz & Shaw (1995) and Bogdan & Biklen (1992). The design elements are focused on the creation of a set of cases which provide a rich descriptive basis for answering the study questions. Yin describes case study research as appropriate in describing phenomena; the current case study describes the phenomenon which lies at the intersection of the rise of technology use in teaching, the need for qualified new teachers, and a developing understanding of the situated (Greeno, 1998) and complex (Shulman, 1987) nature of teacher knowledge.

Participants

Yin (1995) speaks of case study participants as being selected purposively, as representing aspects of phenomena. The participants and setting of this study serve the purpose of illuminating the intersection between the rise of technology and the need for new teachers with its accompanying emphasis on the importance of teacher preparation.

Participants for this study were selected based on technology access criteria and on accessibility to the authors. Six participants—three experienced classroom teachers and their student teachers— were approached to participate in the study, based on their placement at the research site described below. All six agreed to participate. The three experienced teachers (two female, one male) each had a minimum of seven years of classroom experience and three years of experience with student teachers. The three student teachers (two female, one male) ranged in age from 23 to 33. All were part of a year-long, interdisciplinary, cohort based program which combines an extended student teacher experience with the coursework necessary for a Master of Arts in education degree and secondary teaching certification. Two of the student teacher/experienced teacher pairs taught middle school science; the remaining student teacher/experienced teacher pair taught middle school language arts. All of the participants were known to the primary study author through his work with their student teaching program, though none of the student teacher participants was under his direct supervision. Tables one through three below give background information on participants' preparation and experiences, as well as giving a narrative description of each participant.

Table 1: Student teacher background

Name	Age	Undergraduate Major	Undergraduate Minor	General Technology Ability	Experiences Supervising Students
Emma Vogel	23	English	German	Medium	Tutored in college Community volunteer reader
Tad Xie	23	Physical Science	Psychology	High	Middle school soccer coach
Helen Johnson	32	Animal Science	Biology	Medium	Previous 9th and 10th grade student teaching Special Olympics ski instructor

Table 2: Mentor teacher background

Name	Years Teaching Experience	Years at Monroe	Years With Student	Other Grade Levels/Subjects

			Teachers	Taught
Sarah Andress	8	5	3	Kindergarten through third grade
Jerry Brewer	9	7	4	High school science
Anna Lloyd	7	3	3	Elementary science

Table 3: Descriptions of research participants and their shared classrooms

In the table below, student teachers are paired in each row with their respective mentor teachers.

Student Teacher	Description	Mentor Teacher	Description	Their Classroom
Emma Vogel	A student teacher in English, Vogel is the youngest participant. Despite her youth, she is extremely competent. Vogel is outgoing, articulate, and genuinely friendly. Although she describes herself as having little technological facility, she displays the ability to use technology for a variety of teaching and professional ends.	Sarah Andress	Andress is a warm, outgoing, entertaining person to be with. Andress has used computers in her teaching to some extent in the past and has learned from previous student teachers.	Andress' English classroom is welcoming and rich with food for thought; her background as an elementary teacher is evident in the way she chooses to set up her classroom. Posters with photographs and motivational thoughts line the room. A stuffed armchair serves as an authors chair.
Tad Xie	A science student teacher, Xie is the most technologically competent of the participants, in terms of non-context-bound knowledge of technology. Xie is athletic; his background includes a season as coach of a middle school boys' soccer team.	Jerry Brewer	A science teacher on the same team as Andress, Brewer is a very sociable person. He seems to enjoy working with student teachers in part because it brings him in contact with another adult during his teaching day. He is low key in terms of classroom management, but his classroom rarely seems out of control.	Over the years he has been a teacher and science department head at Monroe, Brewer has assembled an impressive collection of science specimens and aging-but-still-useful equipment. In an office attached to the classroom is an ancient photocopier which provides easy reproduction of classroom materials.
Helen Johnson	Johnson is a science student teacher who lives in Grantwood within ten miles of Monroe Middle School. Like Vogel, she would not describe herself as technologically advanced. She is the only participant who had her own laptop computer. This constant access had ramifications for her teaching and professional uses of technology.	Anna Lloyd	Lloyd is a very professional science teacher. She is a leader in the science education professional community in the Garth-Grantwood schools. Her classroom is orderly, emphasizing student inquiry and science labs where possible. She is an active user of e-mail and uses technology extensively for presentations.	Lloyd places a heavy emphasis on the importance of technology use in science teaching. Her classroom computer is centrally located in the room. She makes frequent use of laser disks and videotapes; a large television monitor is also centrally located for this purpose.

The Research Setting

As educational technology knowledge is the focus of the study, the authors sought a research site which had technology available for the participants to use. Without technology access, participants would lack a context in which to acquire or use technology knowledge. Balancing the necessity for technology access was a recognition that the research site should not have so much technology available as to be unrepresentative of public school sites in America. Glennan and Melmed (1996) cite two types of schools which are likely to have significant access to technology: Schools which serve an upper income population and schools which, though they serve lower-income communities, have become adept at alternative funding through sources such as grants. The research site falls into the latter category. The school is located in a lower middle class and working poor area of a blue collar suburb of a large industrial Midwest city. Students are ethnically diverse, with a large proportion (approximately 20%) of African-American students. In areas other than technology, the school site is somewhat run-down, but clean and reasonably well kept. Technologically, the school is somewhat more well equipped than other schools in the district and area, but not so much so as to be greatly discrepant. Each classroom has a desktop computer which is connected to a school-wide network and to the Internet. The school also has two thirty station computer labs, one of which is Internet connected, available to classroom teachers and their students. Other technology is also available: There is a classroom set of laptop word processors, several laser disc players on mobile carts, and a fiber optic flexible video camera for each science classroom.

Teacher Preparation Program

To understand the context of this study, it is important to have a picture of the preparation program in which the student teachers were enrolled and in which the mentor teachers are viewed as an integral part.

At the beginning of July of each year, a cohort of approximately thirty students arrives at the large Midwestern research university which conducts their teacher preparation. For five weeks during the summer, they take part in coursework designed to begin to give them a grounding in educational foundations, literacy, educational psychology, educational research, and educational uses of technology. This coursework continues throughout their yearlong program, taking place two evenings per week at seminars during the school year. These seminars combine content from educational psychology, literacy, and foundations with ongoing discussions of their student teaching experiences. In addition to the twice-weekly cohort seminars, student teachers enroll in graduate courses in their content areas during the fall semester. During the winter semester, students work with faculty advisors to design and carry out action research projects.

For these student teachers, their field placements are stable throughout the academic year. In the fall semester, they are present in their field placements two days per week. With the beginning of the second semester, the student teachers become responsible for an increasing teaching load and are present in their field placements whenever school is in session. This continues until mid-June when their schools end their academic year.

All of the student teachers in the program are placed in the Garth-Grantwood district. All are secondary students who are preparing to be middle or high school teachers; their content areas include math, science, language arts, social studies, and foreign language. In the year in which this study was conducted, student teachers were placed in both district high schools and three of the four district middle schools.

The role of the mentor teachers is taken extremely seriously in this program. Mentor teachers meet as a group monthly with program faculty and the assembled cohort of student teachers. Mentor teachers and student teachers are also visited weekly in their classrooms by faculty members. The purpose of these visits is to maintain communication between the university and the field settings.

It is common for mentor teachers to have student teachers from this program for a number of years. Over this time, relationships between program faculty and mentor teachers have become quite close. More importantly for this study, there is a continuity of mentor teachers which assures that student teachers will have a rich source of knowledge from mentors who are familiar with the teacher preparation program and its goals.

Data Sources

Two main sources comprise the data for this study: Field notes from classroom observations and teacher conversations, and transcripts from semi-structured interviews.

Field notes were collected over a twelve week period from March 1 to June 21, 1999. Classroom observations began with a two week data collection instrument development period. An iterative process produced a database which served as a collection space for field notes as well as a framework for the observations. A journal which served as a meta-space for researcher observations and further note-taking was also created. The database and journal were structured by considering both the classroom setting and the conceptual underpinnings of the study.

The primary author conducted all of the classroom observations and was present at the research site every school day, with the exception of a week spent at the 1999 AERA conference. Classroom observations and teacher conversations yielded over 200 entries into the field notes database, with each entry relating to a class period of classroom observation or a researcher-participant conversation. At the close of each research day, the primary author created a journal entry which served as an overview of the day's research activities. Journal entries were cross-referenced with the field notes database by numbered reference to field note database entries.

Concurrent with the classroom observations, a series of three interviews was held with each participant. Structure for the interviews was organized in large part by Seidman's (1991) model for conducting ethnographic interviews, with the interview structure determined in part by themes identified in the classroom observations. Briefly, the three interviews concerned 1) Background information, initial knowledge and beliefs 2) Reflection on specific use of technology observed in the field notes and 3) Reflection on the twelve week data collection period.

The first and third interviews were similar for all participants. While the interviews were semi-structured, allowing the participants to determine to some extent the content and character of the interview, care was taken to retain a similar structure for all participants, in order to allow for comparisons to be drawn. The second interview took a different form. Each pair of participants was engaged in a conversation about a particular type of technology which had been used in that pair's classroom practice. In these second interviews, the primary author's field notes were used to determine the prompts for each pair of participants. The same protocol was used for both members of the pairs, but this protocol differed from that used with the other pairs. The protocols for all three interviews can be found in Appendix A.

The data set which resulted from the field notes and interviews transcripts was quite large. Table 4 shows the distribution of data in the set.

Table 4: Components of data set

Item Type	Number
Classroom observations	149
Prep period and planning sessions	35
Conversations with teachers	26
First interview lines (average)	3565 (509)
Second interview lines (average)	4272 (610)
Third interview lines (average)	3848 (550)

Analysis

Data analysis keyed on the classroom observations. One of the central purposes of the study is to show how educational technology knowledge is acquired, shared, and used in classroom teaching practice. From this standpoint, the classroom observation field notes were the axial component of the data set as it was in this setting that teachers instantiated their knowledge. Themes from the observations were developed first, with the interview transcript coding tied to these themes.

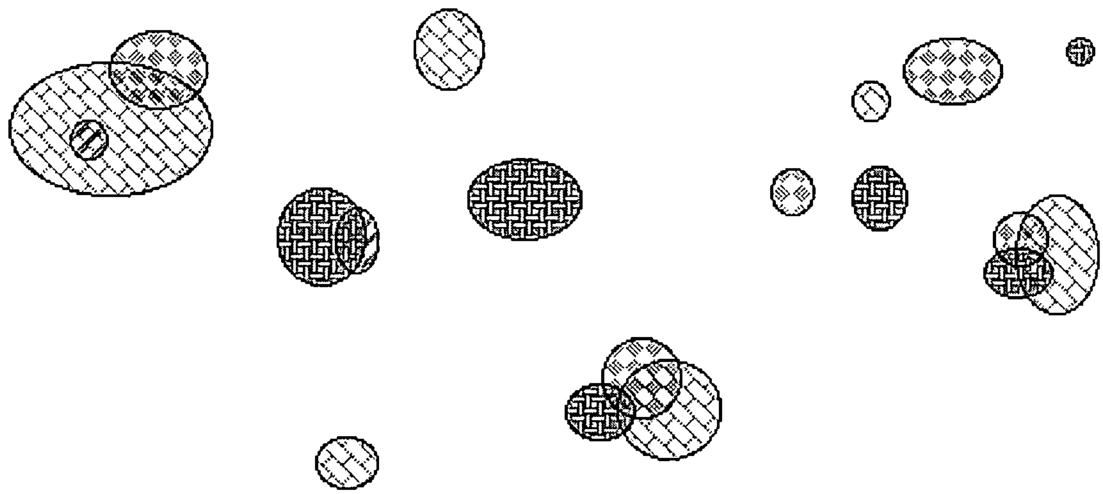
Data analysis was accomplished through a recursive process of identifying themes in the classroom observation field notes and interview transcripts, followed by a process of creating narratives describing sections of the data rich in thematic information. During a first pass through the data, a process known as "bootstrapping" was employed; emerging themes and categories were recorded in the database. These became the basis for the coding structure. The compiled list of emerging themes were compared with each other, with redundant themes merged. Additionally, the data were coded along conceptual lines suggested by Shulman (1987) in his descriptions of the structure of teacher knowledge. The resulting coding structure is shown in Appendix B.

With the coding structure in place, the data were again examined and coded at the paragraph level for field notes and the line level for interviews. This process was similar to verbal analysis coding (Chi, 1997), in which a researcher's subjective impression of a data set is used to create a structure which can be partially quantified to aid in the identification of larger themes.

Analysis was accomplished using QSR NUD*IST (an acronym standing for Nonnumerical Unstructured Data by Indexing, Searching and Theorizing), a standard qualitative data analysis tool. NUD*IST is a database tool which is capable of coding and searching very large sets of text-based data.

After the data set was coded, the database was queried for intersections of codes. These intersections coalesced into areas of overlap which we describe as *grounded events*. These events are reported narratively below in the results and discussion section. Figure 1 shows a diagram of how these codes and their intersection might be conceived visually.

Figure 1: Codes as a site for narratives



Notice that in the figure above, codes converge in areas of the data set, indicating a section of the data set which may be a grounded event. For example, the lattice, checkerboard, and brick ovals have large areas of overlap in two areas of the figure. Other instances of the code exist elsewhere in the data set as well. To create the narratives, we focused on areas of convergence, telling the story of what was happening in the classroom or the interview at that point. However, the narratives are supported by data from other sections of the data set. The grounded events which we describe are illuminated by data from the area of convergence and supported by other data.

Results and Discussion

In the sections below, we describe the results of this study in terms of a series of grounded events. Each section opens with one or more narratives of such events. Following the narrative description(s) of the event and its context, we discuss the implications for our understanding of teacher knowledge of educational technology, as well as for teacher preparation and development. The particular events we report here are described in terms of content knowledge, pedagogical knowledge, and pedagogical content knowledge, Shulman's three broad categories for teacher knowledge. Following these three conceptually-framed section is a description of a cycle of educational technology knowledge acquisition; this cycle has intriguing implications for teacher education and points up a little-studied benefit of the model of teacher education being instantiated in the research setting. We close the results section with descriptions Jon's evolving role as a participant-observer and some obstacles to the acquisition of technology knowledge.

The findings we describe are:

- Content knowledge differences between student teachers and their mentors
- Mentor teachers as a source of pedagogical knowledge of educational technology
- Pedagogical Content Knowledge (PCK) of educational technology; an evolving theoretical construction
- A cycle of knowledge acquisition
- The evolving role of the researcher as an on-site technologist
- Barriers to the acquisition of educational technology knowledge

Content Knowledge of Educational Technology: Current Ideas From Student Teachers, Specific Applications From Their Mentors

For purposes of this study, content knowledge is defined as knowledge regarding the existence and capabilities of various technologies for teacher and student use. Content knowledge might include knowing which software would be appropriate for a particular teaching and learning task and how to use that software. In all three pairs of student teachers and mentor teachers, content knowledge of educational technology flowed in both directions, though the kinds of content knowledge each participant brought to the setting differed.

The three student teachers brought with them a relatively broad range of knowledge of technology applications. This was especially true of applications which are generally used for personal productivity. All of the student teachers were proficient e-mail users, all were able to find information using search engines on the World Wide Web, all used word processing software to create documents for their own personal and professional uses. On some occasions, they shared this knowledge explicitly with their mentor teachers. As an illustration, when Andress wanted to create a relatively complex document, Vogel sat down with her during a planning period and introduced her to the use of Print Shop.

For Brewer (the mentor teacher in pair 2), content knowledge was acquired more indirectly than for Andress. He had this to say about acquiring content knowledge from Xie:

> He's absolutely helped me in some ways, but I've learned I think, probably I've learned from him better by, instead of saying 'teach me how to do this,' my better approach is to say 'okay, would you start doing this and I'm going to watch over your shoulder.' And he explains it to me no problem. —Brewer, third interview

In crediting the student teacher with helping him to acquire content knowledge, Brewer also drew a distinction between the immediacy of access to the student teacher and the relatively removed nature of inservice programs:

> I've usually found that in-services, seldom are you able to walk out of it and incorporate it immediately. You know, usually it takes me a while to digest, "All right, what is it that you learned. How can I use this now?" It's not as yielding. You've got to figure out, "Okay, now here's the technology, here's how you use the technology," now you've got to bring your personality around to be able to use it and use it comfortably.

Grounded event one: Content knowledge flows from student teacher to mentor teacher

As part of her science methods class, Johnson (the student teacher in pair three) had been exposed to a variety of Web sites. These sites were found and shared among the methods students as a class assignment. On day forty-two of the study, Johnson implemented a lesson in which she had her students explore one of these sites.

The Web site (which can be viewed at http://ampere.scale.uiuc.edu/~m-lexa/cell) allowed students to view images of a plant cell as seen by optical and electron microscopes. Students could manipulate the cell as if they were dissecting it with a scalpel. Parts of the cell were labeled, with text on the Web site explaining the functions of the various cell components.

In planning the activity, Johnson used the word processor on her laptop computer to create a worksheet to accompany the Web site. On this sheet, she asked students relatively low-level questions such as fill-in-the-blank definitions. She also asked higher level questions: In one section, she asked students to draw what they saw on screen and tell her what the part of the cell reminded them of.

Lloyd (Johnson's mentor teacher) took a less active role in the planning. In the days prior to students' exploration of the Web site, she had viewed the Web site. While Johnson was responsible for the planning of the activity and the creation of the accompanying materials, Lloyd conferred with her during their planning period and was aware of the steps being taken by Johnson.

Implementation of the activity went smoothly: Students seemed engaged in exploring the Web site and completing the assigned worksheet. Aside from occasional crashes caused by the computers' Web caches overflowing, there were no technology failures and no instances of students straying from the Web site either intentionally or unintentionally.

After watching Johnson implement this activity in three consecutive classes, Lloyd taught the same lesson plan. Her implementation was very much like Johnson's: Each spent approximately the first twenty minutes of a fifty minute period giving directions and showing the site on a computer projection system called a "SmartBoard." Following this introductory session, students worked in pairs for the remaining thirty minutes of the period, browsing the Web site, viewing on line slides, and completing the worksheet.

In the second interview, Lloyd had this to say about the activity:

> Jon: If you were going to tell [another teacher] how to enact this lab, what would you tell that person?
>
> Lloyd: I'll say 'you've gotta do this!' I don't think they need a whole, whole lot [of technology knowledge]. I mean, it just depends on how they are technology-wise and the lab people can do that. I'd tell them about the fact that after a few hours we found that we had to restart. Because we started having the crashes. So that's a management issue. [...]
> So I think really once the legwork is done on it, it's really pretty, a simple thing to do. Just do it. I'd say 'do it.' [laughs]. 'Don't skip this one, this is fun.'

<u>Grounded event two: Content knowledge flows from mentor teacher to student teacher</u>

The mentor teachers who participated in this study held content knowledge which allowed them to use technology in their teaching as well as in their professional and personal pursuits. In certain instances, mentor teachers held more content knowledge which was functional in the particular setting. While the student teachers had been at the university or in the business world for the previous five years, the teachers had been working in their classrooms. In terms of technologies in use *for teaching in their* *particular setting*, the mentor teachers were therefore more "up to date" than their student teachers.

In one instance, Johnson commented to Jon that she had never used laser disks, which were used occasionally by Lloyd. To Johnson, this was a "new" technology of which she had no content knowledge. For Lloyd, this was a system which she had learned about through her classroom practice and about which she had considerable content knowledge.

Discussion

Content knowledge of educational technology serves at least two broad purposes: To allow teachers to envision instances in which technology might be appropriately used in their teaching and to allow them to instantiate those visions. Content knowledge is the basis on which all other knowledge is built. Without content knowledge, teachers' options are limited and their applications narrowed.

At this site, content knowledge was held by both student and mentor teachers. Conversation in interviews and observations of participants indicated that in general, student teachers were knowledgeable regarding personal productivity software and current technologies. However, mentor teachers' knowledge of technologies in use at their site gave them an unexpected benefit in using technology in their teaching. This reveals an important distinction: The content knowledge required for teaching and learning can be different than that which allows teachers to accomplish personal tasks. There is a danger in assuming that student teachers who know a lot about technology as used in their everyday lives will have the content knowledge needed to be successful in their teaching lives.

Pedagogical Knowledge Of Educational Technology

Pedagogical knowledge of educational technology involves understanding how general pedagogical strategies apply to the use of technology. To some extent, these principles can be addressed through university coursework. All of the student teachers had completed methods course which had as one of their major foci the study of pedagogical knowledge. Additionally, the educational technology course offered by their teacher preparation program infused pedagogical aspects of educational technology throughout the instruction. However, pedagogical knowledge can be acquired in field settings in ways that may be more powerful than pedagogical knowledge acquired in university settings. The grounded event below illustrates one such occasion.

Grounded event: Management of technology by paralleling attendance system

Pair one (Vogel and Andress) made use of portable word processors several times throughout the study. These machines, called AlphaSmarts, are roughly the size of two paperback books laid end to end. AlphaSmarts have small liquid crystal display screens which are capable of showing approximately four lines of text at a time. Monroe Middle School owns two classroom sets of AlphaSmarts, which travel on a rolling cart. Schoolwide, they are primarily used by the Language Arts classes, though they are available to other teachers. In this study, only pair one (the Language Arts teachers) used the AlphaSmarts.

During the first occasion in which Jon observed the AlphaSmarts in use by this pair's students, Andress used a simple but effective strategy for managing the classroom set of AlphaSmarts. As she took attendance, Andress assigned numbers to her students. These numbers were the numbers in her gradekeeping file on the computer. The slots in the cart full of AlphaSmarts had corresponding numbers. After she had taken attendance and assigned numbers, she had students come up in groups of five by student number to pick up the AlphaSmart with the same number.

This strategy achieved two purposes. First, by establishing a consistent one to one correspondence between students and machines, Andress was able to easily keep track of which student was responsible for which AlphaSmart. Second, once the numbers were assigned, Andress had a means by which to limit the number of students who were at the cart at any particular time.

When she first used the AlphaSmarts, Vogel (the student teacher in pair one) did not use the same strategy. In the interview about their use of the AlphaSmarts, she remarked:

> Vogel: Mostly what I learned is like how to hand them [the AlphaSmarts] out and how to collect them. Honest to G-d that was about the biggest thing I learned [laughs]. I think the first time I sort of just said 'okay go get your AlphaSmarts.' And it was like mass herding to the little cabinet. And again, I didn't learn my lesson then and I said 'okay, well, put your AlphaSmarts away.' And mass herding.
>
> Jon: So did that change over the course of the day? The way you handed them out?
>
> Vogel: Absolutely. [laughs]… I mean I learned by watching [Andress]. I'll be perfectly honest about that one.

In observing differences between Vogel and Andress, Andress' simple technique for managing the AlphaSmarts had distinct advantages. After trying to regulate students taking out and returning the AlphaSmarts without using a numbering system, Vogel observed Andress' approach and was able to improve her own instructional management.

Discussion

Once content knowledge is established, pedagogical knowledge needs to be acquired in order for teachers to be effective users of technology in their teaching practice. Pedagogical knowledge can—and should be—addressed in university coursework. As tools and technologies are introduced to students, teacher educators have an obligation to place the use of those tools within a teaching and learning context. However, pedagogical knowledge can be difficult to impart through learning experiences which are not embedded in a classroom setting. The grounded event above illustrates an example of a simple strategy which improved instructional management. The strategy was acquired by the student teacher after she had tried to manage the technology without it. Observation of her mentor teacher allowed her to see a different approach; access to teaching opportunities allowed her to instantiate this approach, making it a part of her own practice.

We don't mean to overstate the importance of the example above. It is, after all, a simple strategy for dealing with a common problem. However, it points up the importance of pedagogical knowledge in using technology and the value of acquiring pedagogical knowledge within the student teaching setting.

Pedagogical Content Knowledge (PCK) Of Educational Technology: An Emerging Knowledge Set Unique To Teaching With Technology

Of the three types of knowledge addressed in this study, Pedagogical Content Knowledge, or PCK, is the most difficult to define. While PCK has become a "cottage industry" (Fenstermacher, 1994) in educational research, no field-based studies of which we are aware address PCK as it relates to educational technology knowledge. We define

PCK of educational technology as understandings for teaching with technology which arise from knowledge of technology as it is applied in classroom settings. PCK of educational technology does not derive from, nor does it necessarily apply to, teaching without educational technology. As such, it is unique to the use of educational technology. In the sections below, we describe examples of Pedagogical Content Knowledge as observed and commented on among the teaching pairs.

Grounded event one: A strategy for using video to demonstrate a science lab

This first event illustrates a simple technique for improving students' use of a piece of equipment. As with the pedagogical event above a simple example, when unpacked, reveals an interesting fragment of pedagogical content knowledge as well as an illustration of how knowledge is acquired and shared.

Both pairs of science teachers made use of FlexCams to help students create presentations for their science labs. A FlexCam consists of a video camera head on a flexible fiber optic stalk. The camera can be aimed at a lab bench, with the components of the lab visible on a large television monitor. By using the FlexCam, students can project a lab, allowing them to show it to the rest of the class; FlexCam demonstrations can also be captured onto a videotape for replaying later.

On day ten of the data collection, I observed Xie (the student teacher in pair two) using masking tape to create a rectangle on the top of the lab bench. When I asked him to tell me about what he was doing, he explained that the masking tape represented the outside border of what was visible on the television monitor when using the FlexCam. Xie had noticed that it was difficult for students to monitor the visibility of items on the lab bench while they were performing their demonstration. To aid students in using the FlexCam, Xie came up with the strategy of creating the tape border.

Observations of students using the FlexCam indicated that having the border set out on the table helped them to keep their demonstration in view on the television monitor. Using the FlexCam, performing the required science lab, and explaining the process to the class is a complex undertaking. Having a strategy to make the camera use easier was simple but not trivial for the students.

A few days after I observed Xie planning for and using the FlexCam, Lloyd used the FlexCam in her classroom. During her planning period, Xie showed her how to set up the tape border on her lab bench. Subsequently, all of the science teachers used this strategy when using the FlexCam.

Discussion

Adding a tape border to a lab bench to aid students in using video is a simple innovation. Realizing it was necessary and creating the innovation is an instance of pedagogical content knowledge gained through classroom practice. The knowledge arises from teaching with technology and is applicable to teaching with technology. Once the knowledge is present in the setting, it can be shared by teachers either in the context of their practice, as within the pairs here, or between the pairs as part of the planning process.

The knowledge itself in this instance could be easily imparted through university coursework. Seeing the need for the strategy and recognizing its utility may be better accomplished in the context of the field setting.

Grounded event two: Adapting to new equipment

In the pedagogical knowledge example above, we briefly describe AlphaSmarts and their use in the classroom. The language arts pair (Andress/Vogel) had used AlphaSmarts on several occasions: Andress had also used the equipment during the previous year and had received inservice instruction by Monroe Middle School's computer lab coordinator in their use. On day 19, Andress and Vogel were surprised to find that the AlphaSmarts they were accustomed to using in their classroom had been replaced by upgraded models. Neither participant knew that they would have new equipment until the students were present in the room and they opened the cabinet containing the AlphaSmarts. As an observer, Jon was reminded of the television commercial in which a voice-over says "We've switched the Smith's regular coffee with Folger's...let's see what happens."

The lesson plan for the day was as follows: The teacher was to spend the first ten minutes of the period going over the previous day's quiz. Students' homework was to prepare a two to three page longhand rough draft in preparation for using the word processors. The bulk of the period was to be spent with students using the AlphaSmarts; students who had not completed their rough drafts were to do so before using the technology. Andress noted in the second interview that use of the AlphaSmarts was motivating to students and that they completed more homework in anticipation of using the technology. That was the case in this activity. Almost all students had a rough draft; turn-in rate for homework otherwise was between half and two-thirds. Throughout the periods in which students were observed using the word processors, students seemed engaged and on-task.

During the first period that the pair used the new machines, the only new feature the teachers had to contend with was a relocated power switch. A moment's exploration of the new machines revealed that the power switch had been moved but that its functionality had not changed. With students in the room, Andress and Vogel could not take the time to further explore any new capabilities of the word processors. As their students used the equipment during this period, their teachers observed their progress and found that the new equipment had built-in spell-checking software. The atmosphere in the room was of co-discovery of differences in the new machines, with the students completing a writing task through the use of the technology and Andress and Vogel watching students work and noticing any differences between previous and new equipment.

In the second period that the pair had students write with the word processors, Andress (the mentor teacher) introduced the new machines to the students. She had students walk through the spell-checking program at the end of the period. Andress directed each step and checked that students all were on the same step of the process. The use of the new feature was directed and managed closely by the teacher.

The third period saw Andress trying a different approach to the new AlphaSmarts. She pointed out to students that the machines had been updated, then asked them to notice what the new features were. She and the students engaged in a conversation about the relocated power switch and the spell-check feature. Having a sense of the new machines and two periods of experience teaching with them, she seemed to open up into a more interactive style.

In the fourth period, Vogel (the student teacher) became the lead teacher. Her task was to enact the same lesson plan that Andress had taught in the previous three periods. In this pair, the student teacher "shadowing" the lesson prepared by the mentor teacher was the most common mode. Vogel's teaching of the writing activity was very similar to Andress'. The only observed difference was that Vogel used more class time going over the quiz; fifteen minutes as compared with ten for Andress. Vogel's classroom management style was less polished than Andress', which made her somewhat less efficient in the earlier part of the class. Andress remained in the room throughout the period, entering grades from the quizzes onto the classroom computer. Midway through the class period, Andress reminded Vogel to introduce the changes in the AlphaSmarts to the students. Vogel looked chagrined to have forgotten to mention this earlier. She mentioned the relocated power switch and Tab key to students, then asked Andress to remind her how to use the spell-check function. As Andress had taught with this equipment in the three previous periods, she was able to talk through the new function from memory.

Discussion

The bustle of classroom life leaves teachers with little time to plan for the integration of new technology. Sometimes, as in this example, new technology appears in the classroom with little or no warning and with no technological support for the teacher or students. Fortunately the particular equipment used in this example was not radically different from that to which the teachers were accustomed. Over the course of the day, the teachers learned about the capabilities of the new equipment. As they became more comfortable with it, their instruction changed from co-discovery to teacher-directed to interactive with the students.

Observing these two teachers, Jon was struck by how flexible they were. The new equipment did not throw them off course with their lesson. They quickly integrated a new function of the equipment into their lesson plan and migrated from a teacher-centered to a somewhat student-centered mode of engagement with the students.

In the university setting, the lack of classroom context might make it difficult for students to acquire knowledge of how to integrate new technology into existing curricular activity. When engaged in the field setting, these teachers adapted quickly to the change. The student teacher gained experience in becoming adaptable. She may not encounter this particular technology in her next teaching assignment, but in encountering this technology and adapting to it, she has gained valuable knowledge.

Grounded event three: Sources of knowledge about curriculum materials

During the study, the science teachers at Monroe were working with a new textbook sequence. One component of the textbook was a CD-ROM containing virtual labs. The CD presented common science problems in a somewhat realistic on-screen lab setting. During the course of the school year, each science teacher used the CD-ROM four to six times. Topics covered included force and motion, acid rain, the Coreolis effect, and factors in plant growth, among other topics.

To prepare them to use the labs, science teachers were shown the labs by a publisher's representative, then encouraged to take their classroom computers and the CD-ROM home. In the second interview, Brewer related the experience as follows:

> The first time I, actually I heard of them was last year when the vendors were wining and dining us as a district, and they had a computer, and they basically showed us. Then, this summer, I took some of the disks home, and I was so naive, I, you know, when the icon comes up on the screen, I clicked on that, and I started getting data that didn't make sense to me. It didn't have like a user-friendly type of table of contents, so I just started clicking through cool stuff. But I had no idea where it was coming from. And then, finally, later on in the summer, because I had taken a computer home from going to an in-service this summer, and I learned that you had to install it on your hard drive, and you had to click on the installer. Then from there, it came up in a nice way-user-friendly menu. So I, probably early August, I was actually able to get on and play with it. …But, as far as implementing it, I think the most honest way was...I didn't do it by the book...I basically got on and played with the labs, just played around in it and saw what all of the bells and whistles were, and I was intrigued immediately. Then from there, I went to the resource component of the lab, basically a hard-covered book and looked at some of the questions they asked and had to weigh, "Are these valuable questions. Are these the kinds of questions that might improve learning or might get them to think?" And, I was pretty satisfied with it.

For Brewer, content knowledge of the virtual labs was gained through exploration of the materials. Pedagogical knowledge was gained through the accompanying teachers' guide and evaluated through the lens of Brewer's classroom experience.

In addition to acquiring knowledge through exploration and interaction with print resources, teachers in this study acquired knowledge from and shared knowledge with other teachers. On day two of the study, pair three (Johnson/Lloyd) were in the computer lab with their students. The students were working in pairs at the computers, completing a virtual lab on acid rain. Johnson and Lloyd, who almost invariably co-taught all lessons, introduced the main question for the lab and the lab equipment students would use. They then took on the role of facilitators, circulating through the room and helping individual pairs of students.

While Johnson and Lloyd were doing this, several other science teachers came into the computer lab on their planning period to see how the virtual labs were being used by students. These particular teachers had not previously been exposed to the materials themselves. In the lab on this occasion, they followed a three step process: First, Johnson and Lloyd directed them to a computer not in use by any students. The teachers looked through the virtual lab, familiarizing themselves with the curriculum materials. Second, the teachers walked through the lab, looking over the shoulders of various students. Finally, they approached Johnson and Lloyd with questions about managing the instruction. Both Johnson and Lloyd fielded content knowledge (lab materials and procedures) and pedagogical knowledge (student and time management) questions.

At Monroe, it was unusual for teachers to visit each others' classrooms. It was also unusual for teachers to meet to plan or discuss instruction. The teaching teams met; pairs one and two were on the same team, which met weekly. These meetings centered almost entirely around student and calendar issues rather than instructional issues. The event described above, in which pair three served as a pedagogical resource for teachers, was an exception to the rule.

Discussion

Lloyd and Johnson served a valuable role in the example above. They were able to introduce new materials to teachers, to model instruction, and to answer content and pedagogical questions. The lab setting, in which Johnson and Lloyd's students were working their way through the materials, provided a rich context for the visiting teachers.

Why was this event so unusual at this school and why, when it did occur, was it situated in the computer lab? Perhaps the lab serves as a neutral setting. Since it is no one's particular classroom, visiting teachers may feel comfortable coming into the room and teachers who are working with students may be more at ease acting as resources.

When we designed this study, we expected more events resembling the one described above than actually occurred. The field setting is potentially a rich source of both questions and answers. Additionally, it is an environment which is difficult to describe, much less replicate, in the context of university coursework.

Still, while it was an unusual event, it was a valuable one. The teachers who visited got a realistic look at how instruction proceeded with real students interacting with real curriculum as part of their normal class work. Johnson and Lloyd had the opportunity to serve as pedagogical guides, adding to their value to the school.

A Cycle of Knowledge Acquisition

Knowledge about teaching with educational technology is evolving rapidly as both our understanding of the role of technology in teaching and technology itself changes continuously. In this research site, we observed part of this development and listened as mentor teachers commented on the larger picture of educational technology knowledge as a multi-year enterprise informed by and informing both student and mentor teachers.

The event

Consider this example: On the first day of the study, Andress (the mentor teacher in pair one) was interested in customizing her record keeping software. She realized that the software's pre-loaded categories for attendance ("Absent," "Excused," or "Tardy") did not match the attendance categories used at Monroe Middle School. To bring her record keeping in line with the system used at Monroe, she needed to be able to record in-school and out-of-school suspensions, as well as field trips.

During a preparation period, Jon showed Andress how to add the requested attendance categories. Doing so required approximately 20 minutes, during which time Jon provided knowledge of the software and Andress contributed knowledge of the school setting. Andress controlled the computer, with Jon sitting beside her. The session was more like a conversation than a tutoring session, with both participants making contributions.

After this session, Andress shared the new knowledge with Vogel, her student teacher. For the remainder of the study, the pair used the system to keep track of their daily attendance. Andress also shared the knowledge with Brewer, who served as the science teacher on her team and the mentor teacher in pair two.

But where did the software itself come from? Brewer indicated that the particular record-keeping software used on this site was introduced by a student teacher the previous year. The student teacher, in turn, had been introduced to the software during his teacher preparation course on educational technology. There is a chain of events: The student teacher is introduced to the software and brings it to the school site. The mentor teacher uses the software, but realizes that it would be more useful if it could be modified for the particular setting. She acquires the knowledge needed to modify the use of the software and shares that knowledge with both other mentor teachers and her student teachers. At each step, knowledge is added, with each participant both gaining and contributing.

Discussion

In this site, knowledge of educational technology is evolving. All of the mentor teachers have been involved with the teacher preparation program for several years. In each year, a student teacher brings her knowledge to the classroom and instantiates that knowledge in the setting. Mentor teachers add value in terms of pedagogical strategies and opportunities for student teachers to integrate content knowledge with their developing pedagogical knowledge.

The cycle continues as a new student teacher enters the setting: Mentor teachers have content knowledge about educational technology which has been constructed, in part, from interactions with previous student teachers. This existing knowledge of educational technology is conveyed by the mentor teachers, but in a more pedagogically-appropriate form than it had been in the previous years. New technology knowledge is brought in by student teachers and shared with the mentor teachers and the cycle continues.

The role of the university teacher preparation program is important in sustaining this cycle. As the educational technologist for the program, Jon structures students' technology preparation in part based on a familiarity with the technological capacities in place in the field settings. Student teachers bring to their settings content knowledge that is applicable to their situations.

For the past three years, the Jon has visited the school sites on a weekly basis. Observations of technology applications in the field settings inform future technology preparation of student teachers. The student teachers serve as a pipeline for educational technology content knowledge; their practices and the practices of their mentor teachers serve as a feedback loop that informs future teacher preparation coursework.

Participant-Observer Status Of The Researcher

This section and the section which follows are not written as grounded events with subsequent discussion. Both Jon's participant-observer status and the barriers to the acquisition of educational technology knowledge were results which evolved over time. As this evolution does not lend itself to the narrative style used in the sections above, we characterize the results in a straightforward fashion.

Over the course of the study, the primary author's role in the setting evolved. Early in the study, the field notes show the researcher as almost entirely an observer. Later entries show the researcher involved with interacting with students, helping to plan activities, troubleshooting equipment, and occasionally filling in with assistance in classroom teaching and even occasionally with student discipline. When asked in the third interview how the teacher education program in which Jon was involved could better serve the teachers, Andress said:

> [Support] the CT's and technology? Send Jon [Margerum-]Leys. Give everybody a Jon [Margerum-]Leys in the classroom; an on-site technology person. That would certainly be ideal.
>
> Jon: What would that person do?
>
> Andress: Well, ideally, that person would have a teaching background. So, just sort of like we do, when I wanted to use the FlexCam, you know. I said, "You know, I want to use it. I'm not sure how we can apply that into a communication arsenal, but I'm sure there's a way." And you were really good about, you know, helping me brainstorm some ideas. Just someone that, you know, could maybe launch you, to get you to try to use different pieces of technology and find an applicable way, you know, to use them in your particular classroom. So, someone that had a good technology base, obviously like you do, and someone who has, you know, just kind of a teaching background, so you could use it for your own professional growth, as well as use it with the kids. Yeah, I'm glad you're going to be around for another year.

When working in classroom settings, it takes time to become familiar with the educational milieu and to gain the trust of participants. There is evidence that teacher development efforts which take place within K-12 contexts are more effective than those which do not (Wilson & Berne, 1999). Wilson and Berne characterize this value in terms of professional development participants acquiring knowledge within the context in which they are to apply the knowledge. Our experience in this site parallels this result; additionally, there is a benefit for the professional developer—or in this case, the researcher—to deeply understand the context in order to be effective. This benefit is in terms both of increased understanding as a researcher per se and increased trust on the part of participants.

While we were careful not to impose our biases on the research setting (or at least to be clear about what those biases were), we were pleased to be viewed as a positive factor in the school and were interested in how that utility played out over the course of the study.

Barriers To Educational Technology Knowledge Acquisition

No setting for knowledge acquisition is ideal—education is a complex, multivariate undertaking. By pointing out that knowledge is acquired and shared in field settings, we don't mean to oversimplify and portray field settings as *nirvana*. Over the course of the data collection, we noted several barriers to acquisition of educational technology knowledge. Two of the most salient are described in the sections below.

Lack of time

Previous scholarship (Margerum-Leys & Marx, 1999) has indicated that a lack of time for educational technology use was a concern for preservice teachers. That sentiment was echoed by participants in the current study as well. Reflecting on the period during which the study was conducted, Brewer notes in the third interview:

> [We used technology] probably as much as I expected to. But not as much as I'd hoped to. With the new curriculum, with time running out, with the close-down of the school. I think there's some more freedom, there's some more kid-related activities I'd liked to have done that ended up being a little more black and white than I'd like....I still think we did a pretty good job incorporating some of the technology, but I pretty much expect that, I wish we could have done even a little bit more than we did.

As we note in a following section, teachers in this setting rarely visited one another's classroom or discussed their planning or instruction. We can only speculate about this lack of interaction, but it seems reasonable to assume that one factor was a lack of teacher time. The constant forward motion of the academic year with the pressures of teaching five classes per day was a significant obstacle to reflection and interaction among teachers.

Issues of classroom management

Classroom management was specifically not an area on which we wished to focus for this study. As it turned out, we found that general pedagogical knowledge (PK) issues impacted the acquisition and demonstration of knowledge for technology use. One area of general pedagogical knowledge is classroom management. If this knowledge is constrained such that classroom management is a significant difficulty, acquisition of technology knowledge may be impinged.

The two science pairs were observed roughly the same number of times during the last month of the study: Fourteen for pair three (Johnson/Lloyd) versus eighteen for pair two (Brewer/Xie). During that time period, there were two instances in which Lloyd took time from her teaching to handle student discipline. Xie took time from his teaching to handle student discipline on eleven occasions during the same time period. In contrast, there were 18 observations in which Xie demonstrated pedagogical knowledge of technology, 32 in which Lloyd did so. We believe that Xie's relatively ineffective classroom management was a barrier to acquisition of educational technology knowledge.

Discussion

Lack of time and difficulty with classroom management are far from uncommon issues in teacher preparation. It is not surprising that these two factors serve as obstacles to acquisition of educational technology knowledge. Awareness of these obstacles may help teacher educators to structure student teachers' field experiences to minimize the negative impact of these and other obstacles.

Limitations and Directions for Further Research

The current study examines the knowledge of three pairs of student teachers and their mentors, within one educational setting, a middle school with a representative level of technology. To study this setting, we spent over three months and conducted eighteen interviews. While our results are instructive, we see several avenues for making this line of research more generative.

First, the current study did not attempt to identify experts. The mentor and student teachers we describe here were not selected based on their expertise and we made no formal judgments about whether or not they were experts either in their content domains or in the use of educational technology. Future research may seek to determine whether the knowledge of experts differs from that of non-experts, as well as whether expert knowledge is more advantageous in suggesting courses of action for teachers and teacher educators.

In a similar vein, the current study was naturalistic. Participants were not selected by virtue of any reform-oriented interventions being instantiated in their classrooms, nor were they necessarily encouraged to adopt any particular curriculum or practices. Subsequent studies may seek to couple an educational reform approach with research into the nature of educational technology knowledge.

We had the luxury of studying this site for an extended period of time. As a graduate student and research fellow, Jon has the freedom to engage in research designs which might be impractical for a faculty member or full time educational researcher. Future modifications to the research methods employed here might lead to more efficient means of study while still yielding rich qualitative results.

Lastly, the number of participants in the current study was small and concentrated in a single school site. As an illustration of an important phenomenon, we do not feel that the study's small size was a fatal shortcoming. Still, increasing the number of cases to be studied in future research might afford a wider set of descriptions which could in turn be of more benefit to the field.

Conclusion

With the rise in access to technology in the schools, student teachers have both an opportunity and an obligation to acquire knowledge about technology's role in teaching and learning. The knowledge that they can acquire in the field has traditionally been difficult for teacher preparation programs to help them to acquire during the coursework phase of their teacher education program. Our results indicate that while university coursework is useful for acquiring content knowledge, pedagogical knowledge and pedagogical content knowledge are more readily acquired within the teaching context.

Understanding how knowledge is acquired in particular field placements can help university teacher preparation programs to make the process of teacher education more explicit and better integrated with learning experiences available at the university. Through awareness of the teaching and technology issues which students may face, teacher preparation programs may be able to better structure their program.

As teacher education students have an obligation to acquire knowledge of educational technology, teacher educators have an obligation to understand the opportunities available to their students and to weave together knowledge acquired in field settings with their experiences at the university. Certain essential educational technology knowledge may be difficult to acquire in the classroom setting; an awareness of the complexity of educational technology knowledge and the mechanisms through which it is acquired can be valuable for teacher educators.

In the learning process, both student teachers and their mentors have much to offer each other. Among other positive contributions, student teachers bring with them current content knowledge of technology. This knowledge has been acquired through their own life habits as members of a generation which takes computer technology for granted. Additionally, student teachers introduce content knowledge which they have acquired through their university preparation.

Mentor teachers serve as pedagogical guides in the process of instantiating educational technology content knowledge and of acquiring educational technology pedagogical and pedagogical content knowledge. Mentor teachers have a deep, situated knowledge of students and their learning needs. This knowledge helps them to understand the pedagogical implications of technology use and in turn to help student teachers to understand these implications. Additionally, mentor teachers may have content knowledge which is more directly applicable to teaching and learning with technology. Coburn (1999) notes the importance of mentors for professional development in educational technology. Mentor teachers in this study provided the benefits of mentoring for their student teachers, aiding them directly and indirectly in learning about the use of educational technology.

The university plays a role in this process of sharing knowledge between mentor and student teachers. Seeding relevant content knowledge in coursework helps the student teachers to have knowledge to offer in their field placements. Developing educational technology knowledge in mentor teachers assures that student teachers will have a productive environment for learning. Through research such as the present study, we hope to bring to teacher education an understanding of the importance of a broad conception of educational technology knowledge. Further, we believe that teacher education programs can profit by long term relationships between university and field settings, using those relationships to further content and pedagogical knowledge. Understanding the nature of educational technology knowledge and its acquisition is key to meeting the demand for new teachers who can enter the field with the ability to infuse technology into their teaching in ways which support student learning at a high level.

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Appendix A: Interview Protocols

Interview 1: Background Information. Initial Knowledge And Beliefs

	History	
Question	Possible follow-ups	Areas of interest
Tell me about the first thing you used computers for in your teaching.	How did you learn about that? What kinds of things did you know then about using computers? When was that? Why did you want to do that? Who else was doing similar things at the time? Would you still be able to do that? Would you still want to?	What stands out in the participant's mind when she remembers her early uses of technology? What are sources of knowledge?
What about uses of technology outside of teaching? What kinds of things have you done in the past?		
Returning to your work as a teacher, what kinds of things have you and your students done with computers since then?	Types of technology use to prompt for: Teacher uses such as E-mail, Web, word processing, newsletters, parent letters, spreadsheet, gradebook. Student uses such as CD-ROM programs, creating reports, communicating with other students/experts.	This part of the conversation should take a while. Explore a variety of different areas. It should be a history of the work participants have done with computers. Knowledge of technology, both content and pedagogical.
What role have your student teachers played in your technology use in the last few years?	Were there instances in which you showed them how to use a particular piece of technology? Have your student teachers introduced you to new technology or new ways of using technology?	Interaction between student teacher and cooperating teacher. Each as a source of knowledge for the other.
	Present	
Question	Possible follow-ups	Areas of interest
Let's move to the present: What have you done with computer technology this year in your teaching?	How did you learn about that? (How did you find out about it, how did you learn what you thought you needed to know?) What do you think you have to know in order to be able to help students use technology in that way?	How do new forms of technology get incorporated into participant's practice? What is their view on knowledge needed to teach with technology?

Here's a printout of all the applications on your computer. Which are the three you think are most important to your teaching and why? Alternatively, are there applications on your home computer or elsewhere which you feel are more vital?	If the applications cited are truly unusual, listen carefully for why they were chosen. Consider pointing out other applications which the participant may have overlooked?	Given the resources available immediately in her classroom, what software does the participant consider most important? What does she know about using that software?
	The Future	
What do you see on the horizon? What will come next for you in using technology in your teaching?	What will you be able to do as a professional? What will you be able to help your students do?	How does the participant view her future with technology?
More generally, how do you know when you need to know more?	How do you hear about new things? When you're in your classroom, do you ever look around and say 'I wish there were something I could do to accomplish x'?	What conditions spark a teacher to want to know more? How does she go about learning more?

Interview 2: Particular Applications Of Educational Technology

To serve as an insight into the participants' perspectives on uses of technology which were unique to their classroom, the second round interview protocols were designed by referring to the field notes on observations which were, at the time of the interviews, very recent (within two weeks).

Pair 1: Sarah Andress and Emma Vogel

	History	
Question	Possible follow-ups	Areas of interest
How and when did you first hear about the AlphaSmarts?	Have you seen similar equipment elsewhere? Have you seen other kinds of software which teaches the same concept or in the same way? Have you seen them used in other places than Adams since then?	What was the nature of A's introduction to this technology?
Did you have a chance to look them over before you used them with students?	What did you do? Were you able to connect them to the printer? What was your opinion about that technology at the time?	Before formally planning to use the technology with students, what experience did A have with these computers?

How often did students use the AlphaSmarts this year?	What kinds of activities? Did their use of AlphaSmarts change over the course of the year?	Was the technology used while the student teacher was observing? How did this impact her impression/later teaching?
	Planning	
Question	Possible follow-ups	Areas of interest
How did you plan to use the AlphaSmarts for the dialogue activity?	Did planning involve fitting into the curriculum?	How does A view planning for use of the AlphaSmarts?
How much planning time did you take?	When you had implemented the technology, did that seem sufficient planning? Would you need the same amount of planning time if you were to do this again?	What is the time needed to get ready to do this kind of activity?
What was the balance in planning between you and Emma?	Did that seem appropriate?	Did V take part in the planning?
	Implementation	
How did the implementation look, from the standpoint of what the kids did?	What did students do? How long did it take? What was their response?	What is A's narrative take on this?
What was your role in implementing AlphaSmarts?	What did you actually do in the classroom? Did that differ day by day? Did it differ throughout the day, in different classes? Was that role different from Emma's role?	A's perspective on the implementation. View of the lessons on which I have observation notes.
How did using AlphaSmarts differ from teaching writing with paper and pencil?	Did student write more? Did you have to do different things than you might have otherwise? What about writing coaching?	Teachers may be more prepared to use pencil and paper than they are to use technology. Do they see differences between the two?
Where do you think AlphaSmarts fit into the curriculum as you used them?	Was your implementation a good fit for the curriculum? How would the curriculum have been different without the technology?	Looking at the big picture, how does this technology contribute to the overall curriculum?
As you think about things you might have learned in professional development activities or from experience with other kinds of technology, how did that learning contribute to using the AlphaSmarts, if at all?	Were there other non-technology English teaching experiences that you brought to bear?	Role of formal teacher preparation in and out of technology.
	Assessment of Student Work	
Question	Possible follow-up	Area of interest

How was student work assessed?	What did you do to assess student work? What weight was given to the dialogues created by students?	How is student work assessed when students use technology? What knowledge is brought to bear?
Did that assessment system differ from the usual assessment in this class?	Had you assessed other technology-supported work? Did students earn higher grades? Why or why not?	Contrast between assessing student work when using technology v. traditional methods.
	Future/General	
Will you continue to use AlphaSmarts in your own classroom teaching in the future?	Why? Would that use be different from what you did here this semester? Does the frequency with which they are used seem about right?	Looking ahead, did the teacher gain something which she will use again?
In general, what does a teacher need to know in order to be able to use AlphaSmarts in her teaching?	About the technology? About the writing students do? How would a teacher learn that?	How does A perceive the knowledge needed?
If you could tell Emma one thing to change about how she uses AlphaSmarts, what would it be?	Could you tell her that?	How does A view her ST's use of this technology? What is their relationship in terms of this technology implementation?
In a "perfect" English classroom, is this a technology you would use?	How might you modify it? Is it worth the cost in time and money?	In the teacher's opinion, is this use of technology effective/worthwhile?

Pair 2: Jerry Brewer and Tad Xie

	History	
Question	Possible follow-ups	Areas of interest
When did you first see the CD-ROM which goes with your textbook?	Was this something which was shown when the company was trying to sell you on the text? Have you seen them used in other places than Adams since then?	What was the nature of B's introduction to this technology? Where did knowledge of it come from?
Did you have a chance to look the CD labs over before you used them with students?	What did you do? What was your opinion about that technology at the time?	Before formally planning to use the technology with students, what experience did B have with this use of computers?
How often have you used the on line labs during this school year?	What kinds of activities? Has your use of the labs changed over the course of the year?	What is the recent history of using the on line labs? What was gained from it?
	Planning	
Question	Possible follow-ups	Areas of interest

In the latest use of the on line lab, the control plant and color changing flower lab, how did you plan for use of that lab?	Did planning involve fitting into the curriculum?	How does B plan for use of this technology?
How much planning time did you take?	When you had implemented the technology, did that seem sufficient planning? Would you need the same amount of planning time if you were to do this same lab again?	What is the time needed to get ready to do this kind of activity?
What was the balance in planning between you and Tad?	Did that seem appropriate?	Did both CT and intern take part in the planning?
	Implementation	
How did the implementation look, from the standpoint of what the kids did?	What did students do? How long did it take? What was their response?	What is B's narrative take on the latest use of the labs?
What was your role in implementing the on line labs?	What did you actually do in the classroom? Did that differ day by day? Did it differ throughout the day, in different classes? Was that role different from Xie's role?	B's perspective on the implementation. View of the lessons on which I have observation notes.
How did using the on line labs differ from how you would have done this lab in the physical world?	Did students make different kinds of observations than they otherwise would have?? Did you have to do different things than you might have otherwise? Does it feel like the kind of science teaching you are doing is different than it would be in a physical lab?	Teachers may be more prepared to use physical lab equipment than they are to use technology. Do they see differences between the two?
Where do you think the virtual labs fit into the curriculum as you used them?	Was your implementation a good fit for the curriculum? How would the curriculum have been different without the technology?	Looking at the big picture, how does this technology contribute to the overall curriculum?
As you think about things you might have learned in professional development activities or from experience with other kinds of technology , how did that learning contribute to using the on line labs, if at all?	Were there other non-technology science teaching experiences that you brought to bear?	Role of formal teacher professional development and experience in and out of technology.
	Assessment of Student Work	

How was student work assessed?	What did you do to assess student work? What weight was given to the worksheets completed by students?	How is student work assessed when students use technology?
Did that assessment system differ from the usual assessment in this class?	Had you assessed other technology-supported work? Did students earn higher grades? Why or why not?	Contrast between assessing student work when using technology v. traditional methods.
	Future/General	
Would you use the on line labs in your own classroom teaching in the future?	Why? Are there downsides to using this technology?	Looking ahead, did the teacher gain something which she will use again?
In general, what does a teacher need to know in order to be able to use the virtual labs in her teaching?	About the technology? About the science students do? How would a teacher learn that?	How does B perceive the knowledge needed?
If you could tell Tad one thing to change about how he uses the on line labs, what would it be?	Could you tell him that?	How does B view his intern's use of this technology? What is their relationship in terms of this technology implementation?
In a "perfect" Science classroom, is this a technology you would use?	How might you modify it? Is it worth the cost in time and money?	In the teacher's opinion, is this use of technology effective/worthwhile?

Pair 3: Helen Johnson and Anna Lloyd

	History	
Question	Possible follow-ups	Areas of interest
When did you first see the virtual cell web site?	Have you seen similar Web sites? Have you seen other kinds of software which teaches the same concept or in the same way?	What was the nature of L's introduction to this technology?
Did you have a chance to look the Web site before you used it with students?	What did you do? What was your opinion about that technology at the time?	Before formally planning to use the technology with students, what experience did L have with this use of computers?
How often have the students used the Web this year?	What kinds of activities? Has your use of the Web changed over the course of the year?	What is the recent history of using the Web with students?
	Planning	
Question	Possible follow-ups	Areas of interest
How did you plan for the virtual cell lab?	Did planning involve fitting into the curriculum?	How does L plan for use of this technology?

How much planning time did you take?	When you had implemented the technology, did that seem sufficient planning? Would you need the same amount of planning time if you were to do this same lab again?	What is the time needed to get ready to do this kind of activity?
What was the balance in planning between you and Helen?	Did that seem appropriate?	Did both CT and intern take part in the planning?
	Implementation	
How did the implementation look, from the standpoint of what the kids did?	What did students do? How long did it take? What was their response?	What is L's narrative take on the latest use of the Web?
What was your role in implementing virtual cell activity?	What did you actually do in the classroom? Was that different from other times you have used the Web? Did it differ throughout the day, in different classes? Was that role different from Helen's role?	L's perspective on the implementation. View of the lessons on which I have observation notes.
How did using virtual cell differ from how you might have studied cell structure in a physical lab?	Did students make different kinds of observations than they otherwise would have?? Did you have to do different things than you might have otherwise? Does it feel like the kind of science teaching you are doing is different than it would be in a physical lab?	Teachers may be more prepared to use physical lab equipment than they are to use technology. Do they see differences between the two?
Where do you think the virtual cell web site fit into the curriculum as you used it?	Was your implementation a good fit for the curriculum? How would the curriculum have been different without the technology?	Looking at the big picture, how does this technology contribute to the overall curriculum?
As you think about things you might have learned in professional development activities or from experience with other kinds of technology , how did that learning contribute to using the on line labs, if at all?	Were there other non-technology science teaching experiences that you brought to bear?	Role of formal teacher professional development and experience in and out of technology.
	Assessment of Student Work	

How was student work assessed?	What did you do to assess student work? What weight was given to the worksheets completed by students? What about more informal assessments: As you walk around the classroom, how do you know if students are "getting it?"	How is student work assessed when students use technology?
Did that assessment system differ from the usual assessment in this class?	Had you assessed other technology-supported work? Did students earn higher grades? Why or why not?	Contrast between assessing student work when using technology v. traditional methods.
	Future/General	
Would you use this Web sit in your own classroom teaching in the future?	Why? Are there downsides to using this technology?	Looking ahead, did the teacher gain something which she will use again?
In general, what would a teacher need to know in order to be able to use the virtual cell Web site in her teaching?	About the technology? About the science students do? How would a teacher learn that?	How does L perceive the knowledge needed?
If you could tell Helen one thing to change about how he uses the on line labs, what would it be?	Could you tell her that?	How does L view his intern's use of this technology? What is their relationship in terms of this technology implementation?
In a "perfect" Science classroom, is this a technology you would use?	How might you modify it? Is it worth the cost in time and money?	In the teacher's opinion, is this use of technology effective/worthwhile?

Interview 3: Reflection On The Data Collection Period

	General	
Question	**Possible follow-ups**	**Areas of interest**
As you think about these past three months, what are the uses of technology which stick out in your mind?	Prompt with uses which seemed prominent from each pair.	When the teacher reflects on the time I've observed, what seems important to her?
You have a computer available to use at home. How has that impacted your use of technology at school?	Do the things you do at home transfer to school in terms of skills? Are you also able to do school work at home?	Is there a connection in the teacher's mind between what she does at home and what she does at school?
Thinking generally about technology in your teaching, did you use technology about as much as you expected, in the ways you expected to?	Was the period of time I observed fairly typical of your technology use this year? Was it different than previous semesters?	Teachers' view of the validity of using this ten week period to draw observations. Correlates with first interview thinking?

	Technology as a teacher productivity tool	
Question	**Possible follow-ups**	**Areas of interest**
One thing I noticed is that the classroom computer is in use almost every period. Could you talk about that a bit?	Prompt for: Grading, e-mail, Web uses.	Teacher productivity was the most frequent and yet least accessible use of technology. Most frequent by a pure count of what teachers were doing, least accessible in that I was uncomfortable peering over teachers' shoulders.
How does having the computer for those uses impact your productivity?	What kinds of things can you do with the computer in your classroom which would be difficult to do without it? Are there things which you do with the computer that you used to not do at all?	
Does having the computer in the classroom impact how much you are in the classroom as compared with previous years when you had a student teacher but did not have the computer available in your classroom?		In the cases of all three student teachers, the cooperating teachers were in the classroom almost all of the time. Often, they were using the computer. What do they say about that?
What knowledge about computers did you need to be able to use it for these kinds of professional productivity applications?	When and where did you learn that?	What is the role of knowledge in using the computer for professional productivity?
	Technology as a tool for student use	
Question	**Possible follow-ups**	**Areas of interest**
Sometimes, students in your classes used technology as a tool in creating things or communicating with others. How do you view that kind of technology use?	Is it an important way to use technology? Who creates the curriculum for students to use technology as a tool? Are there access issues involved with this kind of use?	Student use of technology was one of the least seen uses of technology. Why?
How does classroom management work when students are using technology this way?	Does classroom management seem different when students are using technology for creative purposes?	
How do you assess the work that students do when the create something using technology?	Is that different from your usual assessment methods?	
What knowledge about technology did you need to be able to support students in using technology as a tool?	When and where did you learn that?	What is the role of knowledge in managing student use of technology?

	Instructional technology applications	
Question	**Possible follow-ups**	**Areas of interest**
A different application of technology (at least it looked different to me) has computers used to deliver some part of the instruction or assessment (RR, virtual labs). How do you view that kind of technology use?	Prompt with a type of instructional technology application. Reading Renaissance for language arts, virtual labs for science.	When students receive some of the instruction or assessment via computer, how does the teacher's role change?
How does classroom management work when students are using technology this way?	Does classroom management seem different when students' learning or assessment is being partly led by the computer?	
How do you assess the work that students do when the create something using technology?	Is that different from your usual assessment methods?	
What knowledge about technology did you need to be able to support applications which deliver some instruction or assessment?	When and where did you learn that?	What is the role of knowledge in managing student use of technology?
	Future/General	
Question	**Possible follow-ups**	**Areas of interest**
Thinking about the uses of technology we've talked about, how would you rate their frequency, importance, difficulty for you to learn/manage?	Ask about these areas separately: Frequency Importance Learning/management	What is the balance among uses for technology?
Taken as a whole this ten weeks, does your teaching with technology differ from your teaching without it?	Does technology favor certain kinds of teaching? Are there teaching styles which are harder to employ when technology is added to the mix?	
In terms of technology use, how has the partnership between you and [your student teacher] worked out?	Have you picked up skills or strategies from her? Do you team teach sometimes? Does technology hinder or facilitate that?	What is the intersection between technology and the relationship between student teacher and cooperating teacher?
Are there things which MAC might do to better support your and your student teacher's use of technology?		What is the role of the university and how can it be improved?

How has my presence altered how you used technology in the last ten weeks?	Were there things which you did differently because I was here? Were there things which you were able to do or felt more comfortable doing because I was here? Less comfortable?	Participant/observer balance and status. My impact on the setting being studied.

Appendix B: Coding Structure

Free Nodes

Miscellaneous notable
Researcher's role

Administrative

Cooperating teacher
Student teacher
First interview
Second interview
Third interview
Classroom observations
- In computer lab

Planning session (formal, informal, or prep period)
Conversation
Student grouping
- Single
- Pairs
- Small Group
- Large Group

Identity

Pair 1
- Andress
- Vogel

Pair 2
- Brewer
- Xie

Pair 3
- Johnson
- Lloyd

No teachers
Researcher

Technology type

Teacher productivity or demonstration
Tool for student use
Instructional technology
None

Teacher learning

Student teacher from mentor teacher (ST from MT)
Mentor teacher from student teacher (MT from ST)
Participant from researcher
Participant through classroom practice
Other teacher learning
Student teacher from student teacher (ST from ST)
Mentor teacher from mentor teacher (MT from MT)
Learning from curriculum materials
Learning from university coursework

Teacher knowledge

Content knowledge
Pedagogical knowledge
Pedagogical content knowledge
Other teacher knowledge

Technology affordance

Management efficiency
Simulation
Management of instructional technology for students
Display of data
Student creation
Technology failure or obstacle
Projection
Information retrieval
Game play
Facilitates professional interaction
Facilitates student interaction
Helps teach specific content
Teacher creation
Assess student work
Intrinsically motivating

Teacher's role

Disseminating information
Managing student activity
Record keeping
Interacting with students
Evaluating student work
ST and MT similar roles
ST and MT different roles
Comment about teacher's style
Planning
Pursuing professional interests
Handling discipline problems
Troubleshooting equipmen

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