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EXPLORING TEACHER LEARNING AND PRACTICE

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Joan Elizabeth Hughes

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Major professor

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TEACHING ENGLISH WITH TECHNOLOGY: EXPLORING TEACHER LEARNING AND PRACTICE

By

Joan Elizabeth Hughes

A DISSERTATION

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ABSTRACT

TEACHING ENGLISH WITH TECHNOLOGY: EXPLORING TEACHER LEARNING AND PRACTICE

By

Joan Elizabeth Hughes

The purpose of this study, conducted during the 1998-1999 school year, was to examine the nature of teachers' technology-supported English practice and understand teachers' learning to teach with technology. Past research has not explored and current research is not adequately exploring how teachers learn and what is required for teachers to know how to use technologies in the English language arts classroom. Further, unlike the unique contexts of study in past research (e.g., high technology classrooms and specialized software use), this study was grounded in more typical school and classroom contexts (modest and eclectic collections of computers and generic software use).

Four middle-school English teachers, who used technology *in support of* teaching English content, agreed to participate in this study. The data included a combination of classroom observations and life-history teacher interviews. Observations focused on the teachers' use of technology in relation to instruction and student learning experiences. The series of interviews explored the teachers' life histories, including history of educational preparation, career(s), teaching positions, technology experiences, technology learning, and technology use.

The dissertation study was written in the format of three journal articles. In the first article, a technology use taxonomy was developed to analyze teachers' technology use. This taxonomy conceptualized three categories of technology use in content areas:

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technology as replacement, technology as amplification, and technology as transformation. Across time, participants used technology across all three categories, *not* in a sequential order. This finding challenges the notion that sophistication of technology use is linked to technology experience. This finding may be explained by the expansion of practical uses for technology, the teachers' reform-oriented beliefs, and the possibility that these teachers learned from others' "expert knowledge." Varieties of technology transformation that may have been obscured in the data analysis are discussed.

Analysis in the second article explored how teachers learned to use the technology they reported knowing. Using technology to support subject matter instruction occurred more often when a teacher's initial learning experience involved either (a) learning technology in the context of learning more English language arts content or (b) learning technology with an awareness of a connection between the technology and the English language arts. From analysis of trends in four teachers' technology-learning, I developed a general model that illustrated the technology-learning process and described how teachers take multiple pathways through this learning model.

In the third article I analyzed and compared why and how teachers learned and used technology. The teachers' reasons for learning technology were closely associated with the reasons they used technology in their teaching practice. Further, the manner in which the teachers learned impacted the design of learning opportunities for their students. Hypotheses about the kinds of knowledge that teachers develop through the process of learning to teach with technology are offered.

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ACKNOWLEDGMENTS

The inspiration for this dissertation traces back to 1993 when I was fortunate enough to be offered a teaching position at St. Mary's Elementary School in Los Gatos, California. The principal, Sr. Nicki Thomas (who also happened to have taught me seventh grade mathematics), hired me to teach computers. In many ways, my experience learning to teach computers was similar to the four teachers (Nell, Doug, Roger, and Laura) who participated in my study. I spent many afternoons trying to learn more and more technology, yet I became more and more convinced that "computers" should not be its own class but should be integrated into content areas. I ultimately decided to go to graduate school to learn about using technology in educational contexts. I would never be writing this today if I had not enjoyed working with technologies, teachers, and children as much as I did at St. Mary's.

Naturally, all my years of coursework, teaching, and research were preparing me for the dissertation. During that time, I was blessed to develop friends and colleagues with whom I learned. Becky Packard, Su Jones, Valerie Worthington, and I worked our way through courses and comprehensive exams together. We supported each other's ideas and pushed each other to learn more. Our comprehensive exam study group was invaluable. Loukia Sarroub and I learned the "research ropes" together as, we began working with David Pearson on research projects in 1995. (We also bought our first ice scrapers together as well!)

I received a Spencer Research Training Grant Fellowship that provided financial support while I conducted a pilot study of my dissertation and that offered yet another group of students and professors with whom I could share and talk about ideas. I

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appreciated and benefited from the intellectual stimulation and the friendships that developed among those of us who worked in the "clubhouse," including Brian Yusko, Beth Herbel-Eisenmann, Jo Lesser, Ruth Berry, Cindy Carver, and Brian Vance. We did more than share a space and bottled water: we watched our lives (and families) grow; we supported each other through all the trials of conducting research and writing; we applauded each others' accomplishments; and we shared intellectual resources. David Labaree was so generous in allowing Brian and I to continue using our Spencer desks during our last year (after our fellowships had ended).

Particular to this dissertation, I must acknowledge the tremendous time and energy extended by each of the teachers who participated in this study. They all are tremendously busy — taking courses, advising teacher-colleagues, doing daily preparation and instruction, spending time with family and friends — yet they opened their classrooms and their thinking to me. I still wish I could have given more back to them. Perhaps, the ideas in my dissertation will inspire new ideas about practice.

At nearly the beginning of the dissertation project, I cut out the following horoscope and tacked it on my desk. It stayed there and now is weathered and yellow. But when I was frustrated, I read it over again and again...

> **Horoscope 1** (*Fall, 1998*)
> Aries (March 21 – April 19)
> Today is a 5—A friend and your conscience are pushing you to get involved. There's work to be done, and it's calling you. You don't know how you're going to accomplish this, but it's important that you do.

Like the horoscope said, work had to get done. And it did get done with the assistance of my writing groups and professors. My writing groups changed as the years progressed, but the core was always Brian Yusko and me. I definitely would not have

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finished at the same time or with the same product without Brian's critical comments and advice. He always let me call him at home, asking "now, tell me again, what was the best way to organize this section?" With Cindy Hartzler-Miller and Gaston Dembele, we all successfully wrote dissertation proposals. Brenda Neuman-Sheldon joined us as she was finishing her dissertation. She helped develop frames for my ideas that ultimately organized my writing.

Professors also supported the work I was doing. My committee: Ralph Putnam, Suzanne Wilson, Yong Zhao, and David Pearson guided me through the process. When confused and framework-less, they offered advice and helped me devise the format that became the dissertation. I have learned a great deal from working with David for the past five years. One of the many valuable skills I developed in working with David was my writing. As surprising as it may seem (surprising because some might assume that I, a educational technologist, would know all technologies), David introduced me to the editing tool (tracking changes) within Microsoft Word. We wrote together using that tool for five years. It was extraordinary because through that, I could see how David rewrote phrases and sentences and actually *crafted* writing.

The dissertation is a daunting task, and I chose to participate in many extracurricular outlets to reduce stress. Gina Cervetti was my workout partner, and I met her at the gym M, W, F at 7am. It was precious time to connect before the day seemed to slip so quickly away. The fun we had working out *and* talking about "annoying man" who hoarded the free weights or "goatee guy" who was just really good looking really lifted my spirits. And of course, there was the Power Penguin inner-tube water polo team. We rarely ever won a game, but we enjoyed trying.

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I need to thank Karla Bellingar for transcribing my interviews even though her time was already booked. Karla always had a cheerful, pleasant smile for me when I entered the office. That smile cannot help but make the day brighter. I also want to acknowledge two others that did not directly work with me but became great friends over the years — Karen Yusko and Steve Sheldon. Karen and Brian invited me over to real home dinners so many times; Steve was my first California ally, to whom I could complain about Michigan winters (Gina Cervetti and Carolyn Jaynes joined the allies a few years later).

My friends and family always reminded me of the accomplishment of writing a Ph. D. dissertation and encouraged me during the process. Craig Rashkis always asked me when I'd be done, and, after I defended, he reminded me what an enormous thing it was. I visited Kristen and Rob Deevy in Colorado a couple weeks after my oral defense. Kristen took me to a spa to celebrate. They happened to receive my graduation announcement while I was there. Rob read it, walked toward the fireplace mantel, and said, "I'm putting this up here because I have never known anyone else who received a Ph.D." My sister, Deidre, kept reminding me that there was a huge difference between getting a Ph.D. and a Master's degree. My brother, Tom, joked about me being in the Ivory Tower. Eileen waited for me to finish so we could go on our walking trip in Scotland. Rosemarie, a student herself, understood the student bank account. Maura vied for me to take a job in Austin. My Mom and Dad trekked out to Michigan for my graduation. As an afterthought, my dad suggested that he could have hooded me! What a wonderful acknowledgement that would have been. When you work on a project for two

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years, it is *very* easy to move on without celebrating it. All of these family and friends helped me remember to celebrate.

And, as fate would have it, I ended just as I began the dissertation. One Sunday morning, instead of getting to work early and revising my dissertation, I sipped some tea and read the newspaper. Then, I happened upon my horoscope once again. It could not have been more apt.

> **Horoscope 2**(*April 30, 2000*)
> Aries (March 21 – April 19)
> The very end of a project is the hardest part to finish but take heart, your reward will be swift upon completion. A neighbor could declare his or her romantic interest, but a love affair with this person has no positive consequences.

No neighbor declared his love, but I finished.

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THE RELATIONSHIP BETWEEN TEACHERS' TECHNOLOGY-LEARNING AND THEIR CLASSROOM PRACTICE

INTRODUCTION

The integration of technology into K-12 education continues to be an important agenda for policymakers, administrators, teachers, parents, and students. Research reports, practitioner literature, and media focus on "integration of technology" as procuring technology resources for schools (e.g., Clinton, 2000; Preparing our Young People, 1997) or using technology in schools (Cuban, 1998; RAND, 1996). Certainly, teachers cannot begin to use technology unless they have it. However, using technology legitimately requires that teachers know how to use it. Criticisms have been leveled at teachers who are not using technologies, such as computers, software, and peripherals, for thoughtful instruction. Estimates identify that merely five percent of computer-using teachers actually:

> ...use computers as a tool to solve problems or to create a product rather than as a reward for completing other work or for skill mastery. They also use the technology to accomplish significant tasks, such as major reports, and for a variety of purposes ranging from simulations to spreadsheets. (Viadaro, 1997, p. 16)

Given the costly nature of technologies, criticisms of low levels of use are not altogether surprising. Yet, it is difficult to rationalize the criticism and blame aimed at teachers when considering few receive quality professional development opportunities that expose teachers to thoughtful, subject-matter-based technology use. According to a Milken survey of schools (Survey of Technology, 1999), across twenty-seven states that responded, teachers received only 5.9 hours of teacher training on "integrating technology into instruction" in the past year. To make matters worse, research has not

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explored and is not adequately exploring how and what is required for teachers to know how to use technologies in these ways. What little we know about how the exclusive five percent of computer-using teachers have managed to learn their craft does not provide much information for helping the masses of teachers begin. Yet, the "five percenters" are portrayed as models of computer-using excellence and, at the same time, used as a basis to berate the teachers who do not use technology at all or use it only in basic ways.

The knowledge we have about the experienced and skilled computer-using teachers is not terribly helpful because it is based on research conducted within contexts that generalize to the wider population of practicing teachers. The Apple Classroom of Tomorrow research projects (e.g., Sandholtz, Ringstaff & Dwyer, 1997) examined teacher learning and practice in technology-rich classroom contexts where teachers received extensive professional support from ACOT staff. Most of the participating teachers eventually became innovative technology-using teachers within their subject matters. However, it is difficult to know how these ACOT teachers' experiences could generalize to teachers in less-endowed U.S. classroom contexts, and it is unreasonable to believe we could create similarly rich learning contexts for large numbers of teachers nationwide.

Other innovative technology-using teachers include those who use specialized educational software, such as web sites and software programs, in teaching. These educational technologies, typically developed by university professors, merge the capabilities of technology with subject matter and learning goals to create innovative tools that support thoughtful instruction. For example, scholars at the Center for Highly

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Interactive Computing in Education[1] (HiCe) at the University of Michigan developed a suite of tools that support scientific inquiry (e.g., Soloway, Krajcik, & Finkel, 1995). Zhao and colleagues at Michigan State University developed Technology Enhanced Literacy Environments on the Web (TeleWeb) (Zhao et al., 1999), a web-based literacy learning software, based on Early Literacy Project curriculum. Scardamalia and Bereiter (1994) developed a computer-supported intentional learning environment (CSILE) designed to facilitate knowledge-building discourse for students and teachers through which "ideas are conceived, responded to, reframed, and set in historical context" (p. 266). Hsi and Hoadley (1994) developed the Multimedia Forum Kiosk (MFK), an electronic multimedia bulletin board that "supports students' knowledge building as they read issues, reflect on comments, and develop a point of view" (p. 1).

The typical project in this group of innovative programs invites teachers from areas surrounding the university to use the technology. The teachers' practice may change as they begin using the technological capacity in innovative and significant ways impacting student learning in the subject matter. Thus, the teachers enter the category of exemplary technology-using teachers, yet their practice has, to a great degree, been led and guided by the university-based software developers. This model of university-based innovations involving teachers during the development and redevelopment process (e.g., Zhao et al., 1999) is becoming more and more common. Even so, the development and use of opportunities with these types of innovative technology applications unfortunately are far removed from the experiences of the majority of U.S. teachers. Again, it is unlikely that we could involve all interested teachers in projects that require liberal resources, as illustrated in this case:

[1] http://investigationstation.org

> ...a team of sixth-grade teachers at an urban school were provided with all of the programming and media assistance they required to create a multimedia program around their classroom needs (Leu, 1996). They worked as a collaborative team with a multimedia software developer, an educational researcher, and over 20 graduate students to develop a multimedia software program that integrated social studies, writing, and literature in a year-long thematic unit on the ancient civilizations of Egypt, Greece, and Rome.... (Kinzer & Leu, 1997, p. 131)

When the number of researchers exceeds the number of teachers, one has to be skeptical about issues of scaling up.

These university-based technology development projects embody the work Pea (1985) endorsed fifteen years ago:

> Research and development activities can be united in the creation of educational software prototypes, which are designed and built by interdisciplinary teams of researchers, educators, and developers, and progressively modified in response to formative testing with students. (p. 178)

Such projects do create research-informed technologies, but their localized impact undermines Pea's reasoning and justification for them. Pea critiqued research that "rel[ied] on off-the-shelf software and limit[ed] ... to describing what happens when it is introduced to the classroom" (p. 178) as irrelevant. Clearly, though, the argument can be made that technological innovations that impact less than five percent of teachers verges on irrelevancy.

If we were to sum all the participants in these two privileged cohorts – those who learned to use technology in technology and support-rich contexts and those who

implement university-developed software – they still do not make up the entire five percent or so of exemplary technology-using teachers documented in surveys about the extent of technology use in American classrooms (Becker, 1994). Attempts have been made to understand what factors have led to teachers' success with technology (e.g., Becker, 1994; Hadley & Sheingold, 1993), but the results have not illuminated how practicing teachers learned technology. Recent national surveys designed to reveal information on teaching, learning, and computing (Becker & Anderson, 1998) have been silent on the question of teacher learning, focusing instead on teachers' computer use, their pedagogies, and their school contexts.

Surveys have found that middle school students in English classes devote 10.5% of their class time to computers, a level second only to math classes (RAND, 1996). Recently, researchers (e.g., Garner & Gillingham, 1997; Gooden, 1996) have begun to examine how technology is being used in support of English subject matter. Having a better idea of what technology is being used for is important, but little research has been conducted to discover how these teachers have learned to do what they do with technology. Again, Becker's (1994) work reveals that, "the younger (less experienced) English teachers were more likely to be exemplary. Also, among English teachers the exemplary computer users had learned significantly more about using computers through self-instruction than through formal training, and they spent much more time using computers at home than did other users" (p. 309). This is the extent of our codified knowledge about how English teachers learn to use technology to support their English curriculum. It is woefully inadequate in explaining their learning—what motivates and

sustains their journey—or in guiding us in developing appropriate professional development or preservice teacher education opportunities.

Given this situation, I decided to turn my research lens on teacher learning directly in order to examine and better understand practicing teachers' learning and use of technology in support of the English subject matter. I began by searching for English teachers who reported using technology (computers, software, and peripherals) in interesting ways. I intentionally avoided teachers who fell within one of the two privileged cohorts described earlier. The teachers selected for the current study had not participated in planned technology reform interventions or worked closely with university faculty. They were not in teaching contexts offering numerous technology resources or high levels of human support. In essence, these were regular teachers in typical school contexts using an eclectic array of educational and utility software. If I could document the learning journeys and classroom practices of these ordinary teachers, the knowledge I gained might provide information that could impact a much larger percentage of teachers than past efforts.

In order to understand teacher learning and technology use, I conducted a qualitative study involving four teachers. To narrow the scope of the project, I examined teacher learning and practice but did not investigate the extent to which technology impacted student learning and achievement. The work operated with the assumption that technology is a worthwhile tool to use in the support of education and improves student learning, a claim still hotly contested. However, this assumption is also the work's major weakness; as Wilson and Berne's (1999) review of contemporary professional development found, "few research programs currently link studies of teacher learning to

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teaching behavior and student achievement" (p. 205). Acknowledging this weakness, I believed the investigation would offer me an in-depth, close view of teacher learning. Though these results are based on a sample of four teachers and therefore do not generalize to a larger population of teachers, the study forms a coherent beginning from which I may identify specific questions to study that include connections to student achievement with a larger population sample. Ultimately, I believe this work will lead to other inquiries, focused on approaches to professional development and its impact on student learning, that will compensate for the weaknesses inherent in the current design. It remains my conviction, however, that the focus and design of the current study is precisely what is needed at this point in our understanding of teacher technology-learning grounded in a content area.

Though my dissertation is based on a single research study, I present it, in written format, as a series of three journal articles ready to be submitted and reviewed for publication. This dissertation admittedly adopts an unconventional and alternative written format (see Duke & Beck, 1999 for a discussion of alternative dissertation formats). Certainly, this format may facilitate more timely dissemination and prepare me for the type of writing expected of me in my career, as Duke and Beck (1999) suggest, but such reasons were not the primary motives for choosing this format. Rather, it was the difficulties I encountered in completing the literature review. As I was trying to organize a review that incorporated the broad issues of technology use in our schools, teacher learning, and computer use in classrooms, it became obvious that I would be introducing foundation work that I would not refer to again for several chapters. My committee and I identified this problem and felt it was problematic for potential readers of the text. A

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suggestion to conceptualize and write the results chapters in the genre of a journal article was accepted as a solution.

Thus, the dissertation includes three journal articles, all derived from a single effort, but reporting on different aspects of the inquiry. The first article, entitled "Teachers' technology use," examines how language arts teachers use available technology. After reviewing past and current methods of capturing teachers' technology use, I develop a new "technology use" taxonomy that accounts for teachers' intended and actual uses of technology within the categorization. The taxonomy is used to analyze the technology uses demonstrated by the four teacher-participants. The results suggest that teachers' technology uses fluctuate among using technology as replacement, amplification, and transformation. Teachers strategically choose technology to match specific subject matter goals not because they were at a theoretically appropriate place in their developmental pathway toward expert use.

The second article, entitled "Toward a model of teachers' technology-learning," aims to better understand the learning processes of middle school English language arts teachers who use technology to support their subject matter teaching. The results bring into question the dominant stage theory used to explain teachers' technology-learning. Instead of a linear, stage model, results describe the process as more iterative, flexible, and motive-driven.

The third article, entitled "The relationship between teachers' technology-learning and their classroom practice," examines the relationship between the teachers' own experiences learning technology and the kinds of learning experiences they provide for

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their students. Results indicate that approaches teachers use in their own learning appear in their organization of learning experiences for their students.

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ARTICLE 1

TEACHERS' TECHNOLOGY USE

Abstract

In this study, a technology use taxonomy was developed to analyze teachers' technology use. This taxonomy conceptualized three categories of technology use in content areas: technology as replacement, technology as amplification, and technology as transformation. Across time, participants used technology across all three categories, *not* in a sequential order. This finding challenges the notion that sophistication of technology use is linked to technology experience. This finding may be explained by the expansion of practical uses for technology, the teachers' reform-oriented beliefs, and the possibility that these teachers learned from others' "expert knowledge." Variations of technology transformation that may have been obscured in the data analysis are discussed.

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Introduction

The use of technology in K-12 schools is a topic of heated discussion. Purchasing various technologies has been an enormous economic investment when considering the 8 million computers in schools (Anderson & Ronnkvist, 1999). Taxpayers, educators, parents, state and national government consistently inquire about technology's use and benefit in schools today, asking such questions as: What are teachers doing with technology? Does it help them teach better? Does it enhance student learning? Does it prepare students for the future? Research, writing, interventions, and many other investigative tools have been used to shed light on these questions. There are even professional conferences solely focused on aspects of technology in education. For example, the International Conference on Learning with Technology (ICLT) has devoted its year 2000 conference to the question, "Does technology make a difference?"

This study focuses on one of these important questions: How are language arts teachers using technology? While others have attempted to answer this question with a wide-angle lens, using surveys to determine national trends, I have opted to use a close up lens, examining more deeply how four teachers actually *use* the available technology in their school and classroom. The four teacher-participants in this study exemplify those U.S. teachers who have eclectic collections of computers, hardware, and software as well as have experienced haphazard (if any) professional development aimed at technology integration in their classrooms.

This teacher population's technology use contrasts with the use of highly specialized software use in K-12 schools (Hsi and Hoadley, 1994; Linn, 1992; Scardamalia and Bereiter, 1994; Soloway, Krajik, & Finkel, 1995; Zhao et al., 1999) and

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the integration of technology in technology-rich schools (Dwyer, Ringstaff, and Sandholtz, 1991; Fisher, Dwyer, and Yocam, 1996; Gooden, 1996; Sandholtz, Ringstaff and Dwyer, 1997). The highly specialized and conceptualized software often supports reform-oriented approaches to teaching in K-12 schools. However, such software is produced by university-based researchers, supported by grant money and research assistants, and predominantly limited to sites near the sponsoring universities. Even though this work developing innovative applications of technology is significant and worthwhile, it is, unfortunately, far removed from the lives of the majority of U.S. teachers. Similarly, instructional use described in technology-rich schools may represent a tiny minority of U.S. school contexts. These special software packages and technology-rich contexts may convey images of what we hope schools might become — places where teachers and students are co-investigating problems in their own backyards with the assistance of many tools like experts on-line or collaborative writing tools. However, we cannot conscientiously convert these images into standards for comparing — or even evaluating — teachers in schools with far less unless we are prepared to provide similar resources for all teachers.

A better understanding of technology use in schools that have fewer technology resources is needed. Though media coverage focuses on the innovative and expert practices among technology-using teachers, survey analysis indicates that teachers' modal technology-based instruction is rather conservative and traditional (Becker, 1991). Most teachers use computers to offer students basic skills practice, but some teachers position computers as productivity tools for students to compile, analyze, and present information. One approach to improve such instruction calls for creating environments

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akin to technology-rich schools because "model programs such as ACOT[1] ... demonstrate that these barriers can be removed and technology can meet its potential to transform education" (Fabry and Higgs, 1997, p. 392). In reality, we cannot create these technology-rich schools. What we can do is discover if teachers' technology practices in low-tech or mid-tech schools are as conservative and traditional as the surveys indicate. Further, we might consider if creating technology-rich environments and providing specialized software are the only ways to promote model technology use.

This research explores those two questions. In this chapter, I (a) review past and current methods of capturing teachers' technology use; (b) develop a new taxonomy that takes account of teachers' intended and actual uses of technology in the categorization; (c) analyze four teachers' uses according to this new taxonomy; and (d) discuss the findings. Such an analysis serves as an exploratory study of a population and context rarely examined. Provocative findings will substantiate the need for further research with a larger participant pool.

Literature Review

Developmental Stage Theories

Past research found that teachers' technology use conformed to a developmental trajectory, with teacher beliefs and computer experience as the crucial determinants of progression. Change in one's own beliefs about instruction and learning occurred developmentally, they claimed, as teachers gained more technology experience. Experience with technology offered alternative and perhaps conflicting images of

[1] Apple Classrooms of Tomorrow, a partnership between Apple Computers, Inc. and a "handful of far-flung school districts" (Fisher, Dwyer and Yocam, 1996) began in 1985. Teachers and students had individual computer access at home and at school. No curriculum was imposed by the project; rather, "local educators used the new technology to create innovative learning environments" (Fisher et al., p. xiii).

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instruction and learning. Eventually (for some, admittedly a very long time) beliefs and technology use changed toward more project-based, student-centered instruction.

One of the major longitudinal research projects was ACOT, Apple Classrooms of Tomorrow. Through more than a decade of research (Dwyer et al., 1991; Fisher et al., 1996; Sandholtz, 2000; Sandholtz et al., 1997), they identified patterns of instructional use among teachers learning to use technology in technology-rich contexts. During what often is a 5-year technology-learning process, teachers progressed through an instructional evolution of stages: Entry, Adoption, Adaptation, Appropriation, and Invention. Teachers in the *Entry stage* used computers seldom with their own students and spent most computer-related time putting the computers together and figuring how to manage their new classroom environment. Computer use during the *Adoption stage* focused primarily on teaching students how to use the computer — keyboarding, word processing, saving, and printing. Teachers also adopted electronic, drill and practice software for instruction, sometimes formal Computer Assisted Instruction (CAI) packages. In the *Adaptation stage*, teachers offered productivity tools, like word processors, databases, and graphic programs and continued using CAI with their students. In the *Appropriation stage*, teachers used technology to solve real work in their classrooms and developed an understanding that technology could have broader application than simply to drill skills. In other words, "Appropriation is the end of efforts simply to computerize their traditional practice" (Sandholtz et al., p. 43). In the last stage, *Invention*, teachers used technology to support experimentation with new instructional strategies and ways of interacting with students and other teachers. Teachers' views of teaching and learning changed:

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> ...ACOT teachers became more disposed to view learning as an active, creative, and socially interactive process...Knowledge came to be viewed more as something that children must construct for themselves and less as something that can be transferred intact. (p. 47)

In the first three stages, Entry, Adoption, and Adaptation, teachers grappled with technical problems and slowly incorporated technology into their practice. During the final two stages, Appropriation and Invention, teachers experimented with interdisciplinary, project-based instruction, team-teaching, and student grouping culminating with higher learning standards and an integrated curriculum.

The ACOT model of instructional change suggested a series of steps or stages that teachers experience while incorporating technology into their practice. Their examples imply no allowance for teachers to skip a stage or enter at a higher stage. It is difficult to believe that all teachers would experience all these stages when using all technological applications. Their participants brought no technology experience or possessed any reform-oriented instructional beliefs, so exploring these stages with a more diverse participant pool could radically alter the stages and process.

In Sheingold and Hadley's (1990) survey of accomplished teachers, they also discovered it took many years — five or more — for teachers to master computer-based teaching approaches. In the process, as teachers gained more experience with technology, their uses of technology broadened. They summarized:

> Initial practices and approaches [with technology] tend to be similar to familiar well-structured classroom technologies (e.g., the workbook), more focused on

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reinforcing directly what is already being taught or, for particular groups of students, providing special opportunities (Sheingold and Hadley, 1990, p. 19). Those teachers who became facile and comfortable with the use of computers "seem[ed] to take a flexible, even experimental, approach to their teaching with technology" (p. 17).

Both research studies claimed that technology use followed a developmental trajectory. Teachers began using technology in ways similar to their established practice and with time, experience, and change in beliefs about instruction and learning, broadened their technology use in support of what they called "experimental" approaches to instruction and learning.

Conceptualization of "Technology Use"

Past research (Becker, 1991; Cuban, 1986; OTA, 1995) concluded that teachers' technology use remains at rudimentary levels (e.g., drill and practice) and does not take full advantage of technology's possibilities. I argue that these studies' conceptualizations of "technology use" may skew the findings toward this conservative outcome.

Survey Item Construction

The research literature, predominantly quantitative in method, have categorized *technology use* by (a) configuration (labs, classroom etc.); (b) activity (word processing, research, games etc.); (c) software type (word processor, database, etc.); or (d) combinations of these three categories. A teacher's identification of particular activities or software used does not accurately represent exact technology use. Consider the following example. A survey question such as "how often do you use computers in the writing process?" may encompass widely varying practices for different teachers. The

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concept of "writing process" may vary widely, contributing to varied technology use that may or may not accord with the survey author's intended meaning.

For example, in recent research, Berg, Benz, Lasley, and Raisch (1998) used both qualitative and quantitative methods to identify and describe how exemplary computer-using elementary teachers used technology in their classroom. Their thirty-nine item teacher survey was compiled from "exemplary uses" nominated by technology coordinators. This survey identified the general software teachers used. However, the authors aimed to describe *how* teachers used the technology they possessed in their classroom. The interpretability of each item is problematic in this survey. When teachers indicated, for example, that they used "Internet to communicate with other schools," readers of the research have no way of knowing *how* teachers specifically interpreted this item. Teachers might have interpreted it as using the Internet to see other schools' web pages, developing student E-mail pen pals across school sites, conducting joint scientific research across grade levels, schools, and countries, or talking with other teachers at other schools. This interpretative problem with the survey items threatens substantive generalization of the results of this study. Jaeger (1988) claimed that aggregating responses to items that, independently, have questionable interpretability does not support generalizations. Because the responses in this survey have questionable interpretability, the results cannot provide valid descriptions of *how* the teachers used the technology. The findings are blurred and lend little new insight.

In a similar way, some of the technology use studies (see also: Lehman, 1994) under-conceptualize "technology use." Mazur (1995), in an evaluation of technology implementation in Kentucky, collected data on types of software used in instruction.

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Participants identified software types and instructional uses from a set of choices that represented mainstream software and instructional use. However, the survey items did not explore to what extent instruction might have changed or been enhanced with the use of technology. Similarly, a RAND report (1996) summarized examples of technology uses in support of established activities in elementary and secondary education. This approach framed technology use within currently popular conceptions for education and did not allow for the possibility that the use of technology in education might radically alter educational activities. The problem with these studies lies in the broader interpretation. They claimed that technology supported established practices, but the method did not even seek evidence for technology's capability to fundamentally change (transform) instruction, learning, or content. We have moved beyond the need to know that technology supports the status quo, we need to know whether it is even possible for technology to transform instruction, learning, or content.

Operating Definitions

The aforementioned survey-based research catalogued teachers' uses of various technologies without assessing its connections to curricular purposes. This circumstance was noted particularly in the work of Mitra (1998). She discussed computer use conceptualization and concluded, "[in the literature] computer use can be considered to be an act where the user engages in applications that are often centered around the computer, which becomes an end rather than the means to an end" (p. 283). In her work, she believed that the computer was "a tool for wider and more diverse use," and she asserted:

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> ...computer use can be related to specific tasks – each of which might be driven by a specific and unique motivation. Consequently, it is important to move beyond particular programs to consider use as it is related to task accomplishment. The assumption that computer use is multidimensional is a significant break from the earlier research, which often considered computer use to be an unidimensional phenomenon. (p. 283)

Mitra identified the major problem with previous attempts to catalogue the ways teachers have used technology: technology use was conceptualized *as an end.*

Contextual Factors

In addition to Mitra's (1998) theoretical advancement that recognized technology use as a means to a curricular end, Wood (1998) considered contextual factors in her examination of technology use in primary level reading and language arts. She developed an analytic framework for analyzing reading and writing. The three categories included (a) *traditional* reading and writing activities; (b) *technology-embellished* reading and writing activities; and (c) *technology-transformed* reading and writing activities. Traditional activities involved students reading narrative and non-narrative texts, listening to read-alouds of print-based texts, writing expository and narrative texts with paper and pencil, and sharing writing in the classroom. Technology-embellished activities involved students listening to digital recordings of read-alouds and on-line texts in linear fashion and using a computer to compose text. Technology-transformed activities involved students reading or listening to electronic hypertexts, creating their own pathways through fluid, on-line texts, and using media in ways that altered students' conceptions of the writing process and the final products. Wood concluded that "the

teacher, the pedagogical values that informed her practice, and the context in which literacy instruction took place were far more important than the application of technological tools" (p. 3). Thus, considering the contextual factors rather than simply the technological tools teachers used, Wood argued, may lead to more accurate portrayals of the use and integration of technology in educational contexts. Bruce (1996) explained this point clearly when he said, "...an account of technology in terms of circuits and processors alone is sorely lacking. We have to have the kinds of detailed and sensitive accounts that stories like these provide if we are to understand what the technology is and what it means for education" (p. xii). Just knowing the technological applications in use does not help us think about the role of technology in education. At the very least, we need to explore how and why teachers use technology.

Policy Implications

State and federal policies pertaining to the certification and re-certification of teachers now include technology preparation recommendations (CEO Forum, 1999; ISTE, 1999; NCATE, 1997). International Society for Technology in Education (ISTE) and NCRTE indicate teachers (specifically candidates seeking certification), "...will apply computers and related technologies to instruction in their grade level and subject areas. They must plan and deliver instructional units that integrate a variety of software, applications, and learning tools. Lessons developed must reflect effective grouping and assessment strategies for diverse populations..." (p. 1). This statement exemplifies the extremely vague nature of policy statements and recommendations. A focus on the intersection of subject matter and technology is weak, and thus, technology appears as an end-in-itself instead of as a means to better teaching in this policy statement. The

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vagueness may be due, in part, to nebulous understandings of actual technology use among teachers in the field.

As a course of action, I believe we need to examine technology use as a means to some pedagogical and curricular end – an end not determined or taken into account in the past research. This method must acknowledge the "specific and unique motivation" (Mitra, 1998) underlying a teacher's choice to use technology. Looking deeper to what end technology serves than simply focusing on the variety and number of software programs teachers use will yield representations of teachers' technology use more accurately than in the past.

Methods

Participants

The participants in this study were four, middle-school English teachers who might be described as "moderately" involved in technology use. That is, while they described themselves as using computer technologies for purposes other than drill and practice (the modal technology use in schools (OTA, 1995)), they did not teach in technology-rich and resource-rich school contexts. Table 1 summarizes the characteristics of the participants and the contexts in which they taught. Teachers were invited to participate through research advertisements on a technology-in-education and a National Writing Project listserv and through recommendations by university faculty. I began by calling each potential participant to invite him or her to share technology-supported teaching practice. I invited four teachers, whose technology use was more advanced than drill and practice, to participate. All agreed.

Table 1

Participant and Context Characteristics (School Year 1998-1999)

Teacher; Grade Level	Years Teaching	Years Pursuing Technology in Teaching	Computers in Classroom (#)	Computers in Lab/Library (#)
Nell Otherby; 7th/8th Grade	26	10	0	29 (PC) 40 (Mac)
Doug Logan; 5th Grade	25	20	8	0
Roger Karpenter; 9th Grade	6	6	9	20
Laura Yates; 9th Grade	3	3	1	35

Nell Otherby

Nell Otherby had taught 7th and 8th grade English for twelve years at Pendleton Middle School, located in a mid-western town. Prior to teaching at the middle school, Nell taught journalism for fourteen years at the high school level where she was so busy with deadlines she did not have time to do anything but teach. At the middle school, Nell had more time and took advantage of many learning opportunities, including professional development workshops, Master's degree courses (education) and a Ph.D. courses (English). Her middle-school principal supported new approaches to teaching, such as when Nell started using a writer's workshop approach.

Nell's classroom did not have any computers, and she spent most days in the school computer labs. In 1998, the school opened a new 29-computer PC lab in October. They also had two Macintosh labs, one with Mac LCs and one with Mac Classics. Teachers checked out computer labs on a first-come, first-serve basis. The school had

recently hired a part-time network administrator, whose schedule allowed little time for teachers to consult with him.

Roger Karpenter

Roger Karpenter had taught 8th and 9th grade English and history at Hallivale Junior High School for six years. Hallivale is located in the urban fringe of a mid-western mid-size city. During those years, he led the school newspaper and yearbook projects. In the 1998-1999 year, Roger taught 9th grade English and 9th grade history in a block style, with two sets of 26 students taking English and history consecutively with him. The block design allowed him to integrate history and English goals and activities across both class periods.

Roger's classroom had nine functioning computers, two printers, a VCR, overhead projector, and TV/monitor. Five PCs were 33 MHZ or less; two were Mac Classics; two PCs were new. Roger's classroom had more technologies than any other classroom at Hallivale JHS. Though students were assigned regular seats, they often worked in small groups, and thus, the individual desks were rarely in orderly rows. In the classsroom posters concerning history or English topics hung wall to wall. The library at Hallivale JHS also had twenty Internet-connected Macintosh computers and two printers.

Laura Yates

Laura Yates had taught English and theater arts for three years at Bancroft High School (BHS), located in the urban fringe of a mid-western mid-size city. In 1998-99, my observations and interviews centered on Laura's 9th grade English classes.

At the end of Laura's second year teaching, the high school moved into a new building. Laura's classroom was equipped with three ceiling-mounted cameras, two TV

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monitors, and a teacher desk that included a PC-compatible computer with E-mail/Internet access and CD-ROM, a VCR, satellite access, video-stacks (in library) access, and a telephone with voice-mail and "homework hotline" features. Computer software controlled the cameras that display and record images from her classroom or other classrooms at the school. The school also had a Macintosh graphics lab and a PC computer lab. These were open for teachers to use when computer courses were not scheduled.

Laura felt very comfortable and confident in her English literature content knowledge. Yet, she recognized a deficit in her teacher preparation — she took very few courses about the teaching of English. Laura was pursuing a Masters degree of Critical Studies in the Teaching of English and participated in a national writing project.

Doug Logan

Since 1980, Doug had taught fifth grade at Algon Elementary School, a one-story building nestled in a rural town. The major area of Doug's classroom was given to student desks, which were organized into six groups of four with a few individual desks against the front wall. There were eight Macintosh computers, ranging from ten years old to a new G3, in the classroom. One computer had a laser printer and Internet access. The school purchased only one of these computers; Doug collected the rest or received grants to purchase them. The entire classroom was covered with students' work, projects, and other colorful displays. The school did not have a computer lab, and there was no technology assistance.

Over the years, Doug became very involved in a state wide technology in education practitioner group. He served in many leadership roles, including being

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Data Sources

Data sources included three individual interviews and at least three teaching observations with each teacher. The interviews focused on obtaining details about the teacher's life history, including education, career history, teaching positions, technology experiences and learning. The series of interviews were adapted from Kelchtermans and Vandenberghe's (1994) cycle of three semi-structured biographical interviews. All interviews were tape-recorded, transcribed, coded and analyzed.

I conducted at least three full-day observations of each teacher. My observations focused on the teacher's use of technology in relation to instruction and student learning experiences. In my field notes, I documented actions, verbal comments, use of learning tools, allotment of time to classroom activities, nature of classroom activities, classroom and lab arrangement, classroom decorations and displays. Instructional artifacts (e.g., quizzes, tests, handouts, PowerPoint presentations, hypermedia narratives, etc.) were also collected.

Analysis

From analysis of classroom observation field notes and interviews, I generated a list of all instances of technology use in each teacher's English subject matter. An "instance" of technology use was defined as a technology (computer software or hardware peripheral) being used during the teaching of English language arts. In some cases, the teacher used the technology either as a general pedagogical tool or specifically related to the teaching of English, and in other cases, the students used the technology.

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These subtleties will be illustrated in the data. For each instance of technology use, several components were noted, including: (a) the software or hardware involved; (b) the teacher's intended use within her/his curriculum; and (c) any opinion or reflections about this particular instance of use. The teachers' intended uses and reflections on the use were collected from teacher interviews.

One particular software or hardware technology may have been identified more than once if it served different curricular goals. For example, Nell used PowerPoint to display a looping poem while students worked, and, at another time, her students used PowerPoint for a book-analysis project. Though PowerPoint was the common technology, each represented a distinct instance of technology use. I was less interested in identifying the raw frequency of technology use than in the nature of its use(s). Thus, the instances represent the *variety* of technology use, not the *quantity* of technology use for each teacher.

Because my literature review revealed that past surveys of teachers' technology use may have inadequately represented the actual use, I examined the technology's enacted use in these teachers' classrooms to provide a more complete understanding of teachers' technology use. As a framework for analyzing the enacted use, I developed a technology use taxonomy. The conceptualization of this taxonomy developed in consultation with past research (Wood, 1998), theories about technology in education (Pea, 1985; Reinking, 1997), and my data.

To develop the taxonomy, first, three use categories were theoretically defined. The three categories were: (a) Technology as Replacement; (b) Technology as Amplification; and (c) Technology as Transformation. The degree to which each instance

of technology use remained the same, was more efficient, or changed in terms of three themes (instructional method, student learning processes, and curriculum goals) determined which technology use category it belonged. Using these conceptual definitions, I categorized each technology instance into one of the three categories (replacement, amplification, and transformation). To establish the reliability of these classifications, two colleagues who had been introduced to the taxonomy categorized a random sample (15 percent) of the technology instances. Their categorizations were compared against mine; some did not agree. We discussed the points of agreement and disagreement by stating reasons each rater categorized technology instances in particular ways. The issues emerging from these discussions were used to revise the taxonomy by adding greater specificity and elaboration. The revised taxonomy was used to test reliability a second time, using a 10 percent sample. Reliability attained 83%.

Findings

The taxonomy was first developed theoretically as a methodological frame for data analysis. However, it was only after I analyzed the data using the taxonomy that I refined and fully conceptualized it. Therefore, the taxonomy was also one of the study's findings. The taxonomy will be described as a methodological tool theoretically and empirically (using examples from the data set). After describing the taxonomy in this way, quantitative results of the categorized data will be presented. These quantitative results describe each teacher's overall use of technology. However, in order to give a fuller representation of the trends, illustrations from each teacher's set of uses will be presented and discussed in light of past research.

The Technology Use Taxonomy

It was not only important to understand the particular technology teachers used but also imperative to consider how or to what end they used technology. Miller and Olson (1994) proposed "we need a context in which to place the use the teacher makes of the computer. In the end, that context is revealed by understanding what the teacher is trying to achieve in the classroom" (p. 136). Therefore, their case analysis suggested "we should consult teachers' intentions through an analysis of their ongoing practice if we are to make sense of practice" (p. 137). The following taxonomy allowed consideration, as Wood (1998) and Miller and Olson (1994) suggested, of pedagogical values and intentions and context of the practice. I settled on three technology use categories: (a) Technology as Replacement; (b) Technology as Amplification; and (c) Technology as Transformation. To determine if a particular technology use replaced, amplified, or transformed practice, each instance of technology use was assessed in a very systematic manner. To ensure that I attended to all aspects of the instructional event in which the technology use was embedded, I developed an infrastructure that forced me to examine specific features of three broad themes (a) instructional method, (b) student learning processes, and (c) curriculum goals. For each of these three themes, I developed a list of dimensions (see Table 2) that might be replaced, amplified, or transformed. All dimensions listed under each theme in Table 2 were considered, and the degree to which any dimension within each theme were replaced, amplified, or transformed were noted. In this way, I tried to ensure that I cast as broad a net as possible for detecting even a subtle impact of the new technology as it was implemented in the classroom.

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Table 2

Dimensions (within Themes) for Guiding Analysis of Technology Use

Instructional Methods	Student Learning Processes	Curriculum Goals
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Teacher's role	Activity task	"Knowledge" to be gained, learned, or applied
Interaction with students	Thinking process – mental process	"Experience" to be gained, learned, or applied
Assessment of students	Task milieu (individual, small group, whole-class, others)	
Professional development	Motivation	
Preparation	Student attitude	
Administrative tasks		

In using the themes (see Table 2) for categorizing instances of technology use, the rule of thumb called for the higher levels in the taxonomy (e.g., transformation) to take precedence over lower levels of use (e.g., replacement). Therefore, it took only one theme qualifying in a higher level to qualify the entire instance of use at that level. For example, a particular technology use might make the instructional method more efficient (amplification), make the learning process occur faster (amplification), but allow for the creation of entirely different curriculum goals (transformation). As such, this use would qualify as Transformation even though more themes were amplified than transformed.

The theoretical and practice-based descriptions of each taxonomy category follow. The descriptions of Technology as Replacement and Technology as Amplification categories are shorter than the Technology as Transformation category. This does not represent an evaluative stance on the importance or placement of these types of technology uses in practice. Rather, the transformation category has not been

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well defined in the literature and, therefore, required more development and illustration than the first two.

Technology as Replacement

Theoretical Basis. The Technology as Replacement category involved technology used to replace and, in no way, change established instructional practices, student learning processes, or content goals. The technology served merely as a different means to the same instructional end. With some exceptions, this category was similar to the technology use described in the early stages of the developmental stage literature (e.g., ACOT). Technology as Replacement did not include technology uses that were a "time-filler," a reward, or a supplement for completing other work (e.g., playing games after completing seatwork) as described by Ertmer et al. (1999). These uses were not included in the taxonomy because they do not usually involve explicit subject matter connections.

Application. The distinguishing feature in categorizing a technology use into the Technology as Replacement category rested on it replicating an already functioning instructional method, learning process, or content goals in the classroom; in essence all that changed was the medium used to achieve a well-established purpose. For example, Doug's students recognized parts of speech by highlighting or underlining examples within text typed into a word processing file. This activity resembled circling the correct word with a pencil on a worksheet. In this case, the technology use functioned exactly as a worksheet. The teacher's instructional method (introducing the parts of speech and assigning an activity to practice identifying them) remained identical $(R)^2$. The student's learning processes were unchanged (R); they still selected the correct answer and worked

[2] "R," "A," and "T" are notations used to identify replacement (R), amplification (A), or transformation (T).

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In another example, Nell typed a poem on slides in a PowerPoint presentation, projected it on the computer lab's wall, and used the looping feature so the poem repeated while students worked on another project. In this case, Nell's instructional method was no different (R) than if she had written the poem on the wall or written the poem on a poster and hung it on the wall. The students' learning process (the degree of appreciation for poetry) was unchanged (R), as few even looked up to read the poem. Finally, the content goal, to expose Nell's students to as much literature and writing as possible, had not changed (R).

As described in past research, some teachers have used technology as an enticement for students to complete an assignment. In other words, they used the "flash" or the novelty of technology to motivate students to complete a task. Such enticement could lead to students' heightened interest and, in turn, a rapid accomplishment of the task, thus, warranting categorization of the technology use into Amplification (see next section). However, in this data set, instances such as these were all categorized as Replacement on the grounds that the novelty effect did not sustain students' motivation and interest in that activity. The task may be accomplished faster the first few times, but as the novelty of the technology decreased, the students' interest in the task once again waned. In essence, because no attribute of the technology besides its novelty impacted the students' motivation, it did not meet my standard for inclusion in the Amplification category. For example, Roger's students used PowerPoint to present the main ideas within a history chapter. The students focused on the glitz and lost focus on the content to

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be understood. In this instance, PowerPoint was not a strategy or tool that would lead students to learn the history content more deeply.

Technology as Amplification

Theoretical Basis. The Technology as Amplification category focused on technology use that amplified current instructional practices, student learning, or content goals. Increased efficiency and productivity were major effects. Pea (1985), who has been instrumental in conceptualizing the nature of technology amplification, described how technology may amplify what we already do, "Computers are commonly believed to change how effectively we do traditional tasks, amplifying or extending our capabilities, with the assumption that these tasks stay fundamentally the same" (p. 168). Pea notes how:

> ...the term "amplify" means to make more powerful, and to amplify in the scientific sense "refers rather specifically to the intensification of a signal (acoustic, electronic), *which does not undergo change in its basic structure*" (Cole and Griffin, 1980, p. 349). As such, "amplify" leads one to unidimensional, quantitative theorizing about the effects of cognitive technologies. (p. 170)

The focus is effectiveness or streamlining rather than change. As in the Technology as Replacement category, there is no fundamental change in any of the themes — instructional methods, student learning processes, or curriculum goals. Cuban (1988) might call Technology as Amplification a "first-order change" whereby technology is used to "try to make what exists more efficient and effective without disturbing the basic organizational features..." (p. 93). Reinking (1997) described amplified uses of technology in the field of literacy.

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Reinking (1997) identified that technology "help[s] us do what we've always done (but doing it better)" (p. 636). Reinking acknowledged "...literacy educators and researchers mainly conceptualized the new microcomputer as a device with potential to enhance conventional instructional activities and goals" (p. 637). Accordingly, research in this tradition sought to compare computer-based activities against traditional approaches in terms of their ability to meet or advance traditional curricular goals. Reinking did not dismiss this approach as passé but recognized:

> Using computers to address the conventional goals of literacy remains a legitimate rationale because printed materials will undeniably be around for quite some time and because many traditional goals associated with print-based literacy carry over into digital forms of reading and writing. (p. 637)

His only caveat about technology use was considering what pedagogical advantage such use of technology offered.

According to the developmental stages, Technology as Amplification aligned most closely with those stages (like Adaptation and Appropriation in ACOT research) where teachers began using technology to support their established curriculum. An increased productivity and efficiency were the differences between Technology as Replacement use and Technology as Amplification use.

Application. Instances of technology used as amplification were responsible for increasing the efficiency or productivity of instruction, student learning or the curriculum. As a teacher, Laura's use of the word processor amplified her instructional preparation (A). She produced handouts, tests, and other student materials for her English classes using a word processor. This use may seem, at first glance, like replacement but

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the difference lies in Laura's evaluation of its usefulness. She explained that creating these materials on the computer served as an archive, in which she could easily change the materials for future activities. It was more efficient than using written or typed materials that, if used again with slight alterations, would require a complete reproduction. Since her use of technology was so focused on instructional preparation, this particular technology use did not impact the students' learning processes (R) and the content goals (R), leaving them unchanged and identical.

In another example, Roger used ProQuest database, a web-based resource of journal articles, as a tool for student research. The use of ProQuest was categorized as Technology as Amplification. In this case, ProQuest did not impact Roger's instructional methods (R) or the content goal (R), yet it enhanced the student learning process (A). The school library did not support an entire class of students conducting periodical research. They did not have enough Reader's Guides to Periodical Literature or enough periodicals to satiate the students' needs for current event information. ProQuest improved the materials students used in research by providing a wider collection of journals and simultaneous access to the same articles and journals. In addition, ProQuest resources made gathering the information more efficient. For these reasons, the use of ProQuest amplified periodical resources and information retrieval.

Technology as Transformation

Theoretical Basis. The Technology as Transformation category involved technology use that transformed the instructional method, the students' learning processes, and/or the actual subject matter. Pea (1985) conceptualized potential transformation in terms of the students' learning routines. He wondered, "How might

information technology redefine the very possibilities of education?" (p. 167) and theorized that "both the content and flow of the cognitive processes engaged in human problem solving" (p. 170) would be restructured or reorganized. Such reorganization involved the following changes:

- The actual mental work changed or expanded.
- The number of variables involved in the mental processing expanded.
- The tool changed the organization in which it had been used.
- New players became involved with the tool's use (or expanded use of the tool).
- New opportunities for different forms and types of learning through problem solving, unavailable in traditional approaches, developed.

These changes described reorganization in the student learning process. Theoretically, instructional methods could transform as well. For example, the teacher may be responsible for shaping "new opportunities for different forms and types of learning through problem solving..." where her role in the classroom fundamentally changed. Technology:

> ...improve[s] the process of bringing thought into communicable expressions in such significant ways that, once the tool is understood and used regularly, the user feels wanting if it is not available *because it has opened up new possibilities of thought and action* without which one comes to feel at a disadvantage. *It becomes an indispensable instrument of mentality*, and not merely a tool. (Pea, 1985, p. 175; emphasis added)

Pea argued that technologies used in work and education restructured the manner in which tasks occurred and the way the user's thought processes were enacted. Because

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technologies were new machines and tools when he wrote on this topic, such reorganization in mental processing was theorized. Analyzing technology solely as amplification or replacement may obscure or hide the discovery of technology's potential transformative effects. Pea summarized, "there are emergent properties of computer-aided thought that are unrecognized when one subscribes solely to the amplifier metaphor" (p. 175). As my literature review indicated, the survey research was developed with an amplifier metaphor in mind, and therefore, technology's emergent transformative properties went unrecognized in data collection.

Computer technology also has the potential to transform more than student mental processes. Modern technologies may spur a transformation in teachers' instructional practices within the language arts curriculum, according to Reinking (1997). He observed how the use of multimedia book reviews changed classroom social interaction – reducing teacher direction, increasing peer interaction and collaboration, and altering student roles. Reinking also acknowledged that we must open our imaginations in order to conceptualize and recognize how technology might transform:

> ... we will be best served by setting our imaginations free from seeing a computer as a machine that lacks the warmth and security of a book, seeing it instead as a technological alternative providing almost unlimited potential to operationalize the humanistic values that fuel our noblest conceptions of literacy. (p. 642)

In essence, transformation is akin to Cuban's (1988) notion of "second-order changes" that produce "new goals, structures, and roles that transform familiar ways of doing things into novel solutions to persistent problems" (p. 94).

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Garner and Gillingham's (1996) work described changes in content that occurred with the use of computer technology, specifically Internet communications. Six teachers in their study sought "alternatives to their current practice" (p. 135). For some, that involved changing instruction that, in turn, altered student learning processes. Others used technology in ways that altered the literacy practices in their classrooms. For example, two teachers sought "new ways for their L2 students to practice speaking and writing in English," and another teacher wanted "ways to encourage open, but respectful, conversation in her classroom" (p. 136). It is more, Garner and Gillingham concluded, than changing materials and methods; these teachers' literacy content goals were transformed.

In terms of developmental stages of technology use, Technology as Transformation most resembled the last stage (e.g., Invention) when teachers began experimenting with new instructional practices, including ways they interacted with students and other teachers.

Application. Technology use that led to or supported transformed instruction, learning, or content distinguished uses into this category. Unlike Technology as Replacement, the technology in this case certainly did *not* reiterate established educational patterns and goals. The technology may, as in Technology as Amplification, have increased productivity but toward a different end. The key in this case is something — the instruction, the learning process, and/or the content — was fundamentally different, thus, transformed, and the technology played a central role in developing such a transformation.

For example, Nell's students used StorySpace software to write hypertext narratives. In this case, the curriculum content goals were completely different (T) than traditional 8th grade English language arts. After learning about and writing hypertext herself, Nell expanded her English goals to include the teaching of hypertext writing. When she took on this goal, she truly stepped out onto the cutting edge of the field. Hypertext is not an explicit goal even in one of the most forward-looking documents available to Nell—the Michigan English Language Arts content standards. The content standard that comes closest to supporting hypertext authoring is the eighth which states that, "All students will explore and use the characteristics of different types of texts, aesthetic elements, and mechanics – including text structure, figurative and descriptive language, spelling, punctuation and grammar – to construct and convey meaning" (Michigan Department of Education, 1995), yet hypertext is not explicitly mentioned. Technology enabled Nell to "transform" her goals for student learning. Instead of writing what Nell called "straight" stories (linear), students wrote intertextually. Nell first attempted to teach hypertext using string and paper. Later, using a software program, her students better understood and grasped the concepts than with other non-computer-based approaches. The student learning processes were amplified with a technological approach (A). Though Nell believed the most effective way to communicate notions of text, writing and reading to her students required the technology, she was able to use a non-computer based approach. Nell's instructional methods were also amplified (A) with technology. StorySpace, the computer program she used, allowed simpler and clearer illustrations of the concepts. With the string and paper approach, textual passages were connected intertextually, denoted with string connectors. Representing more lengthy

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writing, as one can imagine, was a mess of string. StorySpace provided several ways to view text and the intertextual links.

One of Doug's technology uses exemplified a type of instructional transformation. Doug used web resources and E-mail for professional development. He found teachers around the world with whom he co-constructed class projects. In this case, the curriculum content goal actually represented a learning goal for Doug, commonly called professional development. Both his knowledge and experience changed when Doug used the web and E-mail technologies (T). Doug had access to teachers that, otherwise, would have been unavailable. This access to a range of teachers provided Doug an opportunity to learn about ideas that he had never thought about at any length and to contact teachers "outside [his] little sphere," a shift from the rather cloistered environment of many schools. He was able to find teaching partners on his "same wavelength." As a consequence, the content of, not to mention the nature of the interaction supporting, his professional development was fundamentally altered.

Quantitative Results: Applying the Taxonomy

I used this technology use taxonomy to categorize the teacher-participants' instances of technology use. As mentioned before, I assessed each technology instance for its impact on the instructional methods, student learning processes and curriculum goals in order to determine its placement within the three technology use categories: (a) Technology as Replacement; (b) Technology as Amplification; and (c) Technology as Transformation. In making this assessment, the technology use was compared against a non-computer version of the same activity. For example, when students used a word processor to write stories and peer edit each other's work, the comparison was made to

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students writing stories on paper and peer editing with a pen or pencil. If a comparable situation was impossible, transformation was considered a likely reason. In all cases, determinations were based on the actual use observed in the classroom or described by the teacher.

Numerical counts of the four teachers' instances of technology use, according to taxonomy categories, are represented quantitatively in Table 3. Recall that these measures represented the variety of technology use. Therefore, the number of instances represent the diversity of type of use. For any given type, the teacher may have used it in that way once or more times. For example, one would read Table 3 as the following: Doug had four instances of technology use that were categorized as replacement, representing 36 percent of his total technology use. All four replacement instances involved his students using the technology tools.

Table 3

Participants' Technology Use, by Taxonomy Category (Total Number of Instances/Percentages By Individual)

Table 3

Participants' Technology Use, by Taxonomy Category (Total Number of Instances/Percentages By Individual)

Teacher	Focus of Use	Technology as Replacement	Technology as Amplification	Technology as Transformation	Total (Instances)
Doug		4 (36%)	5 (45%)	2 (19%)	**11 (100%)**
	Student	4(36%)	4 (36%)	2 (19%)	10 (91%)
	Teacher	0 (0%)	1 (9%)	0 (0%)	1 (9%)
Laura		1 (5%)	17 (95%)	0 (0%)	**18 (100%)**
	Student	1 (5%)	3 (17%)	0 (0%)	4 (22%)
	Teacher	0 (0%)	14(78%)	0 (0%)	14 (78%)
Nell		5 (42%)	3 (25%)	4 (33%)	**12 (100%)**
	Student	4(35%)	3 (25%)	3 (25%)	10 (83%)
	Teacher	1 (7%)	0 (0%)	1 (7%)	2 (17%)
Roger		1 (11%)	6 (67%)	2 (22%)	**9 (100%)**
	Student	1(11%)	5 (56%)	2 (22%)	8 (89%)
	Teacher	0 (0%)	1 (11%)	0 (0%)	1 (11%)

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Doug and Nell both showed the most even distributions across all taxonomy categories (see Table 3). They also used technology similarly, in terms of student versus instructor use, favoring use that puts technology into the hands of the students. Doug's students used technology 91% of the time and Nell's students used it 83% of the time. Roger and Laura both predominantly used technology as amplification (67% and 95%, respectively). Yet, they diverged in their focus of use. In Roger's classroom (like that of Nell and Doug), technology was used predominantly by students (89%). Laura, though, implemented technology for her own benefit, as a teacher (78%), more than for student use.

These data on technology use speak directly to the developmental stage theories of technology implementation. In different ways, Doug, Nell, and Roger's experiences provide counter evidence for the stage theories. The stage theories, as described in the literature review, purported that teachers ascended through a set of stages often over five years or more. According to the stage theorists, teachers would use technology as a replacement, slowly move to amplification and then, perhaps, into transformation. Figure 1 depicts each teacher's instances of technology use, as categorized in the technology use taxonomy, across time. In this depiction, stage theorists would predict that a teacher's use would begin with R (replacement), transition into A (amplification), and culminate with T (transformation). Doug, Nell, and Roger represented three pictures of technology use that challenge any account that posits discrete invariant stages. Doug had used technology in his classroom for more than a decade; according to stage theory, Doug still would not be using technology as replacement in 1998 like he did (see Figure 1). Nell would never have begun her integration of technology with technology as transformation.

Again, Roger's use did not follow the replacement > amplification > transformation pattern. Rather, he used technology as transformation earlier than he used technology as replacement (see Figure 1). In fact, all three teachers intermingled uses of technology as replacement, amplification and transformation across time.

	1980----------1990---------- 2000
Nell	A T RAARR TTTRR
Roger	A ATAA AT AR
Doug	A R T AA AT A RRR
Laura	RAAAAAAA AAAAA AAAAA

Figure 1

Uses by Taxonomy Category, Across Time

Laura's technology use was the most consistent with a developmental stage theory. Stage theorists would predict that Laura, a third-year technology-using teacher, might use technology largely as replacement and occasionally as amplification. She would most likely not be using any technology as transformation in only her third year. In fact, Laura's technology use mirrored these stage theory predictions (see Figure 1).

What might explain the divergent patterns that emerged from these four teachers' technology use? Why do Doug, Nell, and Roger challenge developmental stage theory

while Laura provides such a classical fit? Examining these questions requires a fuller understanding of these teachers and the context of their technology use. The ensuing analysis and discussion indicates issues worthy of further consideration and research in this field.

Qualitative Results: Understanding the Context

In the presentation of the taxonomy, examples of the four teachers' technology uses were offered in order to illustrate the taxonomy categories. In addition, Table 3 offered a quantitative view of the four teachers' technology uses in the classroom. This section presents a richer narrative representation of each teacher's technology use. This chronological narrative guides the reader through Figure 1. For each teacher, representative technology uses are described in order to understand the divergent patterns among the teachers.

Doug Logan at Allendale Elementary School (5th Grade)

As the quantitative data revealed, Doug used technology across all categories — as replacement, amplification, and transformation. Doug's use was surprising in terms of the developmental stage theories because his use was so divided among all the categories. Even as a teacher who had used technology for almost twenty years, he still used technology as replacement. In addition, he did not *begin* by using technology as replacement, and he used technology as transformation rather early in his technology-using career (see Figure 1).

Early in his career, Doug learned LOGO programming, but found no place for it in his curriculum. He thought, "What good is this? I don't want to add another curriculum 'How to program' to my six subjects. What good is it for math, social studies, and

science?" (2, 5)[3]. As a solution, he taught willing and interested students LOGO as enrichment after school. Thus, this first technology use is not depicted in Figure 1 because it was not related to the teaching of English. His first curriculum-related technology use occurred after a stagnant period of time during which Doug pondered how or why to use technology inside the classroom. Craig, Allendale's reading specialist and a doctoral student at a nearby university, and Doug began E-mail writing projects for Doug's fifth-grade students and Craig's college students. Doug became interested in E-mail and Internet projects, and they wrote and won a grant that provided Doug's classroom with a computer, scanner, video camera, laser printer, and Internet access. With these resources, Doug and his students found and contacted people and classrooms all over the world.

E-mail Correspondence: Amplification. Doug found partners around the world who would write with his students, "The idea is that your kids get a partner, a friend they can talk to and practice writing with and that is good. So that's the underlying theme, to continue writing" (2, 13). These letters were identical to pen pal communication. In this case, though, the correspondence time was greatly reduced. The frequent letters and their content provided the students motivation and inspiration to write, provided more writing opportunities, and expanded their conceptions and understandings of the world. Motivating students to *want* to write was a challenge, Doug explained. Consistent E-mail correspondence with Australian students and others pushed Doug's students to inquire, research, think, and write. Doug explained:

> ...it got my kids to write and to want to write... One [Australian] kid asks, "What does it feel like when it snows?" And the question was, "what does it *feel* like?"

[3] Notations such as (2, 5) refer to Interview 2, Transcript page number 5.

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> You think about that. I had my kids go outside and feel the snow and come back in and write about it. Phenomenal! It was awesome. My kids were writing. ...it gave my kids a reason to want to write and got them writing.... (1, 12)

Opening the world to Doug's students was also accomplished with the E-mail correspondence. Doug described:

> ...by bringing in, having these collaborative partners from all over the world, my kids now have partners who are different races, colors, religions, and ...before I would tell them that you shouldn't be prejudice and now, they have a partner who is Black living in wherever or a student who is Jordanian....That is the big value added. We are in a society that's saying "we've got to break down these barriers".... (1, 5)

Before E-mail-based partnered conversations occurred in Doug's classroom, he taught that one should not be prejudice against others. With the partnered conversations, though, these ideas became more explicit because the issue became relevant after his students communicated with people around the world who *were* different. The E-mail partnered writing activities served the same purpose as pen pal letters. However, the increased frequency of letter exchange, facilitated by E-mail technology, allowed Doug's class to examine differences among people whether it be geography, experiences, beliefs, religion, or race.

After his experience with LOGO programming, Doug became committed to using technology in his classroom only if it related to his curriculum. E-mail correspondence amplified the student writing experience, and thus, Doug continued to support such projects. Why did Doug begin with an amplified use rather than a replacement use, as the

literature proposes? Part of it was due to his classroom resources at the time. Doug had a few Apple II computers and one Internet-connected Macintosh (supplied from the grant). This configuration did not lend itself to replacement uses. There was no projector, and there were not enough computers to institute a center approach where students could cycle through a computer-based activity.

Expanding Pen Pal Projects: Amplification. Doug worried that students might bore of E-mail partner letter exchange and therefore, felt a need to "spice it with a project here and there." They started exchanging "All About Me" or "All About Allendale" HyperStudio stacks with their partner classes. These projects, especially about the town, amplified learning across content areas. Doug explained that the students started considering various aspects of Allendale life:

> In the process we learned about immigration, we learned about what makes up a community, we discussed what would you tell people about Allendale, we had categories, you know the businesses, the churches, the extracurricular things that happen out here like the fair. The community, the housing, the various types of housing, the farms as opposed to the village. So we separated that off. And then like in businesses we had offshoots, you know, orchards as opposed to the rubber plant over there. So it was manufacturing as opposed to agriculture. So then we studied those. (2, 13)

In turn, students also learned about their partner's geographical, agricultural, and economic roots. Doug connected these video and HyperStudio projects to exchanging electronic field trips, the next application of technology in Doug's curriculum. Doug said,

"...it was a natural process then to go to: what else are we going to do? Let's, oh, we're going on a fieldtrip, we might as well parlay the fieldtrip into something" (2, 13).

Field Trips: Transformation. Developing and exchanging electronic field trips began when Doug discovered their Nebraska E-mail partners resided near Independence Rock, a site along the Oregon Trail. Doug and the Nebraska teacher decided to document and exchange local fieldtrips between their classes. The Nebraska partners electronically documented (using video, HyperStudio and/or the web) a field trip to Independence Rock, and Doug's class constructed an electronic fieldtrip from their visit to Greenfield Village in Detroit. Doug's students learned more about the Oregon Trail while the partners used the Greenfield Village field trip in their study of the industrial revolution. These projects continued with other E-mail partners. When studying early American explorers, Doug's Newfoundland partners created an electronic field trip of John Cabot's monument.

The student learning process and instructional method related to class field trips transformed with the introduction of electronic field trips. Instantly, field trips transformed from being a supplement to the textbook content into a local site about which to teach others. Doug's instructional preparation and follow-up transformed. Small groups were assigned to document particular aspects of the field trip. Guidance was provided related to documenting valuable information and constructing the case. Instead of mindlessly walking through "another old building" or solely remembering the bus ride, his students now had a purpose in mind, "to tell or relay what you have learned to somebody else" (2, 16). Doug and parent chaperones reported that even after students collected the information required for their part of the report, they uncharacteristically

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continued to ask questions and inquire about the topic of the field trip. Having a peer audience for their electronic fieldtrip spurred his students to pay attention and be responsible for learning. Doug reflected, "It was really a win, win, win" (2, 16). It was at this point, not long into his use of technology, that a technology use transformed aspects of student learning process.

Partnered Writing Projects: Replacement. After conducting the E-mail and HyperStudio projects with distant partners, Doug expanded his use of partners into other writing assignments. For example, Doug's class and a partner group developed a story's beginning, what Doug called a "story starter." The classes exchanged the story starters and individuals completed writing the story. In another example, Doug and his Louisiana partner, Kristen, decided to teach about descriptive writing. The students in each class wrote a description of their playgrounds. Students traded their written descriptions and drew a representation of the other student's written description. A final exchange back – the initial description and the picture – communicated the success of the descriptive writing. These projects used technology as replacement, for they supported writing that was unchanged by the use of the technology. Exchanging writing, whether by mail or E-mail, with classmates offered the same audience. The student learning process may have been transformed if the distant audience had altered the students' writing task or approach. There was not enough evidence to suggest that Doug's students' learning process had changed in response to a distant audience.

Computer Days: Replacement. Eventually, Doug had eight computers in his classroom. These computers had varied software. Doug organized "computer days" where the class cycled through centers, one of which was a computer "center." The

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computer activities in this center combined a language arts goal and a computer goal. Doug explained, "...we are taking language arts skills and putting them, this is parts of speech stuff, find the noun, the conjunction ... we're telling them when they find them, to highlight them and use another feature [of the word processor]... maybe we'll tell them to change the font or size..." (1, 5). Another assignment required students to identify all the adjectives in a list of sentences by changing them to an italicized font. This technology use replaced traditional worksheets to practice parts of speech identification and taught the students various word processing functions. With greater numbers of individual computer stations (not connected to Internet) in his classroom, Doug created assignments like these that replaced established English goals. The main advantage in these assignments involved the students' exposure to the actual technology. But the taxonomy was not focused on technology as an end but as a means to learn English language arts. So in this instance, the technology offered no advantage over the traditional English worksheet.

Summary: Replacement, Amplification, and Transformation Intertwined. Doug was a multi-tasker, for in any given school year he used technology across the taxonomy categories. The examples provided here are typical of all his uses. For example, a student practiced sentence construction skills (replacement) by manipulating words in a draw document. Doug used resources like electronic encyclopedias and satellite-accessible stations (CNN and the Weather Channel) to amplify the research and writing process, and he transformed his own professional development activities by developing on-line collaborations with teachers across the United States (described in the Taxonomy section).

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Doug did not use technology as was predicted by a stage model, but rather, consistently used technology as the context deemed appropriate, whether it be replacement, amplification, or transformation. When considering Doug's eclectic and decidedly functional philosophy on technology's role in his classroom, it was no surprise that he used and continued to use technology as replacement, amplification and transformation. He explained, "I want to be able to get it, to use it, to facilitate what I'm doing" (1, 1). When Doug taught parts of speech skills, using word processor worksheets (replacement) to practice identifying the parts of speech seemed natural and productive for his students. E-mail pen pal communication (amplification) decreased the response time for receiving letters, providing students more time to develop writing relationships with peers. Developing and exchanging electronic field trips (transformation) with partner schools expanded the content resources his students came into contact with when studying various topics in class. It was logical for Doug to use the computer in this way, as well. A visit to Doug's classroom in 2010 might reveal a teacher who continues to use technology to serve all types of tasks.

Laura Yates at Bancroft High School (9^{th} Grade)

Laura's technology profile revealed that she predominantly used technology as amplification and within that category, mostly for teacher purposes. Since Laura was a third year teacher who had used technology to some extent since she began teaching, the developmental stage theory slotted her exactly where she was — using technology as amplification. Yet, the predominant use for teacher purposes was unexpected. The technology available in her classroom, though, provided one explanation for the high density of technology as amplification of teacher purposes.

Newspaper: Replacement. During her first teaching year, she constructed a class newspaper using a word processor. Using a novel as the context for newspaper topics, small groups of students wrote sections to complete a newspaper. However, the students did not use the technology to produce the newspaper; rather, Laura collected the various hand-written newspaper sections and constructed it with a word processor. She explained that her students had not developed enough word processing skills and experience to use it, so she constructed it for the class. Therefore, in this case, Laura's use of word processing replaced traditional newspaper design and writing. The use of technology did not alter the instructional method, the student learning process, nor the writing content, as compared to the development of a hand-written newspaper.

Word Processing: Amplification. A modern computer laboratory in the one-year-old building provided Laura's students the opportunity to use word processors to support writing. She had, on occasion, taken her students into the lab to write and edit their work. However, it was not usual. She spoke of peer editing and revision occurring in the lab. Though I did not observe students using these computers, such word processing work amplified students' writing practices with the ability to organize and revise. This is one of the few technology uses in Laura's class that involved the students using the actual technology.

PowerPoint: Amplification. Laura used PowerPoint program to plan, guide, and support discussions in her classes. A PowerPoint presentation file containing quotes from To Kill a Mockingbird was displayed on the two large TV screens during a whole-class discussion of themes in the book. Laura often flipped to quotes to support students' ideas and to start conversation and discussion of themes they might not have considered. Laura

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felt this use of PowerPoint was faster than using transparencies or the white board, and it benefited the students' learning because she could easily print out "lecture notes" for students who were absent. In terms of instruction, these notes were then easily available for future use. PowerPoint, then, primarily amplified Laura's instructional methods.

DeskCam Cameras: Amplification. Laura used the ceiling-mounted cameras for purposes an overhead projector might serve. However, the camera amplified Laura's instruction because not only did it display non-transparent objects, it did not require transparencies at all. Laura acknowledged that with the camera, she was able to quickly display something versus going to the photocopy machine to make a transparency or to make a set of classroom copies. For example, Laura used the camera to display newspaper advertisements for cultural events and to display the book they were reading out loud in class, to assist students in following the lesson. She also was able to use student examples more thoroughly in her class. Laura explained the benefits:

> I wouldn't give it up. As far as putting worksheets and stuff up, that's not that big of a deal, but if I don't, kids will say, "Can you put that up on the screen?" Because I'm pointing to it and they get lost or distracted. Especially with ADD kids, they're facing the TV because for whatever reason, they attend better to that...I like being able to put student examples that are hand-written up here...that kind of learning on the spot whereas if I was gonna try to do that by transparency, then I'd have to run and do it and hope it doesn't melt.... If I just read it aloud, there are kids that don't get it that way. I'd say that's pretty important. (3, 29)

The deskcam camera saved Laura instructional time and offered an alternative display appreciated by most students.

Microsoft Word: Amplification. Laura also used MS Word, displayed on the two TV screens, as visual help in doing daily teaching, much like the use of the overhead projector. She and her students designed a grading rubric together – "putting it up on the screen and we'll edit as we go" (1, 10). In other instances, she used Word for class-produced writing, and she identified an advantage:

> Another time we were talking about what makes good poetry and we were going to try to write a poem as a class. And if you put it up on the board, you end up with squiggly lines everywhere, and it is a big mess. So we put that up on the screen [TV monitor]. So I did it in Word and made the screen big. (1, 10)

Using the computer projection on the TV screen was more effective for Laura and her class to work together and produce neat, organized products.

WinSchool Administrative Tools: Amplification. Laura's school used a software package called *WinSchool* that provided a grading program, attendance program and student information search program. Unlike other teachers at the school who kept grade books and just inputted final grades into the system, Laura used these software programs immediately and fully. She used the suite of tools everyday, and Laura claimed, "If I didn't have this [grading] program, I would go out and buy one. Just because I know at a glance where a kid's at and if they're in trouble" (3, 34). Again, in this case, Laura tracked attendance and noted students' grades just as any other teacher did, but these programs allowed her access to sort and analyze information instantaneously, allowing more time to help students. In this way, this suite of tools amplified Laura's administrative duties.

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Summary: Amplification of Teacher Tasks. Laura's instructional methods and assessment became more efficient with the use of technologies, like overhead DeskCams and projections of PowerPoint and Word files. Laura felt that she better supported students' learning when she was able to efficiently guide discussion in the classroom, determine a student's grade or assignment status, or project teacher or student-generated work and examples immediately for the entire class.

The classrooms at BHS had built-in technological capabilities that facilitated, if not catered to, this technology use. The classrooms came equipped with a set of three cameras in the ceiling, two TV monitors, and a teacher desk which included a PC-compatible computer with E-mail/Internet access and CD-ROM, a VCR, satellite access, video-stacks (in library) access, and a telephone with voice-mail and "homework hotline" features. Computer software controlled the cameras. The computer was loaded with Microsoft Office programs as well as multimedia/communications software. The CD-ROM was used for software and/or music. Laura was able to play videos from her own VCR in her classroom or through scheduling delivery videotapes housed in the library "stacks." Overall, Laura used these technological devices available to her to amplify established teaching techniques and strategies.

Nell Otherby at Pendleton Middle School (7th and 8th Grade)

Nell, like Doug, used technology as replacement, amplification and transformation across her career. Nell began investigating technology's use in her English classroom ten years ago, yet the majority of her technology endeavors occurred in the past year (concurrent with a new PC lab in the school). Nell's beliefs about the teaching and learning of English pushed her quickly to use technology as transformation which did

not conform to developmental use trends in the literature (that would have started her with replacement use). Nell's case revealed a major clue as to why these teachers diverged from developmental expectations. Nell's beliefs about language arts teaching and learning had an impact on her using technology as transformation. Unlike the teacher population involved in the ACOT research, Nell was not a "traditional" teacher; she had reflected on her practice and chose to change it often. Since moving to the middle school twelve years ago, Nell explored new ideas and theories in order to improve her classroom teaching, such as using Writers workshop and alternative assessments. Nell always searched for new ways to teach and for her students to learn about literacy.

Word Processing: Replacement and Amplification. With her own exposure to word processing, Nell believed that it was integral to the writing process. The computer, Nell explained, developed concurrently with writing process theory, and she felt one cannot "truly practice the writing process without a computer because of the ease of revising, revisioning the text" (3, 37). Nell's students used the Macintosh labs in her school to write using a process approach. The technology amplified this practice of writing. However, when competition for lab time occurred, she abandoned the computer-based process writing altogether because she believed computers needed to be used *throughout* the process, not just when haphazardly available. Nell chose to not use computers for writing unless nearly daily access was available.

In the most recent school year, Nell used the new PC lab in her school on a daily basis. Some of the word processing activities she led this year used technology as a replacement of established writing goals and practice. For example, using a word processor, Nell's students constructed a Poetry Anthology that required compiling poems

students had written over the school year along with some favorite published poems. Nearly all the students retyped their poems because they either had a hand-written copy or had lost the electronic files. Either way, Nell required a particular format for the presentation of the poems, and students needed to format them accordingly. This project's use of word processing replaced production of a hand-written Poetry Anthology. Nell's instructional method, the students' learning process, and the curriculum goals were not changed. In fact, using the word processor may have taken longer because students had a difficult time formatting each poem in the manner Nell desired. Again, if technology skills were the goal, this assignment would have been a learning opportunity for the students. But in terms of the English language arts, it did not offer any amplified benefit or transformation of instruction, learning, or content.

In another writing project, Nell's students participated in an interdisciplinary Slavery Project with a group of students from Ghana. Nell's students either wrote a hypertext slave narrative or a "straight story"[4] narrative. Those students who wrote straight stories used the word processor as if they were writing a story with pen and paper with little revision. Students entered the laboratory, sat in front of their computers, and typed their stories. The Ghana students had provided four versions of the first half of the story, and Nell's students chose one version to complete. However, Nell's students read the Ghana versions once and then immediately began writing their part. Students did not use word processing features to brainstorm the organization of their writing. They did not print out their stories for personal or peer review and revision. They printed it when nearly complete so Nell could review it once. Students engaged in limited revisions, in

[4] "Straight story" is a term Nell uses to describe traditionally-written, linear texts, as opposed to a hypertext approach to writing.

response to problematic issues Nell identified in the writing. In this case, the technology appeared to be identical to student writing if done as a hand-written assignment. The potential for amplification existed, but students did not appear to enact substantial revision.

In another class, Nell's students peer edited each other's linearly written stories. Students read another student's paper and typed any comments in all CAPS. The author then read through the edits, and the peer reviewer clarified any questions. Typing the comments directly into the electronic text replicated hand-written peer editing, but the author's ability to quickly and easily revise based on the peer's suggestions were amplified. Because the student did not have to completely rewrite the story, she had more time to contemplate the suggestions and try to respond to them.

HyperText: Transformation. As described in the Taxonomy section, Nell also expanded her curriculum goals to include the teaching of non-linear writing. She used a computer program, StorySpace™, to support students' hypertext writing. In contrast to the students who chose to write "straight stories" for their slave stories, some students chose to write their slave story as a hypertext. After selecting the first half of the story (from the Ghana students), Nell's students imported the first half of the story into the software. As they constructed the second half, they were constantly developing a web of links between aspects of the stories.

Internet searching: Amplification. Students researched the Chernobyl nuclear disaster on the Internet to support their reading and interpretation of the book, Phoenix Rising. Students consulted web sites such as MIT and chernobyl.com. The Internet amplified traditional library research methods because it offered students greater access

to information. In actual practice, a few of the students' Internet searches did not necessarily amplify the learning process. The increased access to information led students to complex information that some students had difficulty understanding. For example, a student was thoroughly confused about statistics she read at a MIT web site, "The number of Chernobyl deaths will exceed four times the estimated deaths caused by WWII nuclear bombings in Japan." The student had difficulty understanding "estimated deaths" and, perhaps, the nature of the bombings in Japan. Trying to make sense of the information they found was difficult and appeared to reduce some students' understanding of information. The traditional library might have offered books and information written at their level of understanding or the teacher may be required to provide more interpretation assistance or guidance. Teachers may help students understand Internet information by leading them to sites that have information appropriate to their reading level and/or teaching them strategies to help decipher more complicated information found on the Web.

Chat Software: Replacement. Nell learned about chat software at a conference. From that, she desired to use chat software in her classroom. She wondered:

> I want them [students] to talk about something that they've read. And to use that [chat] as a response to reading and, and I want to see if conversation, written conversation about books differs than sort of the real surface kinds of things they talk about when I try to engineer that in the classroom ... will they be more focused if the text is visible to them? (2, 9)

In this case, the potential for chat software to be transformative existed if it changed students' discourse patterns. However, rather than using chat as a medium for discussion,

as she indicated in the quote, she chose to introduce chat technology for students to practice sentence combining skills. Nell's classroom-based lesson on sentence combining failed to engage the students. This lack of engagement prompted Nell to try using chat software for sentence combining. It failed to meet Nell's expectations. She explained the disappointing results:

> I was having them do that [sentence combining] in the chat room, hoping that they would talk to each other about that, but they don't. They [say], "hey, what's up?" [or] "who's 'cutie pie'?" And they're doing all the kind of mindless chat room things or what I consider mindless chat room things. They think it's fabulous. And I was typing in, "I need your [sentence]," and so they would send in, put their sentences up and as soon as they'd done that, then they would go back to chatting... it didn't work the way I wanted it to ... (3, 39)

The chat approach replicated the regular classroom instruction. The students posted their sentence when prompted by Nell. Otherwise, students were off-task. This approach was just as ineffective in engaging students in the task. It replaced an ineffective, non-technology assignment. Chat obviously was not the technology solution for teaching sentence combining.

Listserv Participation: Transformation. Nell also used listservs for professional learning and communication. She frequently contributed and responded on many listservs, including a [local] Writing Project, NCTE, Milken Foundation, Assembly for Computers in Writing (ACW), Assessment Reform Network (ARN), RetNet (rhetoric), Discourse, and TechTomorrow[5] grant listserv. These listservs provided professional development in a way unattainable without the technology and, therefore, were

transformative. Nell participated to make connections with other educators and to "test out" her own developing theoretical ideas.

Listserv discussions challenged Nell intellectually, as they provided her with a professional community she could communicate with everyday, if she desired. Nell described this new "world" she became a member of:

> ...and it [NCTE listserv] opened up this whole world. And what I really like about it is that especially in the beginning, where it was all new to me, as topics would come up, it would force me to think about them. It would send me to the books that I'd been reading for classes. It allowed me to play with my beliefs, sort of objectify them. It put me in situations where I had to argue my side... (2, 10)

Nell's continued involvement in listservs allowed her to participate in conversations that challenged her ideas and theories. She described herself as a "theory" person and explained, "But I am very active on the list, and I am a theory person and...I join in on the theory conversations and that kind of stuff" (2, 10). These listserv experiences may be compared to learning communities that educators strive to develop (e.g., Pfeiffer & Featherstone, 1997). For teachers like Nell and Doug, it was impossible to develop groups such as these without the presence of technology. Technology may have reduced one of the major obstacles to success — finding willing participants. However, listserv technology, in Nell's case, did not eliminate challenges inherent in teacher study groups. Listserv participants constantly fluctuate. Some members are unknown "lurkers." For these reasons, listserv participants are never sure about who the "group" consists of or to what extent they will be supportive "critical colleagues."

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[5] Pseudonym for a listserv for technology grant recipients.

Nell's participation in listserv conversations helped develop a status for her among this group of colleagues. Nell distinguished herself as a "theory" person as compared with a "cute lesson" person who used the listserv for cute lesson ideas. Reflecting on the first contribution she made, Nell revealed that her first few contributions were not acknowledged because, "I didn't have any status," and she continued, "And now, it's funny, if I wrote that, it probably wouldn't be a whomp at all. It would be 'Oh, this is what Nell said'" (2, 10). Her status revealed itself explicitly when she received E-mail from colleagues, as Nell recalled, "...every once in a while I get something from somebody. 'You and Kermani [another listserv participant] are my gods.' I mean, I got something like that...or 'I always read everything you write.' I mean, it's funny... Oh, it's great" (2, 10). Developing a status rewarded her professionally. For example, she was invited to participate in a Milken Exchange on Educational Technology chat on the topic of writing and technology. Not only did she participate, but she also recognized other participants, "I get in [to the Milken chat last fall] and low and behold there are other people, like from NCTE, and we just talk" (1, 10). Developing such a wide group of teacher colleagues would be close to impossible without the technology. The technology's expansion of professional colleagues and its impact on Nell's professional development was similar to Doug's ability to find close teaching partners through E-mail and Internet.

Summary: Multiple Technology Use. Nell's technology use spread across all Taxonomy categories. Though Nell held beliefs about how technology might transform student learning methods or her own instructional practice, sometimes the enacted practice, exemplified in the Chat use, ended up replacing a current problematic practice

that she was trying to improve. Likewise when students used the word processor to write stories, they did not always appear to take advantage of the word processing features that might have amplified their learning process. Some of Nell's endeavors failed to meet her expectations, perhaps, because Nell's real passion and energy was channeled into the hypertext projects and her listserv participation. Nell's major area of technology focus for the year involved teaching her students about and practicing hypertext theory, a use in the Technology as Transformation category.

Roger Karpenter at Hallivale Junior High (9th Grade)

Though Roger used some technology as replacement and transformation, he predominantly used it as amplification. Because Roger had eight computers in his classroom and access to twenty computers in the school's media center, he used technology as much as possible to support and enhance his curricular goals in English and history classes. To that end, Roger used word processing and research tools extensively.

Web Research: Amplification. Similar to the function ProQuest served, Roger also allowed students access to the Internet for research. Again, to augment the research resources in the school's library, Roger developed a set of bookmarks to news organizations or news magazines to support his students' research. These web bookmarks were available on one computer in Roger's classroom and thus, allowed more research time than just what was allowed for the entire class in the library.

Representing Ideas in HyperStudio: Transformation. Roger's students used HyperStudio to gather, organize, and present information in their English and history classes. Roger believed HyperStudio and hypermedia programs like it (e.g., PowerPoint

and web authoring) allowed students to understand the structure of English language and composition, like no other strategy he had used before. He explained:

> ...it helped them with their paragraphing, helped them with organizing and writing their papers in different ways. It helps with that and they can see it. One of the things that happens in English sometimes is you're teaching them, and you're telling them to write papers, and you're asking them to look below what they're trying to say and look at the formation, the syntax and how things are put together underneath — like topic sentence and supporting information and your thesis statement, and you're asking them to look at, okay, how long is your introduction here? How long is your second supporting piece? And you talk about it, but within the writing text of the paper, it's more abstract. When you get it onto the hyper mode, it becomes more concrete. They can see those pieces much more clearly and they become much more understandable. And it takes those structures and gives you a new format to talk about them. (3, 10)

As students constructed hypermedia-based presentations, Roger was able to guide them in this structural analysis of their writing and organization. HyperStudio's card framework and PowerPoint's slide framework offered a concreteness through which students were able to talk about writing structure. Individual or class discussions about writing, without these technologies, were too abstract and were very difficult for students to grasp, Roger reported.

Word Processing: Amplification. Roger incorporated the ideas of Writer's Workshop into his class through a year-long writing project called "First of the month papers." Roger described:

> ... we do writer's workshop for 10, 15 minutes every day and what we do is we work on our pieces, we conference, we do this, we do that. We take full days here and there. The first Friday of every month, they have a paper due. And it's of their choice. It's an essay; it's a short story; it's poetry. (4, 3)

For those students who chose to use the optional classroom computers for the first of the month papers, Roger explained how fundamental the computers were given the long duration of this project. It amplified the student learning process and the teacher assessment. Roger encouraged students to work on one piece of writing for the entire year. For those students who used the computers in the room, those fifteen minutes each day could be spent on editing and revising their writing, not rewriting the text over and over. In addition, Roger claimed that collecting students' writing on disks helped him assess it quickly and easily.

Electronic Portfolios: Transformation. Hallivale Junior High already had begun to use a standards-driven portfolio for assessment. Roger worked to develop an electronic medium for the portfolio. Roger piloted an electronic portfolio system with a few students. It transformed the student learning process due to its ability to include varied media. The standard portfolio at the school contained mostly written products. The electronic version, though, accepted video and audio as well as writing and drawing. If implemented, the electronic portfolio could transform what the students *and* teachers attended to as indicators of learning and development.

ProQuest Research: Amplification. A vital part of Roger's history curriculum was developing research skills *and* developing knowledge about current events. Because Roger's goal for history was to help students "look at what happened in the past and

maybe relate it to what's happening now" (4, 9), understanding the challenges in today's society was vital. Roger had used activities that examined current events as a way to expose these ideas to his students. These goals of research and knowledge of current events, in the past, were challenging to adequately attain. Through the use of a new technology, ProQuest database system, Roger was better able to keep his students abreast of current events and provided them with more research opportunities and resources.

In past years because Hallivale J.H. did not authorize a newspaper subscription for Roger's class, he used journals in the library, collected magazines from his dentist, students, and visitors, and brought his own newspaper to support the current event work. This year, the librarian alerted Roger to Hallivale's access to ProQuest, an online (Internet) database of thousands of current journal articles, many providing full text. "It was two weeks," Roger explained, after finding out about ProQuest before he used it with his students. He continued,

> ... when I saw it, it was exactly what I was looking for, and so it took me, it was like something that when it came up, it was, it was like - It was a message from the gods! Okay? No, it was like it was there, it was what I was needing, what I was wanting, and I was like yippee yi, yippee yi, yippee yi yo kiya. I was pleased as punch, and we were ready to go with that. Yeah. I couldn't get on it quick enough. (2, 19)

This ProQuest technology served several functions that amplified Roger's curricular goals. First, logistically it allowed Roger's students an easy, accessible way to learn about current events. The library resources were limited to a few journals and those few did not accommodate the number of students in Roger's class. Before, wait time was more

prominent than research time. With ProQuest, all students could work in pairs at computer terminals researching topics and accessing pertinent, current journal articles. Second, a layer of teacher-direction was removed. Before, Roger supplied all current event resources. By the time students began research, one step of the research process had already been performed by Roger. With ProQuest, the students themselves decided if the sources of information were reliable for their work.

PowerPoint: Replacement. In history class, Roger's students used PowerPoint software to present the main ideas of a section in the textbook chapter. As a jigsaw, small groups of students were responsible to teach the rest of the class about their area of concentration. The project did not offer any advantages and ultimately failed because student presentations did not adequately educate their classmates about the chapter contents. The small groups had focused on learning the software rather than *using* the software. Again, in this example, technology as an end became more prominent in the students' minds than learning the content.

Summary: Technology as Amplification. Roger's use of technology focused on using available technological resources as support for his established curricular goals and student learning. Most often, his uses amplified the teaching and learning process. His uses emerged directly from his goals to find ways for students to get more and better information to help their studies and engage more readily in the writing process. By chance, in a few instances he began using a technology that had transformative effects on his students' learning processes.

Discussion

This inquiry sought to understand technology use in four English language arts classrooms. This analysis reveals trends that question the applicability of a developmental trajectory that assumes teachers' technology use develops from simpler replacement use toward transformative, innovative use. By looking deeply at these teachers' instances of technology use and considering the contextual factors including curriculum goals and the enacted practice, we see that teachers are, to varying degrees, using technology to transform instruction, learning and content goals. But what could have influenced these results that differ so significantly from past research?

Reconstructing Technology Use

Cohort Effects

A cohort effect may be operating in this population. In more recent years, perceptions of technology and its role in education have changed. The four teachers in this study, to some degree, function within a different cohort than the teachers involved in the research begun at least ten years ago that conceptualized the developmental stage theories. This may explain why in some cases these teachers' technology use diverges from the developmental trajectory.

In the past two decades, as new technologies and certain educational theories have become more prominent, the role for technology in education has changed. A decade ago, computer-assisted instructional software packages were the effective technology use. In fact, Becker (1994) explained that a 1989 survey found that "a majority of surveyed computer-using teachers indicated that their major goal in using computers was to help students master basic facts or skills" (p. 293). Teachers appeared less knowledgeable

about technology, as reflected in past literature's first developmental stage targeting novice technology users. For example, in ACOT's Entry and Adoption stages, the teachers grappled with plugging in computers, loading, and learning software. In addition, the contemporary technology continually changes, as Becker (1993) summarized, "At various times what has been thought in the United States to be the most effective instructional uses for computing resources has changed—roughly from computer programming to mastery of basic skills to computer 'tool' applications of various types" (p. 129).

Teachers' technology use has moved away from emphasis on "computing studies"—teaching students about computer skills (e.g., LOGO programming)—and has moved closer to learning with, through, and from computers (Morton, 1996). Past approaches (see Winnans and Brown, 1992) of integrating technology into schools have set the responsibility of teaching essential *computer skills* on the subject-grade teachers. Winnans and Brown found that being accountable for such skills constrained teachers' technology use.

The participants in this study, though, show varied technology use. Considering past research that indicated the modal use of technology remained primarily drill and practice (OTA, 1995; Becker, 1994), it is encouraging that among the four participants, only one used, and then only to a limited extent, drill and practice instructional technology. These teachers' technology use extends beyond the modal practices. Perhaps it is due to the changing accountability, as Morton (1996) hints, for the teachers in this study were not formally responsible for teaching any technology skills. When not responsible for covering technology skills, teachers may feel more apt to experiment with

roles for technology in their teaching by focusing on one new technology for a longer duration.

Perhaps the answer lies in the fact that now we have teachers, like Roger and Laura, entering the teaching field with much more knowledge of and personal experience in using technology. That experience, coupled with the teaching of more theoretical perspectives, such as social constructivism and socio-cultural perspectives on learning that champion the concept of cultural tools, during preservice education may help account for the wider use of technology as a tool to assist in students' own construction of knowledge. In fact, among the four teachers, student interaction changed — there were more dyad and small groups working together and students interacting with peers in other parts of the world. Students began assuming more responsibility for their own learning by documenting and presenting their knowledge to others and writing on topics of their choice. And more tools became available to assist students' work and learning — video production, multimedia presentation software, hypertext authoring programs, library research resources, satellite access, and more. Teachers who attempt to use technology in recent years may possess different tools, knowledge, and beliefs that prepare them to consider a wider array of technology applications than teachers had a decade ago.

Beliefs and Change

Within the technology field (Sandholtz, Ringstaff, & Dwyer, 1997) and the teacher learning field (Borko & Putnam, 1996; Putnam & Borko, 1997) a change in teachers' beliefs and values of teaching and learning is required for profound changes in instructional approaches. This finding is the crux of the developmental stage trajectory. Without a change in beliefs, the argument goes, technology will continue to be used in

support of "traditional" approaches to learning and teaching, like Doug's use of computer worksheets. If all we knew about Doug was that he created word processing "worksheets" for his students to practice identifying parts of speech, we might assume that Doug's technology use replicates transmission-style instructional practices. Yet, this is not the case. He actually used technology to support reform-based approaches to teaching like his distance-partnered-projects that directly attack the problem of "audience" in student writing.

This contradiction is the heart of the problem with the developmental model. It assumes that teachers are novice technology users and "traditional" teachers with little knowledge of reform-oriented approaches. It is argued that the ability to reform emerges from exposure to technology. The developmental conceptualization does not accommodate the possibility that more experienced technology-using or reform-knowledgeable teachers would use technology as replacement. When we see Doug using technology as replacement, their model would conclude he is a beginning technology user because it does not allow varied instructional practices. In the same way, Nell was a novice technology user but worked on a doctoral degree in English. She was steeped in reform approaches to teaching English and theories about literacy. Her beliefs led her directly to use technology as transformation, a use that would label her as a veteran technology user when she was not.

Laura's technology use primarily amplified her own instruction. This finding may be due to her status as a beginning teacher, her extensive past experience with technology, and the technology resources in her classroom. In the beginning years of teaching, teachers struggle with challenges like classroom discipline, organization of

classwork, appropriate materials and supplies (Veenman, 1984). Technology is a well-known tool to Laura, and her current use may be a response to beginning teacher pressures. In addition, Laura's classroom, as all the classrooms in her new building, has a technology-multimedia teacher station. These stations may privilege technology use by the teacher, as opposed to the students, with computers, VCRs, and cameras hooked to large display screens.

Technology Use

The varied technology uses of the four teachers in this study are consistent with Hadley & Sheingold (1993) findings that computers were not single-use machines but used on average for fourteen to fifteen different practices. Further, they found that the technology-experienced teachers in this study did use "instructional software" (category included: tutorial programs, drill and practice, and problem-solving). In fact, use of instructional software was second in frequency to word processing. When asked how often they use the programs, word processing ranked first (75 percent), drill and practice programs ranked second (37 percent) and tutorial programs ranked third (24 percent).

Hadley & Sheingold (1993) also concluded that teachers gradually began to manage more technologies at once. They explained:

> ...what teachers do with computers in their classrooms reflects how much experience they have had. Initial practices and approaches tend to be similar to familiar well-structured classroom technologies (e.g., the workbook) more focused on reinforcing directly what is already being taught or, for particular groups of students, providing special opportunities.... Gradually, teachers are able to manage more expansive uses that differ from more familiar technologies, that

> afford self-generated learning opportunities for all students, and that may engender new approaches to the curriculum itself. (p. 279)

This conclusion, along with some of Becker's (1993) ideas, help us understand why teachers might have an eclectic collection of technology uses — including uses that replicate their traditional teaching, as well as others that support more innovative practices. Becker (1993) investigated the extent to which users of technology may pick up on "expert" knowledge, knowledge already developed through others' learning trials. He states,

> ...at least in the United States, schools with less experience in using computers are not "stuck" in early models of using computers, but display roughly the same pattern of alternative uses as schools that have had computers longer and that have more of them. We regard this as a healthy sign—that, at least within this country, there is diffusion of expert wisdom about how computers should be used and that novice computer-using schools need not go through the same stages of trying one thing and then another that characterized early-adopting schools. (p. 142)

Becker's work suggests that teachers may not have to start at the beginning, but the potential exists to start learning at the level of those more experienced. Laura or Nell who began to use technology to support their practices about five to ten years after other Doug and Roger, might start by learning and implementing the practices of those more experienced. With more models and wider range of technologies, more recent technology-using teachers may immediately put technology to use as amplification or transformation. In fact, that is exactly what Laura and Nell did. Teachers currently may

be moving away from basic-skills uses for technology. Perhaps the drill and practice we do see is a legacy of the early technology adopters. This finding has implications for professional development. It suggests that starting in the middle or the end, instead of always with what some believe to be the "basics," may well be a viable option. Professional developers may begin teaching teachers about transformative technological uses instead of "easing" them into technology use with drill and practice software.

Accuracy in Representing Technology Use

The work reported here reveals how survey-based reports of teachers' technology use may not accurately represent actual use. Surveys' indistinct questions and teachers' differing interpretations of those questions combine to make survey results problematic. In this study, I used both indirect indices of use (the interviews) as well as more direct indicators (the observations) so that I could uncover both perceived and enacted uses of technology. How was the technology implemented? Did it support what the teacher intended it to support? What did the students do with it? These deep, contextual considerations allowed a more accurate representation of technology use among these four teachers.

For example, one might conclude, as I did, that Nell's election to use word processing to assist in "going to the workshop approach" exemplified technology as amplification. Of course, the technology as Nell explained amplified a student's ability to plan, revise, rewrite, and rethink a piece of writing with ease. Without knowledge of the enacted practice, we might erroneously assume other instances of word processing use, like for the Poetry Anthologies and writing traditional, linear stories, were instances of

technology use as amplification. The enacted practice indicated in those cases the word processor was actually used as a typewriter, or in terms of the taxonomy, as replacement.

Considering enacted practice also led to categorizations of technology use into Technology as Transformation that might not have been categorized as such without the complete understanding of the use in the classroom. For example, Doug used the Internet to find teachers around the world to work with in various ways. One might consider this a use that amplified his acquisition of new teaching ideas. Instead of a newsletter or instructor magazine, Doug found teachers with whom to talk directly. Yet, it was a transformative use because Doug came to regard these teachers as close colleagues not just idea-generators but colleagues that he could not find in his own school or in the district. He developed trusting, reciprocal relationships with them. They challenged him with new ideas and understandings about teaching. In this way, it transformed Doug's professional development practices in a way a magazine or even teachers in his own school could not do.

On Transformation

Were these four teachers' technology practice as conservative and traditional in their technology use as teachers studied in earlier efforts? The short answer is, no. With Laura as the exception, Doug, Nell and Roger all used technology in ways that transformed their practice (19%, 33%, and 22%, respectively). These three teachers have more in common with the teachers in case illustrations that highlight innovation and creative uses of technology to support learning (e.g., Drier, Dawson, & Garfalo, 1999). The examples of Doug, Nell, and Roger's transformative technology uses, though, requires some qualification. The data analysis accepted all technology uses that

transformed instructional methods *or* student learning process *or* curriculum goals. The analysis was focused on differentiating among the three taxonomy categories — replacement, amplification, and transformation. In this way, it did not distinguish among the themes (instruction, learning, and curriculum) within the transformation category.

Yet, there are differences between transformative technology uses. When all instances of technology use as transformation are grouped together differences among them may be obscured. Compare the following three instances: Doug used Internet and E-mail to develop enduring, productive teaching partners around the United States; Nell's students wrote in non-linear (hypertext) ways with computer software; Roger used hypermedia programs to help his students better grasp structure and art of writing. These examples differ in significant ways. Table 4 summarizes all the teachers' transformative uses and separates them into the theme most appropriate, given the context of use.

Table 4

Transformative Technology Uses, by Theme

Instructional Method	Student learning process	Curriculum Goals
Nell Otherby used listserv communication to develop several professional inquiry groups.	Roger Karpenter used hypermedia tools to facilitate students' understanding of writing structure.	Nell Otherby introduced the notion of non-linear or hypertext writing to her students, facilitated through software programs like StorySpace.
Doug Logan used E-mail and Internet technologies to find teacher colleagues, some of whom eventually became distant teaching partners.	Roger Karpenter started to develop an electronic portfolio assessment that allowed students to expand "what counts."	
	Doug Logan developed HyperStudio electronic fieldtrips, through which learning and the role of students in learning changed.	

Nell and Doug used technology to access and communicate with a wider array of professional colleagues. The technology provided a method for these two teachers to communicate and develop strong relationships with teachers who challenged their thinking and pushed them to learn more. These new connections helped them learn about new possibilities for designing their instruction. Nell reported that, "as topics would come up, it would force me to think about them. It would send me to the books that I'd been reading for classes. It allowed me to play with my beliefs..." (2, 10). Likewise, Doug explained, "It exposed what life is like out there for me and this is what really opened my eyes at how different things are in different places. And on some occasions, how alike we are" (3, 29). Doug's distant partners became close colleagues as he described, "They [teachers] can actually become closer and work better with their, their Internet partner or Internet collaborator than they do with the partners they have in the building. Because you truly get to find somebody that's right on your same wavelength" (3, 26). Without the technology to access and communicate with a wider array of teachers, both Nell and Doug's practice would have been quite different. Both these teachers' distant collaborations made them consider their teaching in deeper ways and eventually impacted what they taught in their classrooms. It is interesting that both transformed uses targeted their professional development, specifically aspects of their preparation for instruction.

Roger and Doug used technology to reorganize or introduce new aspects to the students' learning process. For most of Roger's students, hypermedia representations of ideas altered the cognitive processing required to understand writing structure. Hypermedia provided an alternative, concrete representation through which to discuss elements of writing. Roger also started experimenting with electronic portfolios. This

assessment tool allowed students to use a wider selection of artifacts to represent and illustrate their learning. Doug's electronic fieldtrip projects facilitated the development of new forms and types of learning. Student learning became more purposeful as they collected information so that they could present and teach it to distant peer groups.

Nell was the one teacher who used technology in a way that expanded the curriculum to include new knowledge concepts. With specialized hypertext software programs, she taught her students about hypertext and nonlinear writing, a topic not included in traditional English language arts content standards. She wanted her students to expand their conceptions of what writing and texts are and could be.

The teachers in this study, like the teachers highlighted in Garner and Gillingham's (1996) exploration of Internet communication in classrooms, are open to learning and developing new ways to teach and help students learn. They develop "an expanded repertoire of materials and methods" (Garner et al., 1996, p. 136) that may impact any aspect of instruction, learning, or curriculum. With this set of teachers' uses, Nell's work with hypertext altered her curriculum scope, Nell and Doug assembled new contexts for professional preparation, and Roger and Doug transformed aspects of the student learning process.

It is difficult to claim that one of these types of transformation is preferable or more interesting than another type. As this study sought to develop and then apply this taxonomy to teachers' technology-supported practice, there is still more refined work to be done in the future. Developing additional analysis tools (e.g., rubrics or surveys) that enable deconstruction of an instance of teaching and determination of the most applicable technology use category (replacement, amplification, and transformation) and theme

(instruction, learning, content) is valuable. Developing measures of this kind and conducting more analysis are beneficial in at least two ways. First, they may capture technology's impact in education (for better or worse). Second, sharing the measures with teachers who are learning and have learned to "integrate" technology may broaden their own conceptions of what it means to teach with technology. I foresee both results having implications for policy and professional development.

All in all, it is encouraging that more stories of transformative technology use occur in schools with modest technology resources. More than a decade ago, Pea (1985) theorized that transformative technology use would be established with the development of more highly-specialized computer programs, "...to inform education effectively, theory and practice will need to be unified through the invention of research-informed electronic learning systems that work in educational settings" (p. 178). In actuality, these teachers' transformative technology use is not based on using specialized software that targets particular aspects of literacy development. Rather, teachers grounded their use of technology within their ideas of how best to teach the important ideas in their discipline. Kay (1996) summarizes this idea-based approach to technology use:

> A good rule of thumb for curriculum design is to aim at being idea-based, not media-based. Every good teacher has found this out. Media can sometimes support the learning of ideas, but often the best solutions are found by thinking about how the ideas could be taught with no supporting media at all. Using what children know, can do, and are often works best. After some good approaches have been found, then there might be some helpful media ideas as well. (p. 3)

These teachers primarily adopted idea-based approaches to technology use. It appears that recreating technology-rich environments and providing specialized software is not a necessary condition for transforming education with technology. These teachers put technology to use in some innovative ways with fairly general software.

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ARTICLE 2

TOWARD A MODEL OF TEACHERS' TECHNOLOGY-LEARNING

Abstract

This study explored how teachers learned to use technology. Using technology to support subject matter instruction occurred more often when a teacher's initial learning experience involved (a) learning technology in the context of learning more English language arts content or (b) learning technology while aware of a connection between the technology and the English language arts. From analysis of trends in four teachers' technology-learning, I developed a general model that illustrated the technology-learning process. The process involved (a) an individual's prior experiences and knowledge, (b) an initial learning experience, (c) reflection, (d) exploration, (d) technology use, (e) evaluation, and (f) rejection. I described how teachers take multiple pathways through this learning model.

Introduction

Local, state, and federal government continually develop more ways to procure technological resources like computers, software, and peripherals for K-12 schools. Even at the highest level of government, technology procurement is seen as an educational goal. President Clinton, in his State of the Union address, recognized that now 90 percent of schools have at least one Internet connection, and he aimed to modernize 6,000 schools in order to "get students out of trailers and into high-tech classrooms" (Clinton, 2000). Indeed, technology has become a more plentiful classroom resource in U.S. schools, as the national average of students per computer has dropped from 10.8 in 1993 to 5.7 (Survey of Technology in Education, 1999). Yet, very few teachers teach with technology – in other words, use computers and peripherals to enhance curriculum to reach learning goals. Becker (1994), for example, estimates only five percent of computer-using teachers use computers expertly to solve problems or create products for their subject matter curricula. The challenge lies in the fact that teachers know little about integrating technology into curriculum, and the research community has not fully examined the teacher-learning process underlying thoughtful technology integration.

Technology's potential to impact teaching and student learning may never be realized unless teachers learn to integrate it thoughtfully into their subject matter goals and activities. Yet teachers are given little professional support in learning technology and far less support learning how to integrate technology into subject areas (e.g., Survey of technology in schools, 1999). Filling classrooms with technology provides access, but it does not ensure teachers will use technology in meaningful ways to support subject matter learning. If simply providing more technology in classrooms accomplished

thoughtful technology use, Cuban (1986) or Postman (1992) would not find the role (more accurately the *lack* of a role) of computer technology in education such an easy target, and Becker (1994) would have found more exemplary technology-using teachers. It is crucial to examine how teachers learn to use technology to support their subject-matter curriculum and goals for learning so that we, as teacher educators and professional developers, will be more prepared to support teacher learning.

Background

Past Approaches to the Problem

Various methods have been used to understand how teachers learn to use technology. One approach identified barriers preventing use of technology and characteristics of successful teachers. This approach assumed that understanding barriers would point to ways to increase the likelihood of successful technology integration among teachers. Across multiple studies, no single set of barriers (e.g., Evans-Andris, 1995; Hecht, Roberts & Schoon, 1996; Rosen & Weil, 1995; Winnans & Brown, 1992) or success characteristics (e.g. Becker, 1994; Hadley and Sheingold, 1993; Sheingold and Hadley, 1990) emerged as salient for participants. In terms of barriers, Rosen and Weil (1995) found that prior experiences (esp. computer experience), age, gender, teaching experience, and computer availability were all predictors of technophobia. Winnans and Brown (1992) discovered (a) a lack of on-site support for teachers using technology, (b) no computer skill teacher, and (c) a limited number of computers, contributed to teachers not using technology in their teaching. Dupagne and Krendl (1992) found that availability and quality of hardware and software, time investment required to successfully integrate technology into curriculum, and a lack of inservice or training to help teachers build

confidence and ability with technology were barriers to success as well. To complicate matters, Sheingold et al.'s (1990) and Hadley et al.'s work indicated that success could be attained even in the presence of barriers. Experienced technology-using teachers, for whom few barriers might be expected, faced many obstacles yet attained success. It appears that barrier and success characteristics may be so idiosyncratic and numerous as to afford little predictive value in helping us understand novel situations. For some teachers barriers do not prevent them from embracing technology. As encouraging as this line of work is, it is ultimately unproductive because it lacks predictive power, providing little insight into teachers' technology-learning process.

Another approach to understanding teacher technology-learning, one that emphasized learning within a richly endowed professional community, was the Apple Classroom of Tomorrow (ACOT) research (e.g., Sandholtz, Ringstaff and Dwyer, 1997). The ACOT work examined teacher learning as one aspect of a more general model of instructional evolution. The model was developed from research on interventions in technology and resource-rich contexts, where corporations donated hardware and software and researchers provided time to guide teachers in planned professional development. Teachers came to these interventions with no technology experience and approached teaching traditionally, predominantly using lectures, worksheets, and textbooks.

ACOT's instructional change model found that teachers began at an Entry level and moved sequentially through five stages until they reached the Invention stage. Teachers grappled with plugging in computers (Entry), began using technology to support drill and practice (Adoption), made their instruction and learning more

productive (Adaptation), became convinced that technology was valuable (Appropriation), and invented new instructional approaches, such as interdisciplinary inquiry projects (Invention). Unfortunately, the applicability and generalizability of this model to other teacher learning situations was compromised by the atypical situation in which the model was developed – namely, the high level of technology and human resources available.

In terms of content areas, there has been an increased interest in technology's role in literacy. Most studies documented (a) what technology teachers were using and how they were using it in their curriculum (e.g., Garner & Gillingham, 1996; Kinzer & Leu, 1997; Oakes, 1996; Stuhlmann & Taylor, 1996), (b) how student learning changed or improved as a result of technology implementation (e.g., Burton, 1996; Leu, 1994), and (c) how technologies redefined literacy instruction (e.g., Baker, 1995; Karchmer, Leu & Hinchman, 1998; Leu, 1996; Wood, 1998). The few studies that examined aspects of English teachers' learning process (Becker, 1994; Leu, Hillinger, Loseby et al., 1998; Garner & Gillingham, 1996) did not offer concrete findings about how the English subject matter played a role in teacher learning. Rather, they implied a role for subject matter. For example, Leu et al. (1998) observed that coordinating software development with curriculum may increase the probability that teachers use the product. Garner et al. (1996) found that technology-based literacy pedagogy shifted away from transmission-oriented instruction. These observations, though interesting and significant, were not the focus of these studies and do not adequately answer the "how" questions — How did teachers learn to use curriculum-coordinated software? How did teachers' pedagogy

shift? We still do not have an adequate understanding of the teacher learning process or the role of English subject matter in teachers' technology-learning.

Rationale for the Current Study

These approaches to understanding teaching with technology have not attended to understanding the intricacies of teacher learning. In addition, they do not generalize to the many teachers who develop professionally on their own and in different contexts. Huberman (1995) indicates "lone-wolf" learning scenarios may be the modal learning experience among teachers. One approach to understand how teachers learn to teach with technology is to study the learning processes of those teachers who have successfully integrated technology into English subject matter. If we can understand that experience more fully, we might gain a better sense of how to support the individual teachers who embark on this learning journey without profuse technology and human resources.

Research Focus

The aim of this research was to learn more about teachers' learning – specifically the learning of middle school English language arts teachers who use technology to support their subject matter teaching. Wilson and Berne (1999) claimed that subject matter likely impacts a teacher's professional development. They stated a "need for subject-specific investigations of teacher learning. If teachers are to acquire subject matter knowledge, and subject matter knowledge is acquired differently across disciplines, then one would anticipate disciplinary differences in professional development" (p. 204). Learning to use technology to support subject matter, likewise, may be acquired differently, based on subject matter. The subject matter of focus was middle school English language arts.

Because this project focused on understanding teachers' learning journeys, starting with their first spark of interest in technology and continuing through their current use of technology in support of literacy goals, I adopted a "naturalistic or voluntary change" approach (Richardson & Placier, in press). The inquiry was guided by the following questions:

- How do teachers change?
- In what direction do teachers change?
- Why and when do teachers change?
- Are there different approaches to change and what affects those differences? (Richardson and Placier, in press)

Examining individual naturalistic change, an understudied area according to Richardson et al. (in press), diverges from the prolific body of research on the effects of planned, professional development interventions (e.g., Darling-Hammond & McLaughlin, 1996; Fullan, 1991, Lord, 1994; McLaughlin, 1991; Miller, 1998). This study illuminates the intricacies of individual learning and change by developing a model that addresses teachers' learning in more "typical" school settings.

Method

Participants

The participants in this study were four, middle-school English teachers who might be described as "moderately" involved in technology use. That is, while they described themselves as using computer technologies for purposes other than drill and practice (the modal technology use in schools (OTA, 1995)), they did not teach in technology-rich and resource-rich school contexts. Table 1 summarizes the characteristics

of the participants and the contexts in which they taught. Teachers were invited to participate through research advertisements on a technology-in-education and a National Writing Project listserv and through recommendations by university faculty. I used an initial phone call to ask participants to share their technology-supported teaching practice and invited four teachers, whose technology use was more advanced than drill and practice, to participate. All agreed.

Table 1

Participant and Context Characteristics (School Year 1998-1999)

Teacher; Grade Level	**Years Teaching**	**Years Pursuing Technology in Teaching**	**Computers in Classroom (#)**	**Computers in Lab/Library (#)**
Nell Otherby; 7th/8th Grade	26	10	0	29 (PC) 40 (Mac)
Doug Logan; 5th Grade	25	20	8	0
Roger Karpenter; 9th Grade	6	6	9	20
Laura Yates; 9th Grade	3	3	1	35

Nell Otherby. Nell Otherby had taught 7th and 8th grade English for twelve years at Pendleton Middle School, located in a mid-western town. Prior to teaching at the middle school, Nell taught journalism for fourteen years at the high school level where she was so busy with deadlines she did not have time to do anything but teach. At the middle school, Nell had more time and took advantage of many learning opportunities, including professional development workshops, Master's level (education) courses and Ph.D. level (English) courses. Her middle-school principal supported new approaches to teaching, such as when Nell started using a writer's workshop approach.

Nell's classroom did not have any computers, and she spent most days in the school computer labs. In 1998, the school opened a new 29-computer PC lab in October. They also had two Macintosh labs, one with Mac LCs and one with Mac Classics. Teachers checked out computer labs on a first-come, first-serve basis. The school had recently hired a part-time network administrator, whose schedule allowed little time for teachers to consult with him.

Roger Karpenter. Roger Karpenter had taught 8th and 9th grade English and history at Hallivale Junior High School for six years. Hallivale is located in the urban fringe of a mid-western mid-size city. During those years, he led the school newspaper and yearbook projects. In the 1998-1999 year, Roger taught 9th grade English and 9th grade history in a block style, with two sets of 26 students taking English and history consecutively with him. The block design allowed him to integrate history and English goals and activities across both class periods.

Roger's classroom had nine functioning computers, two printers, a VCR, overhead projector, and TV/monitor. Five PCs were 33 MHZ or less; two were Mac Classics; two PCs were new. Roger's classroom had more technologies than any other classroom at Hallivale JHS. Though students were assigned regular seats, they often worked in small groups, and thus, the individual desks were rarely in orderly rows. In the classsroom posters concerning history or English topics hung wall to wall. The library at Hallivale JHS also had twenty Internet-connected Macintosh computers and two printers.

Laura Yates. Laura Yates had taught English and theater arts for three years at Bancroft High School (BHS), located in the urban fringe of a mid-western mid-size city.

In 1998-99, my observations and interviews centered on Laura's 9th grade English classes.

At the end of Laura's second year teaching, the high school moved into a new building. Laura's classroom was equipped with three ceiling-mounted cameras, two TV monitors, and a teacher desk which included a PC-compatible computer with E-mail/Internet access and CD-ROM, a VCR, satellite access, video-stacks (in library) access, and a telephone with voice-mail and "homework hotline" features. Computer software controlled the cameras that display and record images from her classroom or other classrooms at the school. The school also had a Macintosh graphics lab and a PC computer lab. These were open for teachers to use when computer courses were not scheduled.

Laura felt very comfortable and confident in her English literature content knowledge. Yet, she recognized a deficit in her teacher preparation — she had taken very few courses about the teaching of English. Laura was pursuing a Masters degree of Critical Studies in the Teaching of English and participated in a national writing project.

Doug Logan. Since 1980, Doug had taught fifth grade at Algon Elementary School, a one-story building nestled in a rural town. The major area of Doug's classroom was given to student desks, which were organized into six groups of four with a few individual desks against the front wall. There were eight Macintosh computers, ranging from ten years old to a new G3, in the classroom. One computer had a laser printer and Internet access. The school purchased only one of these computers; Doug collected the rest or received grants to purchase them. The entire classroom was plastered with

students' work, projects, and other colorful displays. The school did not have a computer lab, and there was no technology assistance.

Over the years, Doug became very involved in a state-wide technology in education practitioner group. He served in many leadership roles, including being president of the organization. He also had won many prestigious awards – a majority of them relating to his work with technology in education.

Data Sources

To explore the learning process and the teaching practice, I conducted interviews and classroom observations. Three interviews gathered details about the teacher's life history (including education, career history, teaching positions, technology experiences, use, and learning), the teacher's goals, preparation, and use of technologies for instruction, and the teacher's English language arts curriculum. The series of interviews were adapted from Kelchtermans and Vandenberghe's (1994) series of three semi-structured biographical interviews. All interviews were tape-recorded, transcribed, coded and analyzed.

I conducted at least three full-day observations of each teacher. My observations focused on the teacher's use of technology in relation to instruction and student learning experiences. In my field notes, I documented actions, verbal comments, use of learning tools, allotment of time to classroom activities, nature of classroom activities, classroom and lab arrangement, classroom decorations and displays. Also, I collected instructional artifacts, such as quizzes, tests, handouts, PowerPoint presentations, and hypermedia narratives.

The main data used in subsequent analyses were teachers' technology experiences across their lifetimes, their reflections on how and why they learned technology, and their perceptions of the role technology played in their classroom.

Analysis

I analyzed participants' learning from a perspective of individual change and learning. My analysis began with a focus on each individual, where I reconstructed their past technology use and learning through various representations such as timelines, diagrams, lists, metaphors and narratives. At the same time, I continued to read literature (to expand my analytic toolkit) and to look across the emerging analyses for patterns and for anomalies that might require me to rethink my developing hypotheses. Based on concepts gained from existing literature and developing trends in the data, I began examining explicit or implicit evidence explaining each teacher's motivation, learning, and sustenance of interest and technology use. I continued until I felt I had accounted for all the data. In addition to providing a complete account of each individual, I have attempted to explain the relationships seen among the individuals in a general learning model.

Findings

Individual Teacher Technology-Learning

For each teacher, I developed a diagram that illustrates instances of technology-learning and technology use across the past twenty years. In these diagrams (see Figures 1-4), each horizontal combination of an oval, circles, and bars represents one *technology-learning instance*. For example, in Figure 1, Nell's first *technology-learning instance* involved attending an inservice on writer's workshop where she learned to use a word

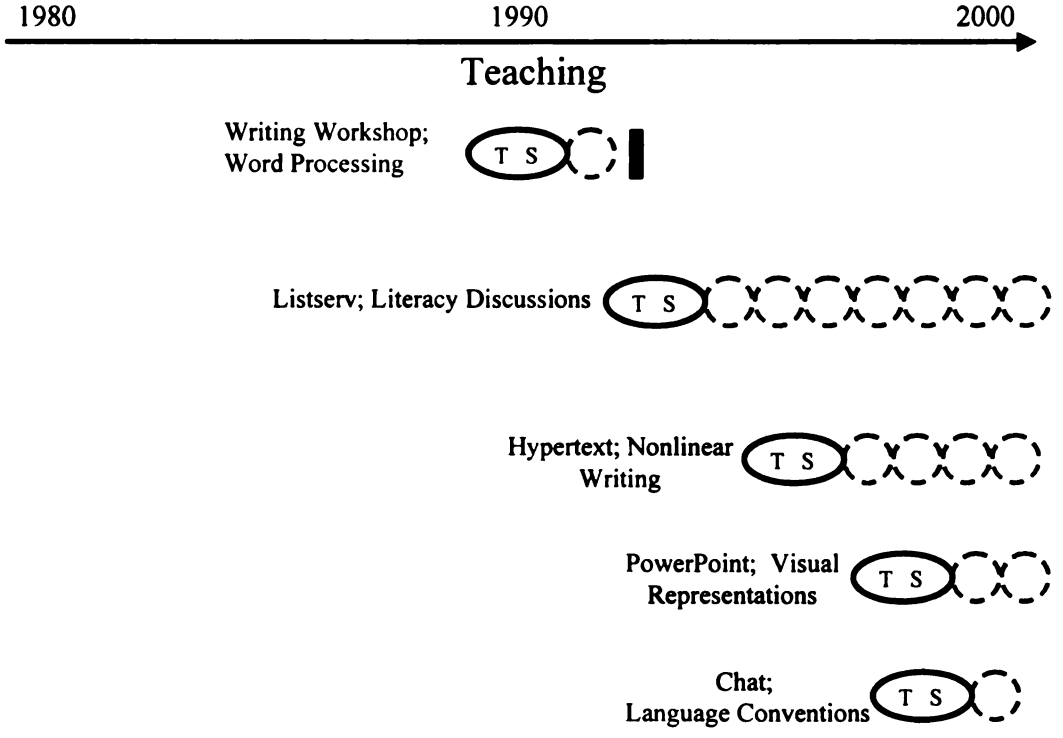
processor (an oval), using the word processor with her students (dotted circle), and stopping use of the word processor (black bar). The oval represents the initial learning experience that involved learning a technology. An initial learning experience may involve a technology (T), an English subject matter connection (S), or a general pedagogical connection (P). If these connections are present, the appropriate letter "T," "S," or "P" is noted inside the oval. Circles with dotted outlines represent a teacher using the particular technology in instruction, for teacher or student use. A black rectangle indicates an instance where a teacher stopped using that particular technology. These timeline diagrams will illustrate each teacher's technology-learning history, and I will describe one of these instances to exemplify the intricacy of the learning process.

Nell Otherby

Technology-learning history. As Figure 1 indicates, Nell's first technology experience occurred when she began learning word processing in 1990, well into her career as a practicing teacher. Since then, Nell learned and integrated five technologies (word processing, listserv communication, hypertext authoring, PowerPoint, and chat communication) into her English teaching. In each initial learning experience (denoted by ovals in Figure 1), Nell learned a technology (T) in the context of subject matter (S). For example, she learned about word processing in the context of an inservice on writer's workshop; she learned listserv communication by participating in a national writing project; she learned hypertext writing in a doctoral English course.

She also subsequently used these technologies to support her English instruction (denoted by the dotted circles). For example, when she returned from the writer's workshop inservice, she felt the writing process was inextricably woven into the use of a

word processor. She felt the only way to honor the writing process involved providing her students access to word processors. She began using the Macintosh lab available at her school. Unfortunately, in this case she was forced to stop using the lab when colleagues complained she monopolized the resources (denoted by a black bar). As another example, after learning PowerPoint, she used it to teach about "representing the ideas and getting more into the representation part of language arts" (2, 19)[1]. Multiple dotted circles in Figure 1 indicate Nell continued to use that technology over time.



Note: T = Technology; S = Subject Matter (English)

Figure 1

Nell's Life History of Technology Use and Learning

[1] Notations such as (2, 19) refer to Interview 2, Transcript page number 19.

Learning hypertext technology. I now turn to describing one instance of technology-learning, specifically Nell's acquisition of hypertext technology. During Nell's fourteen-year tenure as a journalism teacher, she was overextended. She felt she "never could fly" — in other words, she had no time to develop professionally through continued learning, as she was constantly engaged with the immediacy of deadlines. With the move to middle school English, Nell actively sought professional growth. She wanted to learn more about teaching English and, without the burdens of her extracurricular journalism activities, had time to devote to professional development. She had already learned about and implemented a writing workshop approach in her classroom and had become a prolific user of listserv communication where she "tested out her ideas" with colleagues. She had completed a Masters degree in Education and was pursuing a Ph.D. in English Education because she had not learned as much about educational theory as she had hoped in her Masters program.

During this doctoral program, Nell took a rhetoric course where she learned about hypertext theory and web authoring to construct hypertext narratives. Though Nell had difficulty mastering the challenging technology, she managed to learn web authoring because she had time and assistance during the software learning process and was very interested in the topic.

During the course, Nell undertook ambitious hypertext projects that frustrated her due to their complexity and her inexperience with the technology. She sought help from her professor, but ultimately relied upon technology consultants at the writing lab. Her vested theoretical interest in the project motivated her even during the most frustrating moments. She resonated with hypertext theory, as she felt "it closely mirrored the way I

think my mind works" (2, 20). She thought that "hypertext is going to change us because ... it's gonna move us away from that sort of false linearity that book technology has imposed upon us" (2, 20). She also felt it focused attention on the roles of readers, writers, and content since "it kind of makes the writer think more about content and so ... you're not focusing so much on structure, you're focusing on content" (3, 13). Hypertext offered new theories of writing to contemplate.

During and after completion of the course, Nell developed a great interest in hypertext theory. She said, "I was so intrigued by it. That's why I decided my dissertation would have something to do with hypertext theory" (1, 6). She wanted to expose her students to this non-traditional approach to writing and reading, and in her dissertation, she imagined investigating children's writing processes when authoring hypertexts. Before actually teaching about hypertext with technology, Nell assessed her own facility with the technology – to determine if she could actually use the technology with her students in the ways she imagined. She had authored hypertexts using the web, but her school did not have web access. She decided to explore other alternatives.

Pendleton Middle School owned HyperCard, another software for creating hypertexts. HyperCard software compiles media (text, graphics, etc.) on individual cards and allows links to be created between information on different cards. A colleague who had used HyperCard in the past had forgotten how to use it and handed Nell the manual, but the manual did not make sense to Nell. With no coach, she attempted to learn the software on her own but could not penetrate the manual.

Nonetheless, Nell was committed to exposing her students to hypertext. She decided to teach hypertext using a non-computer approach – paper and string. She

described, "I had my students write a piece of hypertext fiction and put it on paper and then had string connecting it. And they highlighted the word and then made decisions. Ok, now this word relates to this page of the story that somebody else wrote over here.... that got the idea across" (1, 10). While Nell felt that this approach successfully communicated the theory, she still sought software that might support hypertext writing. In many articles, chapters, and books about hypertext theory, Nell discovered StorySpace, another computer software that allowed links between information. Nell purchased the program and started learning it on her own.

Nell went to work, "And so [I] kind of played with it [StorySpace] and played with it....and even after a couple of months of dinking around with it, and I'd play around with it for a while and get frustrated and do something else, I finally had to call them [helpline] and say, 'Okay, how do you make a link?' And it's really easy" (2, 27). Playing with it was not sufficient for Nell to learn the program. Instead of abandoning the learning pursuit, she invoked a familiar strategy and sought a "consultant." In contrast to learning HyperCard, in this case there was a "consultant" available via telephone to assist her.

Once comfortable with StorySpace software, Nell wanted to use it to support her teaching of hypertext concepts to her students. Nell applied for and won a grant that supplied her school with 50 individual computer licenses for StorySpace software. StorySpace was loaded on new PCs, and she started teaching about hypertext using this software.

Nell's students first used StorySpace to compose hypertext poetry. Nell evaluated the project favorably. She wanted her students to think about relationships between ideas,

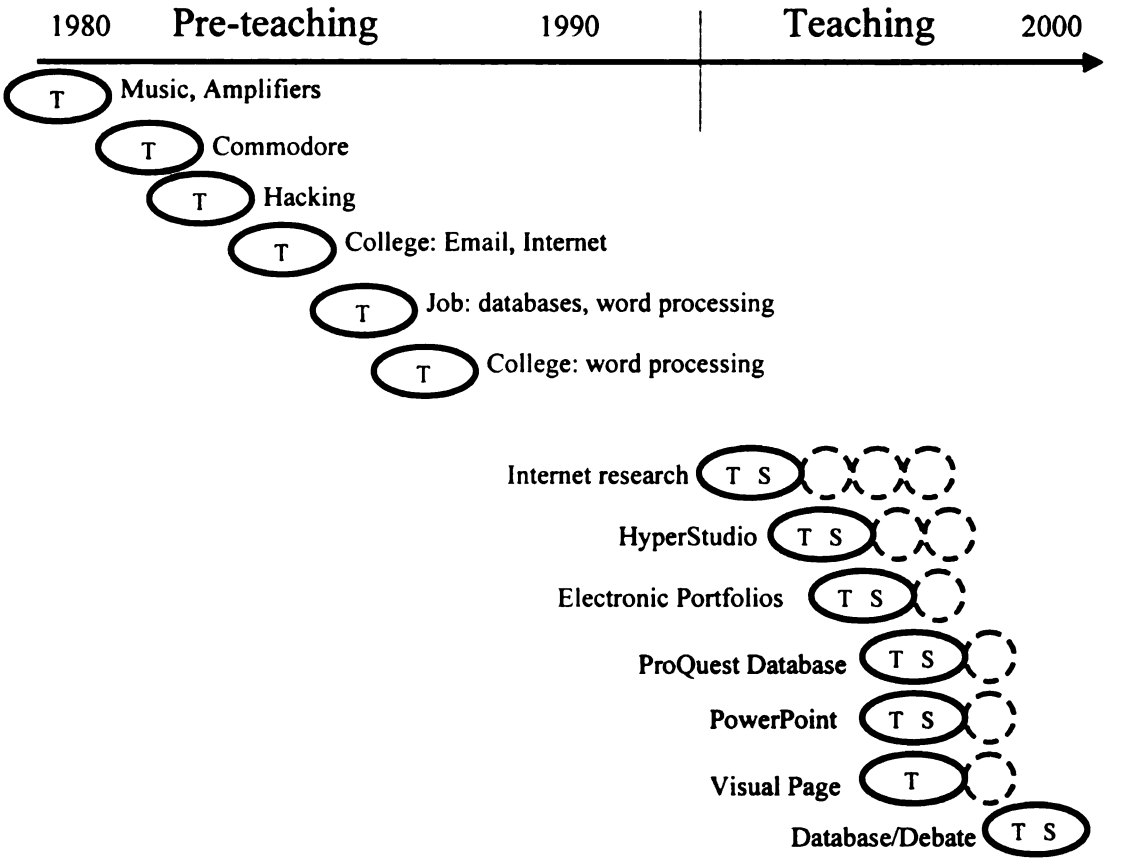
and she concluded, "And StorySpace is wonderful for that." Nell's students began other hypertext projects, including writing hypertext biographies and narratives.

Summary. Nell began to learn technology 16 years into her teaching career, with no prior experience with it. Her technology-learning was grounded in her learning of English subject matter. Her integration of technology into her teaching was achieved through subject matter-based projects. She did not use canned drill and practice software with her students. Finally, it is important to note that Nell found a way to use **every** technology she learned in her English curriculum.

Roger Karpenter

Technology-learning history. As Figure 2 illustrates, Roger began learning technologies during his childhood. Roger played with music technologies and then began working with computers shortly after high school and through his college years. Therefore when he entered the teaching profession, he had extensive experience with technologies. In six years as a teacher, he had learned and used seven technologies.

Roger's initial learning experiences as a teacher (denoted as ovals), like those of Nell, involved learning technology connected to subject matter. For Roger, the subject matter involved in the initial learning experience were problems of practice or subject matter-related interests – not learning English content as a learner himself. In terms of technology, once he became a teacher he essentially re-learned familiar technologies (i.e., those he first encountered in his pre-teaching days) for one of two reasons—so that he could adapt it to a subject-matter related purpose or because it had changed so much since he had first learned it.



Note: T = Technology; S = Subject Matter (English)

Figure 2

Roger's Life History of Technology Use and Learning

For example, before teaching, Roger already had learned to communicate via the Internet. However, when he began teaching, the Internet supported graphical interface browsers such as Mosaic. He wanted to use resources on the Internet for student research because there was a dearth of materials on-site, so he re-learned how to use Internet resources – specifically how to use these new browsers. This same resource problem prompted him, later, to learn ProQuest database. As another example, in the year I observed Roger, he was re-learning database software to serve as an organizing tool for a debate project he was designing for the following year. He had led a debate project but felt the students had trouble organizing and subsequently accessing the information they

needed. He thought a database would serve the students for this project. Roger's learning of Visual Page, a web-authoring software, presents a slightly different case. When he first learned it he had no specific subject matter teaching goals in mind; only later, when the need to design a class web page arose, did it occur to him that it supported his teaching.

Learning ProQuest database. In Roger's English/history class, he regularly included current events within the curriculum. Since, Hallivale JHS never authorized a newspaper subscription, Roger used the few journals in the library, magazines from his dentist, students, and visitors, and his own newspaper to support the current event work. Despite the enduring problems with the breadth of literature available in the school, Roger planned a project in which his students studied and prepared to debate each other on three current-event topics (death penalty, charter schools, and drug testing).

Roger had extensive experience with a wide variety of technologies. He also had some experience using technology to support his teaching. For example, he had created bookmarks to informational resources (e.g., CNN and MSNBC) on his one Internet-connected classroom computer to serve as another resource for student research. This approach had its problems, though. Few students could use one computer simultaneously; these sites did not necessarily provide rich information about the topics under study; and the school required Roger to monitor students' Internet use. Using these online resources seemed like a step in the right direction, but it did not completely solve or alleviate the significant problem of access.

A few weeks before the debate project was to begin, the school librarian alerted Roger to the fact that the school now had access to ProQuest, an Internet database of thousands of current journal articles. ProQuest was similar to a *Reader's Guide to*

Periodical Literature but with a majority of the references providing full text. Roger started using this resource within two weeks. He explained:

> ...when I saw it, it was exactly what I was looking for, and so it took me, it was like something that when it came up, it was, it was like - It was a message from the gods! Okay? No, it was like it was there, it was what I was needing, what I was wanting, and I was like yippee yi, yippee yi, yippee yi yo kiya. I was pleased as punch and we were ready to go with that. Yeah. I couldn't get on it quick enough. (2, 19)

Roger "played with it [ProQuest] a little bit " or "putzed," (2, 18) as he described it. The librarian had not yet learned it, so Roger began learning it on his own. Roger quickly became comfortable with ProQuest. He was convinced that ProQuest would help the resource problem, and he planned to use it as a student research tool in the debate project.

Roger conducted a brief overview of the software for the students, and they worked in pairs on the project. Despite a few technical glitches during student use (that Roger solved with little angst), Roger believed the software program was an invaluable solution to his periodical literature problem and planned to continue using it.

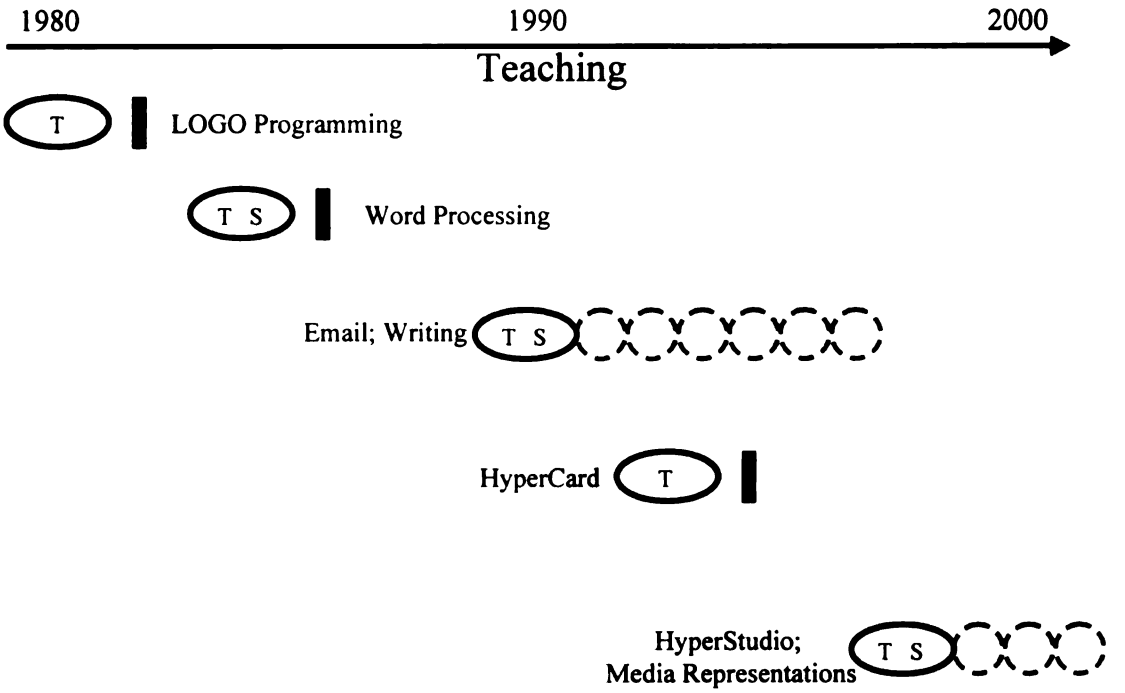
Summary. Roger brought extensive technology experience and knowledge to teaching. Even though he was acquainted with several technologies, he re-learned them in order to use them in meeting instructional challenges, such as limited library resources or students' ability to communicate ideas. Roger did face occasional technology glitches but only as he used technology to support students' learning goals.

Doug Logan

Doug had been learning technology since early in his teaching career, circa 1980 (see Figure 3). Since then, he integrated two (E-mail and HyperStudio) of the five technologies he learned into his teaching. Two of the three technologies that never made it into the classroom — LOGO and HyperCard — were learned with no connection to subject matter. Doug merely learned the software as a technology. In the case of LOGO, after learning it, he realized there was no connection to his subject matter and chose to teach it in an after school club. In the case of HyperCard, colleagues suggested that Doug learn HyperCard, but he saw no straightforward connection to English and felt his "technology-learning card" was full.

Doug used technology in his classroom when he saw how the technology could assist in his teaching of subject matter. Unlike Nell, Doug did not initially learn technology in the context of improving his own subject matter knowledge; nonetheless, his learning was often sustained by his first impressions of the technology's capacity to support particular aspects of the English curriculum. For example, Doug learned E-mail when a colleague proposed an E-mail pen pal project between Doug's fifth graders and the colleagues' university preservice students. Doug saw how the project would certainly involve his students' writing, so he went along with it. After participating, Doug found even more capabilities for E-mail projects to support the writing process. In the case of HyperStudio, Doug saw demonstrations of the software at a conference that offered visions of how it could support students' media representations of knowledge. He chose to learn it. In a similar way, he learned word processing because he saw how it would

support writing. Unfortunately, he was unable to actually have his students use it because, at the time, his classroom did not have enough computers.



Note: T = Technology; S = Subject Matter (English); P = Pedagogy

Figure 3

Doug's Life History of Technology Use and Learning

Learning HyperCard and HyperStudio. Early in his career, Doug's principal noticed his interest in technology and encouraged him to continue learning it as a professional focus. In addition to learning and using technologies, Doug became involved in a state wide technology-in-education association (TIEA). In his beginning years of pursuing technology, Doug learned programming, word processing, and E-mail. Use of E-mail led to many distance projects that supported writing development for his students. Doug claimed technology-based projects "spiced up" his curriculum and his teaching. As soon as Doug felt his students were getting bored or he was getting too comfortable with

the projects, he sought opportunities to learn about other technology that might support subject matter in different ways.

At the TIEA annual conference, Doug's favorite activity was serving as a presider where he introduced presenters to their audience. In doing this, he learned about innovative ideas in the field. At one of these conferences, colleagues encouraged Doug to learn HyperCard software. At the time, Doug did not feel ready to learn a new technology. He explained how he felt, "I'm handling this right now and I can't even look at that because I don't want to try to learn something new" (2, 15). He eventually examined the software but realized, "you get lost in the lingo real quick, and I didn't like HyperCard" (2, 12).

A few years later, at the same conference, colleagues shared information about a new program called HyperStudio. At that point in his career, Doug felt, "I needed to move on...again the stagnation" (2, 15). He was open to change and, "as soon as I saw it, I went 'Wow, way cool.' And I got involved" (2, 15). The HyperStudio demonstrations led Doug to believe that it was "kid-friendly" and could assist students in communication skills or "telling stories." He had been accumulating an eclectic collection of computers in his classroom and believed he would be able use this program to support student learning.

Doug already had a set of "partner classrooms" that worked on E-mail projects with his students. He thought that he might be able to use HyperStudio with his partner classes "to spruce things up." Doug and his students began using HyperStudio to compile information about their community, in a project entitled "All About Allendale." The project was cross-curricular, involving issues of geography, social studies, math, science,

and language arts. Once the HyperStudio "All About Allendale" stack (the term for a HyperStudio project) was completed, they exchanged it with partner classes.

Doug felt that "it [HyperStudio] takes the technology and takes all the various components – the text, audio, and video – and brings it all in one nice neat package that looks good; kids understand it, and they understand how to use this technology with those three concepts to tell their story" (2, 15). Sharing the Allendale project led the partner classes to learn more about the Allendale students and their town with the assistance of multiple media. This inspired Doug to want to use HyperStudio in other ways in his curriculum.

Doug realized that his Nebraska E-mail partners resided near Independence Rock, along the Oregon Trail, a topic his students studied in social studies. Doug proposed an electronic fieldtrip exchange with his Nebraska partner teacher. The Nebraska class planned on studying the industrial revolution. Both Doug's students and the Nebraska students used HyperStudio to develop electronic fieldtrips of sites local to them (e.g., Independence Rock, Nebraska or Greenfield Village, Detroit) to share with each other. Doug's work with E-mail projects was enhanced by the inclusion of HyperStudio as another resource by which his students could communicate.

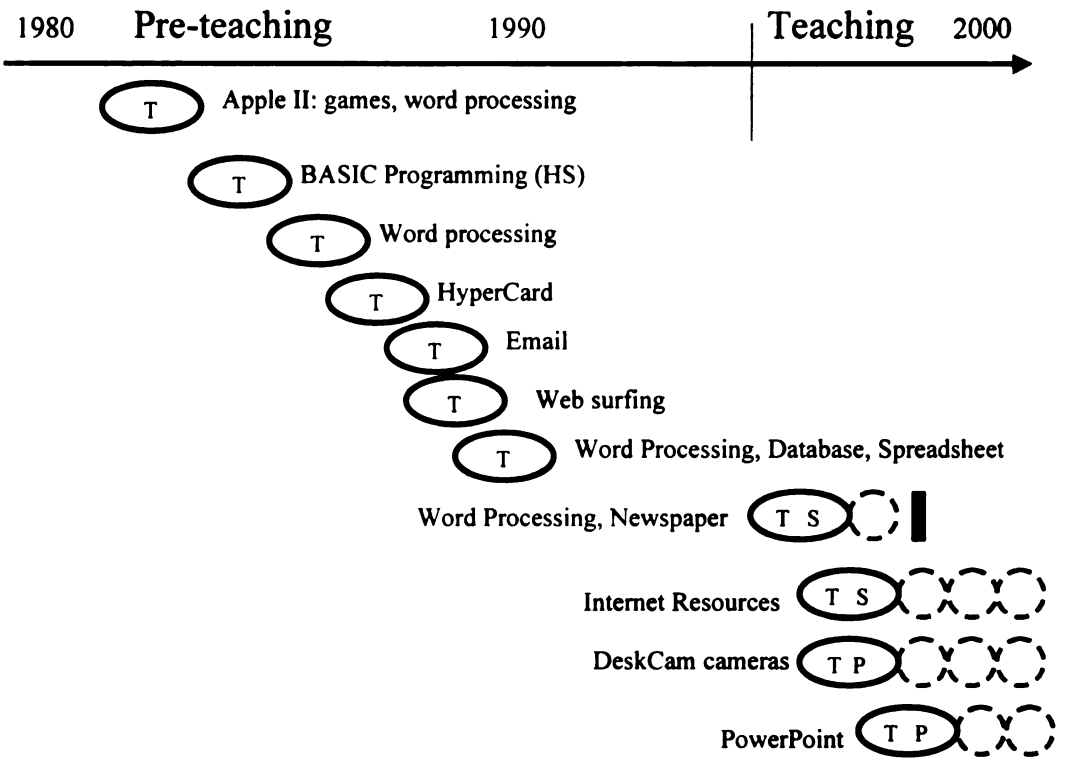
Summary. After the LOGO experience, Doug appeared to look more closely for subject matter connections before learning technology. Ultimately, Doug was more successful learning a technology and integrating it into his English teaching when he saw a connection to curriculum prior to learning the technology.

Laura Yates

Laura (see Figure 4) grew up using Apple II computers as a student and could not conceive of life without them. Rather than learning technologies that relate to English subject matter, she learned a great deal about technologies that support her work as a teacher, which then might, or might not, show up in her teaching of English. As a teacher, Laura used technologies in support of her *teaching* of English but not in direct support of her students' *learning* of English content or processes.

The one case where technology had potential to get in the hands of students was a newspaper project. Laura had just learned word processing during previous summer employment, and as she learned it, she saw potential applications for its use in her English class. Shortly into her first teaching year, Laura implemented a newspaper project. Laura felt that her students did not have enough computer and word processing skills, so students hand-wrote the newspaper while Laura assembled it in a word processor.

The other instances of technology-learning and technology use involved Laura learning technology tools (offered on her high-tech teacher desk) and using them in her teaching — but specifically as a tool for her, the teacher. The students tangentially benefited from the technology. For example, Laura used the Internet to immediately find answers to student questions. She used PowerPoint to display excerpts or quotes for help in guiding discussions of literature.



Note: T = Technology; S = Subject Matter (English); P = Pedagogy

Figure 4

Laura's Life History of Technology Use and Learning

Learning Web as Information Tool. Laura was the newest teacher among the group of four participants, having taught for only three years at the time of this study. Like Roger, she grew up using technologies both in her own education and for her personal use. She taught in a new high-tech school with a high-tech "teacher desk" in every classroom. She had a networked computer, VCR, multi-use cameras, satellite access, and two large class monitors. The school had invested in computer technologies instead of print materials for their library under the philosophy of offering the most up-to-date information. Laura used her extensive technology experience and the technological features of her classroom to facilitate her classroom instruction.

Laura learned to navigate the World Wide Web during college with assistance from her husband. After his introduction, Laura managed to play with it occasionally. At that time, she just browsed for interesting web sites like the "jelly belly web site."

As a teacher, Laura participated in a National Writing Project and began thinking about the web's applicability in education. There, she learned to compose her own web page and examined many more. She saw demonstrations of web authoring, and with assistance from project leaders, she had time to develop her own web site. In her teaching context, the library was extremely limited, as the school did not choose to spend money on book and periodical acquisitions. Consequently, she saw web browsing as a possible solution to these limitations.

After moving to the new school building, Laura had immediate access to the web at her teaching station. She began using the web in her daily teaching, as demanded by student questions. For example, while reading Edgar Allan Poe's "The Cask of Amontillado," she found students had difficulty understanding the story. She thought having a better picture of the story's setting might help them. In the moment, she searched for "catacombs" on the web and found the Vatican offered an electronic field trip through catacombs. In another instance, Laura used the web as a learning resource for herself. She had difficulty explaining the Cold War to her students – as background for a story they read. After school, she found resources on the web to educate herself, so she could explain the concepts to the students adequately. Laura found that using the web to access information, sometimes instantaneously, offered her students the supplementary information required to understand concepts and stories they read about in class but that were not available in the school library.

Summary. Laura learned technology that had more connections with general pedagogy than with English subject matter. Not surprisingly, she used the technologies to support teaching, as opposed to providing technology as a tool the students used for meeting subject learning goals.

Technology Learning Trends

These teachers integrated technology to support their subject matter instruction more often when their initial learning experience involved (a) learning technology in the context of learning more English/language arts content or (b) learning technology with an awareness of a connection between the technology and the English/language arts. Translated into the graphics of their learning histories, there are more dotted circles (indicating continued use) following ovals with a TS denotation than with ovals with only a T denotation. This trend illustrates the importance of subject matter connections as part of the technology-learning experience. The ACOT researchers found teachers' approaches to and beliefs about teaching changed as teachers were exposed to technology, suggesting that *exposure to technology* was the impetus underlying reform in teaching with technology. However, the trends across the four teachers in this research suggest that learning about subject matter — or at least thinking about subject matter while learning technology — impacted the extent to which the technology was actually integrated into instruction as a support of subject matter teaching and learning. Certainly, simultaneously offering exposure to technology and connections between the technology and subject area may afford the best possible learning situation.

Teachers brought varied levels of technology experience to their encounters with technology. At the very least, stage models like the ACOT model should not assume that

teachers learn technology tabula rasa, as blank slates without any technology history. Roger and Laura, who brought extensive technology experience to initial technology-learning experiences, skipped the beginning stages that involved grappling with technology installation and organization and using technology for drill and practice. The developmental stage model broke down.

The stage model did not hold up well even for those teachers, Nell and Doug, who first encountered technology while they were teaching. Nell never struggled with the computer installation and put her first learned technology to use for purposes aligned more with the ACOT invention stage. Doug struggled more with finding thoughtful use of technology for his English instruction than with actual computer set-up. This difference may be attributed to the fact that Nell, especially, held more reform-oriented beliefs about teaching English *before* pursuing technology-learning. With such beliefs, it seems unlikely that the teacher would use drill and practice software with her students. Recall that ACOT participants' instruction was characterized as more "traditional" at the beginning of the project. Nell's experience with alternative approaches to teaching might have made her more comfortable with the sometimes unfamiliar changes in classroom organization and student interaction that accompanies approaches like student-centered instruction.

Learning Model

By examining trends across the four teachers in this study and the cases of individual instances of learning technology, I developed a general model that illustrates the technology-learning process. In the next section, I present the model and explain it

empirically (recalling the aforementioned data) and theoretically (using educational theory and philosophy).

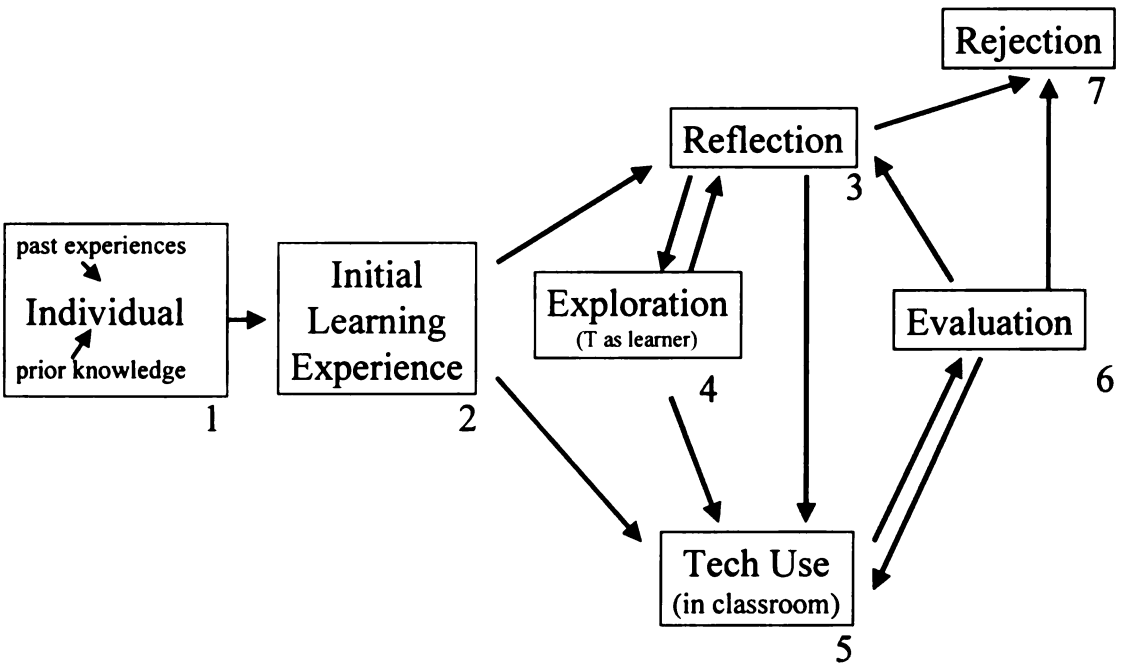


Figure 5

Practicing Teachers' Technology-Learning Model

The learning model (see Figure 5) consists of several phases. The learner (1) has an initial learning experience (2), may reflect (3), explore further (4), or use the technology in her classroom (5), and finally evaluate the technology's effectiveness in attaining the set goal (6) which may lead to more use (5), rejection of that particular technology use (7), or further reflection (3). Not every learning experience unfolds in the same pattern, as the many arrows depict the potential variation in pathways through the model as seen in my data. In Table 2, each teacher's narrative of one *technology-learning instance* from the preceding section is summarized using the model in Figure 5. This instance is represented by a series of numbers that refer to a path through the general

learning model in Figure 5. For example, when Nell learned hypertext authoring, her path, according to Figure 5, was 1-2-3-4-3-4-5-6-5. Nell was an individual learner who brought some personal experiences with technology (1). She learned hypertext technology within a doctoral course (2). During and after the course, she reflected on the applicability of teaching hypertext to her middle school students (3). Nell learned web authoring, but her school only had HyperCard software. So she explored and tried to learn HyperCard (4). She could not understand HyperCard and reflected on her next step (3). She taught hypertext theory to her students without technology. Meanwhile, she explored other possibilities and learned StorySpace software (4). Once comfortable with StorySpace, Nell taught hypertext theory and writing to her students through the use of StorySpace (5). After her first hypertext project, she evaluated it as successful (6) and led a series of more hypertext writing projects (5).

Table 2

Teachers' Pathways through Technology-Learning Model

Teacher	Technology Learned	Pathway through model*
Nell	Hypertext authoring	1 – 2 – 3 – 4 – 3 – 4 – 5 – 6 – 5
Roger	ProQuest database system	1 – 2 – 3 – 5 – 6
Doug	HyperCard/HyperStudio	1 – 2 – 3 - 7 // 1 – 2 – 3 – 5 – 6 – 5
Laura	Web as informational resource	1 – 2 – 3 – 5 – 6 – 5

Note: *Numbers refer to the categories within the general learning model (see Figure 5)

The following section includes a fuller description of each category within the learning model (Figure 5).

The Individual Teacher (1)

Nell, Doug, Laura, and Roger entered the learning process with different sets of prior experiences and pre-existing knowledge, specifically in relation to teaching the English language arts and knowledge and experience with technology. This knowledge and experience shaped each teacher's interests, thinking, observations, commitments, and goals in prospective learning opportunities. In this way, the learner played a vital role in choosing what to pursue as a learning goal. Nell's desire to learn and change her teaching made her seek opportunities to learn more about the teaching of English (where she just happened to be exposed to technology tools, as well). Laura's and Roger's extensive technology experiences prior to teaching placed them in the position of naturally exploring technological tools to help alleviate problems of practice — including teaching English subject matter or improving their general pedagogy. Doug, with a professional interest in learning about educational technology, took advantage of most opportunities that involved learning technologies. Bransford and Schwartz (1999) describe how these prior experiences and knowledge function as interpretive lenses for subsequent experiences. Given a new situation, the teacher interprets, thinks, questions, or evaluates it based within her "field" of alternatives — the field being her previously acquired knowledge and experiences. Jarvis (1987a) characterizes such previous experiences as an individual's "biography," which functions similarly to Bransford & Schwarz's "field."

Initial Learning Experience (2)

Depicting an individual as responsible for developing learning goals is common among constructivist perspectives on learning. A stimulus, which may be an outside situation or an internal thought and evaluation, ultimately prompted discord between the

teacher's prior knowledge and the world with which (s)he interacted. Such discord is called cognitive conflict (Pressley & McCormick, 1995) and essentially created disequilibrium in the teacher. Jarvis (1987a) described this process as "personal biography" conflicting with an experience, culminating in action to accommodate new experiences:

> Disjuncture, or discontinuity, between biography and experience of the wider world is a fundamental condition of human learning...the need to establish this harmony or mastery is at the start of the learning process: this continuity may be between biography and present experience or between biography and idealised experience. Where there is no harmony, this creates in human beings a state in which they might question their present situation, where they might seek to add to their skills, etc. so that they might achieve the desired state of equilibrium (Jarvis, 1987a, p. 80)

Nell and Roger's disequilibrium was prompted by a discord between their biography and their *idealized experience*. For them, the initial learning experience was a measure taken to reestablish equilibrium (see Figure 6). Doug and Laura's disequilibrium was prompted by a discord between their biography and *present experience*. For Doug and Laura, the initial learning experience was the "present experience," and the force of disequilibrium (see Figure 7).

Each teacher had an internal disposition or "biography" or "field" developed out of their life experiences. In the case of Nell and Roger, each had also developed in Jarvis' (1987a) term an "idealized experience." Disharmony between their biographies and their idealized experiences caused disequilibrium, prompting action on their part. Nell, upon

moving to the middle school, described herself as ready for change. She felt she had a knowledge deficit in terms of her knowledge of English and the teaching of English. She wanted to become a better, more "creative" teacher. Not being the creative teacher she idealized prompted her to begin developing professionally. She enrolled in and obtained her Masters degree, then began pursuing her doctoral degree. Indeed, it was participation in these initial learning opportunities she had chosen to pursue wherein she also happened to learn technology that prompted her to develop curricular innovations that included technology.

Because Roger had *not* been given opportunities to use computers in school, his ideal educative experience had students receiving every educational advantage, especially access to technology. Therefore, Roger brought every technological opportunity that he had found personally useful to his students. For example, he slowly increased the number of computers (albeit older models) in his classroom for greater access. To some extent, Roger was in constant disequilibrium. It is uncertain when Roger might have felt he had the exact set of resources that adequately provided his students with technological experience. It was the process of searching for more technological opportunities for his students when Roger learned new technologies (his initial learning experiences). As depicted in Figure 6, Roger and Nell were in a state of disequilibrium and chose learning experiences that they felt might provide them knowledge and experience that would move them closer to an idealized state.

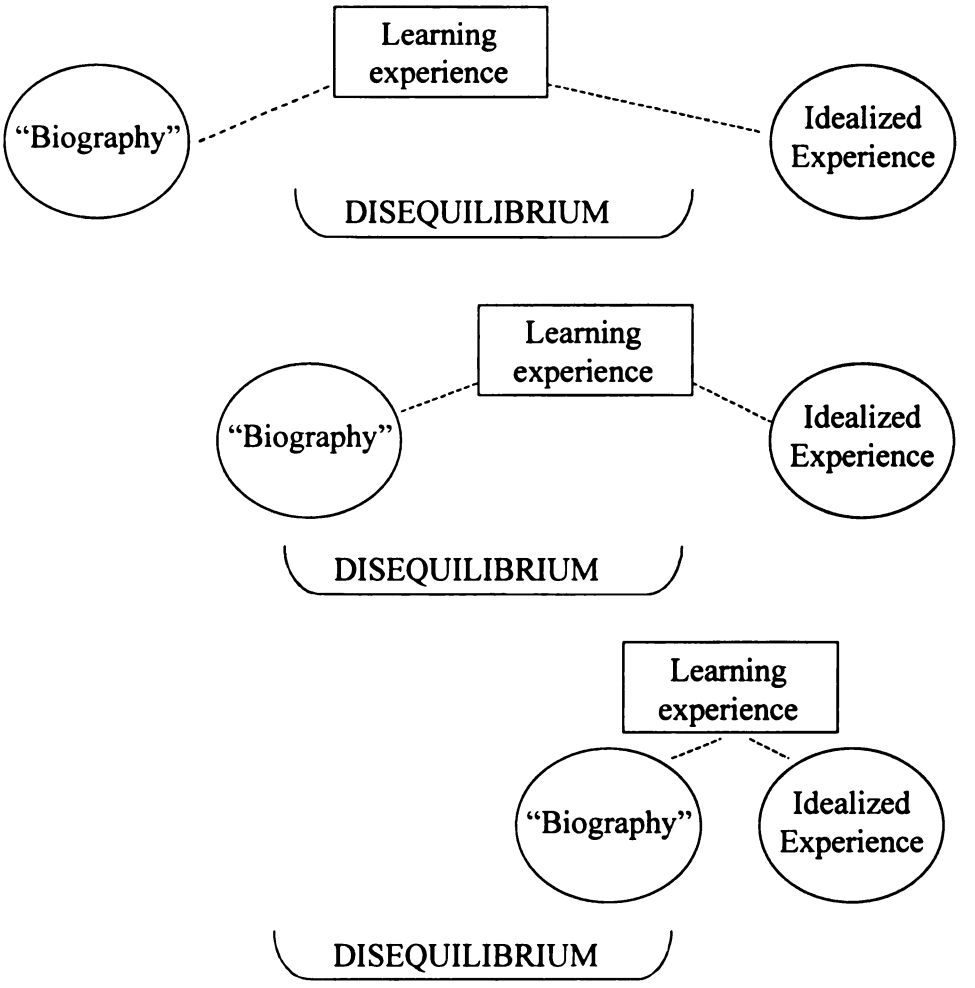


Figure 6

Learning Experience as an Equilibrating Force

Doug and Laura's disequilibrium emerged from external experiences in which they participated. Doug's general interest in educational technologies transformed into a professional focus. He always searched for opportunities to learn more and participated in projects that involved the use of technology. It was the potential connection with English subject matter that Doug identified in the technologies after he was exposed to them that caused disequilibrium. When such discord occurred, he finished learning the technology, if needed, and used it or explored the technology more fully until he was able to use it.

For Laura technology was so commonplace as to be almost invisible. She believed technology was an everyday tool, and she regularly witnessed the advantages it brought to her in preparation and teaching. Like Doug, her disequilibrium occurred when she participated in an experience that indicated the potential benefit of a technology for her teaching. This potential benefit prompted her to learn completely the technology to support her teaching. The role of the learning experience as it functioned for Doug and Laura is illustrated in Figure 7.

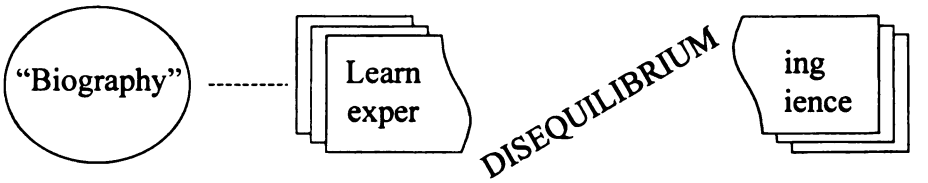


Figure 7

Learning Experience as a Dis-equilibrating Force

In most cases, it took considerable time for technology to actually be integrated into the classroom. For teachers like Roger and Nell who had idealized goals for which they strove, not just any learning experience would do. It took time for each to identify and partake in experiences that matched their interest or could solve their problem. So, as a teacher developed more specific goals, the likelihood decreased that more general in-service would match the goals. For teachers with vague, general interests in technology, like Doug and Laura, finding an appropriate learning opportunity was not the problem. These teachers learned about many technologies, but not all the technologies served a purpose. Another way to characterize this important distinction between these pairs of learners is to suggest that for Roger and Nell, the technology is always a means to an end,

with the end being either greater student opportunity to learn (Roger) or greater teacher opportunity to learn (Nell). For both Laura and Doug, technology is just a part of life. And if one experiences it often enough, occasionally, uses will present themselves to the teacher. For Laura and Doug, the uses of technology were learning induced whereas for Roger and Nell, the technology-learning was goal induced.

Reflection, Exploration, and Technology Use (3, 4, and 5)

Once the initial learning experience was completed, a teacher proceeded to one of three phases: reflection about the technology, exploration with the technology, or actual technology use in teaching. Teachers did not necessarily proceed to each of these phases nor did they experience them in a particular order, as illustrated in the cases. For example, Nell moved back and forth between reflection and exploration several times before use, yet Roger reflected and then directly used the technology in his classroom.

Reflection involved (a) examining a technology's potential applicability for supporting the curriculum, (b) assessing if appropriate resources existed in the school, and (c) conducting a self-assessment of one's perceived ability with the technology. A teacher's reflection may have pushed her to explore it or other options further or reject it altogether (little applicability and/or low self-assessment and/or lack of required resource). For example, during Nell's reflection after learning hypertext software, she realized her school did not have the appropriate resources (web authoring capability), so she proceeded to explore other technologies that support hypertext writing. After Doug learned LOGO programming, during reflection he realized programming had little applicability to his curriculum, and he rejected its use for the classroom.

Reflection may also have led a teacher to use the technology in teaching (when she sensed high applicability and/or high self-assessment). Roger, after teaching himself the ProQuest database, reflected that ProQuest would alleviate his literature access problem (applicability), and he was comfortable with the software (self-assessment). Laura's easy access to the web and her comfort with Internet browsing (high applicability and high self-assessment) led her to use it for supplemental information that their library could not provide.

During exploration, the teacher became a learner again, seeking out or creating more opportunities to master the technology. This occurred when teachers needed to identify a more suitable technology for a task or to increase one's facility with a technology, as illustrated when Nell stopped learning HyperCard and chose to explore StorySpace software. After exploration, the teacher reflected again to assure that the technology was applicable to a goal and the teacher was comfortable with the technology, itself.

Teachers also used a technology to support their classroom instruction and students' learning. This often occurred after reflection, when a teacher felt a particular technology supported a curricular goal (path 1-2-4), or immediately after the initial learning experience (path 1-4). Doug's initial learning of E-mail was immediately followed by an E-mail writing project involving his students and university teacher education candidates. He described the project as "doing a favor" for the teacher education instructor, and he used the technology in the classroom without exploration or reflection. It was after using it that he evaluated the technology's effectiveness, engaged in further reflection, and explored new applications of E-mail for writing projects.

Evaluation (6)

After using technology, teachers evaluated the degree to which the technology met the instructional goals the teacher intended. If the evaluation was positive, the teacher continued to use the technology. Laura felt her use of the web to answer students' questions helped them better understand story content. Thus, she continued to use the web as an information tool. However, if the evaluation was negative, the teacher ceased using it altogether or reflected upon its use to develop different uses for it. Laura used word processing as a support for developing a newspaper. After the project, though, Laura felt that she had done most of the word processing (due to the students' lack of technological skills). She chose to discontinue that project. Nell also evaluated her first application of PowerPoint in her English class (using it to display a poem) negatively, but she developed another curricular use—having students use it to communicate their thoughts about a book they had read.

Rejection (7)

As indicated, a teacher's reflection and evaluation ultimately may lead to rejection of a particular technology use. During reflection, many situations may lead to rejection, including a low self-assessment of one's ability with the technology, a lack of appropriate resources at the school, or a lack of coordination between the technology and the desired subject learning goal. Likewise, after using a technology, the teacher evaluated the extent to which the technology was helpful. If a teacher determined that the technology did not support or detracted from a subject learning goal, she may stop using that particular technology altogether.

Discussion

Teachers take multiple pathways through this learning model in order to maintain or reestablish equilibrium, which is the state to which learners aspire. In the process of equilibration, Piaget (1964) distinguishes between assimilation and accommodation. Assimilation occurs when an individual does not restructure his or her prior knowledge (cognitive concepts or structures) but rather reinforces them. In the case of assimilation, learning a technology may satisfy a teacher's desire or interest but does not impact or provoke change in a teacher's practice. Equilibrium is achieved but little new learning has been developed. Accommodation, on the other hand, occurs when an individual develops new cognitive structures (Greeno, Collins, and Resnick, 1997) that compensate for discordant experiences or information. The process of equilibrium is not established quickly or easily. An individual may make small accommodations over a long period of time. Together, these accommodations reestablish equilibrium, which may explain the longer "germination" periods Huberman (1995) identifies in lone-wolf learners. For example, Nell's initial learning of hypertext theory, reflection and exploration with hypertext technologies, and several different uses in the classroom occurred over a three year period. During this span, she changed (accommodation) her conceptual understanding and practice of writing instruction. This perspective that conceptual understandings and eventual use change over lengthy periods of time coordinates with a new conception of transfer of learning and knowledge described by Bransford and Schwartz (1999).

These longer periods of learning and the role that prior knowledge and experience play in my conceptual framework support a reconceptualization of transfer, called

"preparation for future learning (PFL)" (Bransford and Schwartz, 1999, p. 68). PFL broadens transfer by defining it as "an assessment of people's abilities to learn in knowledge-rich environments" (p. 68) where learners can make use of available resources. The focus shifts from determining if a learner can generate a finished product (replicate previously "learned" material) to determining if a learner is prepared to learn to solve new problems, over time, or "extended learning" (p. 78). At the core of this new conceptualization is acknowledging that people "'know with' their previously acquired concepts and experiences" (p. 69). Those prior experiences and concepts form a "field of alternatives" that impact how a learner interprets an experience and what s/he observes in future experiences.

Not only do prior knowledge and experience impact how and what the learner learns, the learner's environment exerts an influence. Unlike former conceptions of transfer that focus on replicating learning in a similar situation, PFL "emphasizes that people can actively change the given situation into something that is more compatible with their current state and goals" (p. 82). The individual may change a situation to be compatible with her interpretation of an apt learning context. Bransford et al. (1999) indicate that creating situations that allow learners to "bump up against the world" (p. 82) to test their thinking is important. Active transfer involves people's willingness to seek others' ideas and perspectives.

The learning model developed to characterize the pathways of these four teachers demonstrates, with real examples, this "potential for learning" perspective. The teachers did not directly apply or transfer the technology learned in their initial learning experience to their teaching. Rather, they spent time reflecting, consulting other

resources, and ultimately building an approach that used the technology to support English instruction — in ways unique to their situation. Often, their first approach to technology use was not satisfactory, leading to reworking of the approach or role technology played in the subject matter instruction. This ability to wrestle with the place of technology, like these teachers do, rather than applying (perhaps thoughtlessly) the technology directly to instruction may better serve the education of students with support of technology.

Past approaches to professional development and inservice training has focused on direct application (i.e., putting the learned technology into use) rather than preparation for future learning and use with technology. These approaches have been organized around teaching technologies to teachers of diverse grade levels and subject matter at the same time, making the possibility of connecting to subject matter rather improbable and infeasible. In other cases, developers have created technologies for specific reform-oriented pedagogical purposes. Yet, teachers use the technology in accordance with their field of experience and particular setting. In assessing teachers who have participated in these past approaches, oftentimes a teacher is described as failing when she uses the technology in a different way than taught. It seems more beneficial and educative to provide the teacher opportunities to learn about technology and time to experiment and develop appropriate ways to use it to support her teaching.

In fact, the learning model developed herein and its corollary finding that teachers may take time to reflect, experiment, and develop thoughtful uses for technology is consistent with research in adult learning (Jarvis, 1987a; 1987b; 1995). Jarvis developed an empirically-based model of the adult learning processes. Common elements between

Jarvis' model and mine include: the person, experience, practice or experimentation, evaluation, and reasoning and reflecting. Differences existed: the data that gave birth to my model did not uncover memorization as a key element, and I acknowledged, yet did not illustrate in the diagram, the difference between a person who changed or had not changed. Jarvis tracked and characterized nine different paths or responses to an experience (potential learning) that grouped into three categories: non-learning, non-reflective learning, and reflective learning (Jarvis, 1995). With a larger participant pool, I, too, can begin to assess different pathways through my model.

Though my model is based on four teachers' experiences and therefore has limited ability to generalize to broader contexts, its resemblance and similarities to that of Jarvis's model is encouraging and suggests that it might well generalize to other learners and settings. Nonetheless, I need to investigate how and if my model holds up across more teachers and across diverse settings. Such an examination would indicate if and how more teachers traverse through the model. For example, the four teachers in my sample represent a very different cohort than recent graduates from teacher education programs that involve technology courses (albeit varied to a great degree). I need to examine how these more recent graduates integrate or learn to integrate technology in their teaching to determine if their experience can be adequately represented by the model I have developed. In addition, working with more teachers will allow me to better characterize what paths lead or do not lead to learning and change in practice.

Explanatory Power of the Model and Implications for Professional Development

The learning model explains why learning to use technology to support subject matter instruction is a lengthy process. Clearly, it is not a simple LEARN + USE process.

Past approaches to technology professional development have been developed according to more traditional models of professional development like short-term inservices. These one-shot, one-day workshops do not change teachers (Darling-Hammond & McLaughlin, 1996; Fullan, 1991, Lord, 1994; McLaughlin, 1991). These findings imply that learning to integrate technology is a lengthy journey that involves more than exposure and learning of discrete technology skills provided as a one-shot professional development activity.

Various personal and contextual factors impinge upon the learning process; however, the research on barriers and successes in teacher learning is so varied (almost idiosyncratic) that it is hard to find consistent patterns. There is no common set of factors awaiting a "fix" or an "accommodation." Instead, these factors, such as the personal biographies, technology expertise, or knowledge all impinge upon a teacher's ability to learn and use the technology. Acknowledging, understanding, and using teachers' unique teaching situations and past experiences are important in professional development experiences. For teacher educators, principals, or even colleagues, it seems worthwhile to listen to and discover more about the teachers with whom we work — before we teach, guide, or collaborate with them.

Providing external stimuli, models, or opportunities is only one part of engaging an individual in a learning experience. We need to acknowledge and respect the fact that teachers' intentions develop through an accumulated set of prior knowledge and experience or "field of alternatives." Understanding the range of teachers' fields of alternatives might lead to more successful inservice activities. We might be able to fashion experiences that accord with teachers' needs and interests. Recall how, for Roger

and Nell, the initial learning experience functioned as a specific strategy to help alleviate their disequilibrium. These two teachers had very specific ideas about what kinds of learning they needed to help move them toward functioning within their idealized experience. Teachers like Roger and Nell will choose *not* to attend some inservices due to a lack of fit between its content and what the teacher deems interesting and worthy of a time commitment. Further, not every idea they learn in a learning experience chosen will be implemented. This must be acknowledged and even shared with teachers. We cannot expect teachers who bring different biographies to hold a similar regard for a common inservice or learning experience. Therefore, mandating technology inservices does little to guarantee that teachers will thoughtfully integrate technology. Yet, it is important to provide many learning options to serve the diverse needs and interests of teachers.

Some teachers hold very imprecise fields of alternatives in relation to technology. They might, like Doug, look for any experience with technology. My findings indicate that simply learning technology does not necessarily lead to integration. It seems important for those responsible for professional development in technology to acknowledge, indeed privilege, subject matter connections, especially for teachers who bring little knowledge of technology to the professional conversation.

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ARTICLE 3

THE RELATIONSHIP BETWEEN TEACHERS' TECHNOLOGY-LEARNING AND THEIR CLASSROOM PRACTICE

Abstract

This study examines the relationship between the teachers' own experiences learning technology and the kinds of learning experiences they provide for their students. Analysis identified teachers' reasoning and justification for learning and using technology and described the context and manner in which teachers used technology. The teachers' reasons to learn technology were closely associated with the reasons they used technology in their teaching practice. Further, the manner in which each teacher learned impacted the design of learning opportunities for their students. I discuss several kinds of knowledge (inferred from the findings) that teachers may develop when learning to teach with technology. They include (a) technology knowledge, (b) technology pedagogical knowledge, and (c) English-technology pedagogical content knowledge (E-T PCK).

Introduction

Common wisdom dictates that teachers have a propensity to teach as they have learned. In his seminal work, Lortie (1975) observed and characterized this phenomenon as a product of individuals' "apprenticeship of observation," the sixteen years of schooling during which students observe their own teachers teach. These apprenticeships of observation have a strong influence on a teacher's beliefs and predisposition toward teaching. A number of studies have shown the strength preservice teachers' beliefs have over other contemporary and better, some might argue, approaches to teaching and learning in teacher education programs (e.g., Book, Byers, & Freeman, 1983; Brousseau, Book, & Byers, 1988; Feiman-Nemser, 1983). It is a continuing challenge to bring the new understandings we have about learning into schools.

Teaching with technology, defined as using computers and peripherals in support of thoughtful subject matter learning, is an example of an instructional approach not learned through "apprenticeship of observation." The majority of veteran teachers never observed their teachers using computer technologies during their own education, and, computer technologies have been in existence only long enough for the newest teachers to have used and observed their teachers using computers. Even ten or fifteen years ago when the newest teachers were in school, if their teachers used technology, it is likely they taught programming (Cuban, 1986), which does not qualify as teaching with technology, as I have defined it. Preservice programs have only recently started to integrate technology into preparatory coursework, and these efforts are spotty at best. The question remains then: If teachers have not developed approaches to teaching technology through an "apprenticeship of observation" and if technology resources have not been

learned during their preservice education, how have teachers developed an approach to teaching with technological resources? This analysis examines that question with four middle school, English/language arts teachers.

While previous research has examined teacher technology use and learning (Hughes, 2000a; 2000b), it does not address the possible connections between teachers' learning and their own technology-supported teaching practice. To understand how four teachers developed approaches to teaching with technology and assisting their students who are learning technologies, I will explore the relationship between their own learning and the ways they teach. After describing this relationship, I will discuss emerging patterns and implications for professional development.

Method

Participants

The participants in this study were four, middle-school English teachers who might be described as "moderately" involved in technology use. That is, while they described themselves as using computer technologies for purposes other than drill and practice (the modal technology use in schools (OTA, 1995)), they did not teach in technology-rich and resource-rich school contexts. Table 1 summarizes the characteristics of the participants and the contexts in which they taught. Participants were invited to participate through research advertisements on a technology-in-education and a National Writing Project listserv and through recommendations by university faculty. I used an initial phone call to ask participants to share their technology-supported teaching practice and invited four teachers, whose technology use was more advanced than drill and practice, to participate. All agreed.

Table 1

Participant and Context Characteristics (School Year 1998-1999)

Teacher; Grade Level	Years Teaching	Years Pursuing Technology in Teaching	Computers in Classroom (#)	Computers in Lab/Library (#)
Nell Otherby; 7th/8th Grade	26	10	0	25 (PC) 40 (Mac)
Doug Logan; 5th Grade	25	20	8	0
Roger Karpenter; 9th Grade	6	6	9	20
Laura Yates; 9th Grade	3	3	1	35

Nell Otherby

Nell Otherby had taught 7th and 8th grade English for twelve years at Pendleton Middle School, located in a mid-western town. Prior to teaching at the middle school, Nell taught journalism for fourteen years at the high school level where she was so busy with deadlines she did not have time to do anything but teach. At the middle school, Nell had more time and took advantage of many learning opportunities, including professional development workshops, Master's degree courses (education) and Ph.D. courses (English). Her middle-school principal supported new approaches to teaching, such as when Nell started using a writer's workshop approach.

Nell's classroom did not have any computers, and she spent most days in the school computer labs. In 1998, the school opened a new 29-computer PC lab in October. They also had two Macintosh labs, one with Mac LCs and one with Mac Classics. Teachers checked out computer labs on a first-come, first-serve basis. The school had

recently hired a part-time network administrator, whose schedule allowed little time for teachers to consult with him.

Roger Karpenter

Roger Karpenter had taught 8th and 9th grade English and history at Hallivale Junior High School for six years. Hallivale is located in the urban fringe of a mid-western mid-size city. During those years, he led the school newspaper and yearbook projects. In the 1998-1999 year, Roger taught 9th grade English and 9th grade history in a block style, with two sets of 26 students taking English and history consecutively with him. The block design allowed him to integrate history and English goals and activities across both class periods.

Roger's classroom had nine functioning computers, two printers, a VCR, overhead projector, and TV/monitor. Five PCs were 33 MHZ or less; two were Mac Classics; two PCs were new. Roger's classroom had more technologies than any other classroom at Hallivale JHS. Though students were assigned regular seats, they often worked in small groups, and thus, the individual desks were rarely in orderly rows. In the classsroom posters concerning history or English topics hung wall to wall. The library at Hallivale JHS also had twenty Internet-connected Macintosh computers and two printers.

Laura Yates

Laura Yates had taught English and theater arts for three years at Bancroft High School (BHS), located in the urban fringe of a mid-western mid-size city. In 1998-99, my observations and interviews centered on Laura's 9th grade English classes.

At the end of Laura's second year teaching, the high school moved into a brand-new building. Laura's classroom was equipped with three ceiling-mounted cameras, two

TV monitors, and a teacher desk which included a PC-compatible computer with E-mail/Internet access and CD-ROM, a VCR, satellite access, video-stacks (in library) access, and a telephone with voice-mail and "homework hotline" features. Computer software controlled the cameras that display and record images from her classroom or other classrooms at the school. The school also had a Macintosh graphics lab and a PC computer lab. These were open for teachers to use when computer courses were not scheduled.

Laura felt very comfortable and confident in her English literature content knowledge. Yet, she recognized a deficit — she took very few courses about the teaching of English. Laura was pursuing a Masters degree of Critical Studies in the Teaching of English and participated in a national writing project.

Doug Logan

Since 1980, Doug had taught fifth grade at Algon Elementary School, a one-story building nestled in a rural town. The major area of Doug's classroom was given to student desks, which were organized into six groups of four with a few individual desks against the front wall. There were eight Macintosh computers, ranging from ten years old to a brand-new G3, in the classroom. One computer had a laser printer and Internet access. The school purchased only one of these computers; Doug collected the rest or received grants to purchase them. The entire classroom was covered with students' work, projects, and other colorful displays. The school did not have a computer lab, and there was no technology assistance.

Over the years, Doug became very involved in a state wide technology in education practitioner group. He served in many leadership roles, including being

president of the organization. He also had won many prestigious awards – a majority of them relating to his work with technology in education.

Data Sources

To explore learning processes and teaching practice, I conducted a series of three interviews with each teacher and observed each teacher's classroom for at least three days.

Interviews

The interviews focused on obtaining details about each teacher's life history, including education, career history, teaching positions, technology experiences, learning, and use. The series of interviews were adapted from Kelchtermans and Vandenberghe's (1994) cycle of three semi-structured biographical interviews. All interviews were tape-recorded, transcribed, coded, and analyzed.

The first interview explored the teacher's career history and technology uses, in personal and professional contexts. Between the first and second interview, I constructed a timeline of the teacher's life that allowed me to highlight when and what technologies teachers had learned in their lifetime.

The second interview was designed to meet two goals. First, the teacher examined the constructed timeline, clarified and corrected any inaccuracies and added any missing information. Second, the interview explored the teacher's goals, preparation, and use of technologies they used during instruction in an attempt to understand how and why the teacher learned it and used it in teaching. I used this data to begin searching for patterns between how and why teachers used technology and their own experiences learning

technology. Between the second and third interview, I constructed a list of the types of technology and technology-based activities present in each teacher's repertoire.

The third interview served three purposes. The first was to explore each teacher's English and language arts curriculum in an attempt to identify each teacher's own understanding of English/language arts and what (s)he thought was important to teach. Second, I wanted to clearly understand a particular technology as it was used in the classroom; thus, the teacher described the planning, instruction, and assessment phases of a technology-supported lesson that I had observed. I tried to understand how students did their work, the criteria the teacher used to judge students' performance, and the location and significance of this lesson in overall curriculum. Third, I tried to gain a better understanding of each teacher's beliefs about the role of technology in their classroom. (I also needed to check my developing hypotheses in this area.) I designed a sentence completion activity to accomplish this goal. The teacher constructed sentences by choosing a card from three tiers (see Appendix A). From a list of technology use/activities identified from past interviews and observations, the teacher chose a piece of technology and identified its impact on student learning or teaching. After constructing each specific sentence, the teacher described and explained more fully what experience or set of experiences helped him/her come to this belief. These associations and explanations began to identify the root sources of the teachers' decisions concerning use of technology in their teaching.

Observations

I conducted at least three full-day observations of each teacher. My observations focused on the teacher's use of technology in relation to instruction and student learning

experiences. Actions, verbal comments, use of learning tools, allotment of time to classroom activities, nature of classroom activities, classroom and lab arrangement, classroom decorations and displays were documented in field notes. Instructional artifacts (e.g., quizzes, tests, handouts, PowerPoint presentations, hypermedia narratives, etc.) were also collected. This observational data allowed me some first-hand experience in understanding the interaction between the teacher and his/her students.

Analysis

I approached the analysis of participants' learning from a perspective of individual change and learning. I began with a focus on each individual in which I reconstructed their past technology use and learning through various representations such as timelines, diagrams, lists, metaphors and narratives. I considered all instances of learning and use, seeking emergent patterns within an individual. The patterns allowed me to characterize a general learning approach for each teacher. The dimensions emerging from these patterns involved both rational and technical features (see Table 2).

The rational lens answers the question, "why?" Analyzing the data through this lens revealed teacher reasoning and justification for learning technology and using it in their teaching. The technical lens answers the question, "how?" Analyzing the data through this lens revealed the nature of learning software and hardware – in what context or manner was the learning accomplished?

Table 2

Teacher Learning and Practice Framework

Lens	Teacher Learning	Teacher Practice
Rational Why?	Why did the teacher learn technology?	Why did the teacher use technology to support curricular goals?
Technical How?	In what context and what manner did the teacher learn to use computer hardware and software?	In what context and what manner did the teacher teach or students learn to use computer hardware and software?

I compared each teacher's learning approach with his/her technology-supported teaching practice to search for patterns. The findings are presented through four cases, one for each teacher. For each case, I illustrate the teacher's approach to personal learning and technology-supported practice. Of greatest interest in this analysis is the question of whether teachers transport their own learning experiences to their teaching.

Findings

Nell Otherby

Teacher Learning

Why? Nell learned technology by happenstance. She was not a techie nor desired to become one. In the midst of other learning experiences about English content, Nell was exposed to technologies. For example, during a doctoral-level rhetoric class, Nell learned

about hypertext[1] in relationship to postmodern accounts of textuality (e.g., Bahktin, Derrida). Through her coursework, Nell learned and used web authoring tools to construct electronic hypertexts. At another time, Nell observed colleagues use PowerPoint, and she saw potential for it to engage her students in what she called "the representation side of language arts." After seeing the potential connection to her curriculum, Nell decided to learn PowerPoint. Nell's exposure to technology always occurred within another content-related context. She chose to further study or learn a technology if she saw connections between it and her curriculum.

How? Nell learned technology by playing with technology, and she relied on others to assist her. After seeing PowerPoint used by colleagues, Nell found the software and started exploring it on the computers in the school lab. When she purchased a personal computer, Nell made sure PowerPoint was loaded because, "I knew I wanted to sort of play around some more with it so that I could eventually have students doing PowerPoint presentations" (1, 1)[2]. Nell reported that "I never looked at a manual. I never read the directions. I just played. Which is partly why I don't know all the bells and whistles...and I'm learning with the students" (1, 1). Nell never used manuals to assist her learning. When trying to learn HyperCard software,[3] Nell explained, "Somebody handed me a HyperCard book. Uh, uh uh, no..." (1, 10). Besides what appears to be an

[1] "The term hypertext refers to computer-based texts that are read in a nonlinear fashion and that are organized on multiple dimensions. The same material (which can be any kind of randomly accessible medium, e.g., text, video, audio) is capable of being explored in different ways, with the different exploration paths producing what are essentially multiple texts for the same topic" (Spiro & Jehng, 1990, p. 166).

[2] (1, 1) denotes the quote came from Interview 1, Page 1 of the transcription.

[3] HyperCard software is organized around the metaphor of cards. Authors insert text on different cards, which together are called a "stack." Authors also can create hotlinks, where a click on words or phrases on particular cards move a reader to linked information on another card. Links are designed by the author and often represent semantic relationships.

immediate distaste for manuals, Nell did look at the text but she could not make sense of it.

When Nell purchased StorySpace[4] hypertext software, she started by "playing around" with it on her own. But she also needed human assistance. She explained:

> And so [I] kind of played with it and played with it....And even after a couple of months of dinking around with it, and I'd play around with it for a while and get frustrated and do something else, I finally had to call them [StorySpace help number] and say, "Okay, how do you make a link?" And it's really easy. (2, 27)

In this case, Nell played with the program for quite some time but sought human assistance when she became perplexed.

Nell sought a great deal of assistance from others to learn web authoring in her doctoral seminar. She sought help from the professor and computer center consultants. The professor's assistance was not completely helpful. Nell described the hurried interaction, "He says, 'What's the problem?' And he takes the mouse from me and does it. I said, 'Wait a minute, I've got to write this down'" (1, 9). Fearing he would leave before she understood completely, she tried frantically to slow him down so she could write down the steps he took on the computer. After that interaction with the professor, Nell relied on assistance from Internet consultants in the campus writing center. She described:

> I think what helped, what was the most helpful was ...the fact that there were Internet consultants...And in the end, I hired a kid in the writing center, we sat and I did it all, but I needed somebody to keep saying, 'Okay, now you've got to

get Fetch.' I needed the security more than anything else. There were too many things that would go wrong, and I had not a clue. And so he just sat right there. (2, 24)

Learning to author hypertexts on the web was one learning experience in which she most heavily relied on others to assist her own learning, yet it is also an instance in which she had the most resources available for help.

Teacher Practice

Why? First and foremost, Nell held an instrumental view of technology. She integrated it into her lessons only when she could see how it would support her English curriculum, never as a way to teach students about technology as an end unto itself. Consider, for example, this description of a particular use of PowerPoint:

> ...It's not that oh, they're learning technology. To me, that's really secondary to the fact that you're manipulating text and it's very efficient to do it on a computer. That's the power of a computer, and so my goal isn't to teach them technology. They just sort of learn it in the course of doing something else. (3, 21)

Just as she learned technology in the course of other experiences, Nell implemented technology when it supported something else, in this case, teaching English.

For example, when Nell's students read the novel, Phoenix Rising in previous years, she was dissatisfied with the quilt blocks students had made to represent their thinking and understanding visually. This year Nell "didn't want a book report, I didn't want anything traditional. I've stayed away from that stuff for a long time" (2, 14-15), Nell thought PowerPoint would support her students in thinking about and representing

[4] StorySpace software is organized around the metaphor of a web. The base level is a "lexia," a textbox that contains text and represents one idea. The content of a lexia is similar to the size of a paragraph. Links are

the novel and considering historical information about Chernobyl nuclear disaster. Nell felt PowerPoint achieved that goal:

> I thought that they were able to tie in Chernobyl much better because they had to create their own material...I think, they did a much better job of connecting. They loved it. And they wrote a great deal ... this was a nice marriage between written text and visual. (2, 19)

Nell had clear, content-based reasons for using PowerPoint for this activity.

Overall, Nell's English language arts goals were "to get them more literate than they were when they walked in the door at the end of August...I put them in touch with as much text as possible" (3, 2) and "to increase their writing fluency" (3, 4). Nell used technology only when she believed it might assist or support (or perhaps change) the literacy goals she held for her students. It is not surprising when Nell saw how hypertext theory encouraged "think[ing] about the relationship between one idea and another, one chunk of text and another" (2, 33), she incorporated the theory and the technology into her course. However, she still maintained that "It's not the technology; it's the thinking and so I wanted them to think multi-linear" (2, 26). Technology was secondary to her.

How? Students in Nell's classes used technology for English projects. Nell provided opportunities for students to learn the technology by providing them opportunities to "play" with the technology and by guiding them carefully in the early stages of learning. Nell felt comfortable relying on students' discovery learning because she believed she could not know *everything*. She explained, "If you go in and tell them you know it all, you're setting yourself up. How could you really know everything, you know? ...If I had had to wait to know it [all] before I went in, I'd never be in there so I

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made between text in different lexias. In total, an author creates a web of inter-related information.

was able to get them started and wasn't afraid to say, 'Oh, I didn't know you could do that'" (2, 16). Because Nell was not afraid to introduce the technology into the classroom prior to her mastery of it, her students used PowerPoint even though Nell, herself, did not understand all features. In the process, Nell learned more about the software's capabilities through the students' discoveries. Students used a technology they might not have if Nell had had a different belief about teacher knowledge.

However, Nell did not leave everything in the hands of the students. In fact, she primarily functioned as a facilitator in the computer classroom. During one lesson I observed, she refrained from lecture-style instruction in favor of a combination of student exploration and informal one-on-one scaffolding and coaching. After a short introduction to a particular technology, Nell gave students ample time to explore the technology on their own and at their own pace. She circulated through the classroom observing the students' work, asking questions, answering student questions, and giving suggestions. In answering technical questions, Nell guided students by either calling out each command while the student followed or by moving into the student's chair, taking control of the mouse, and completing the computer task, as the student watched.

Nell's assistance to her students, more often than not, resembled the very approaches that frustrated her when she learned technology. Nell complained about her professor's hurried assistance when learning web authoring: "And he [professor] takes the mouse from me and does it. I said, 'Wait a minute, I've got to write this down'" (1, 10). Similarly, Nell dictated many directions to students, allowing little wait time. In the following excerpt, Nell directed each step of the process, without offering the student a chance to choose commands or even think about Nell's choices. Nell directed:

> Get Word up. New Document. [Nell puts disk in computer.] Point – click on that. Open file – Click A drive. Click on "Coki" [name of file]. Hang on. [waiting for file to open]. You want to take sections of this and put it in lexias. Let me sit down for a second.... [Nell sits in the girl's seat and takes control of the computer.] So let's say this is going to be one lexia right here. Copy it. I'd suggest just numbering the lexia and rename them later." (FN, 5/11/99)[5]

Ultimately, when things got frustrating for particular students, Nell (just like the professor she complained about) took control of the computer, not allowing the students to act on directions Nell provided.

Often Nell directed her students to "move over" or "let me sit down." Upon sitting at the student's computer station, she took the mouse and chose the appropriate commands. As the student stood next to Nell and away from their work on the computer screen, Nell talked through the steps. The students never wrote down the order of operations nor actually practiced the steps. Some managed to remember the steps but many asked their questions again. As another example, a student explained, "Netscape is acting weird," and Nell viewed the computer display and indicated dispassionately, "Oh. I know it does this. It's glitchy. Move over. [Nell sits down.] Let's try it again. There we go. I don't know why. Sometimes, bingo!" Nell may or may not have understood the problem. Instead of explaining the problem to the student and suggesting she try again, Nell took over the machine completely by sitting in the student's chair and fixed the problem.

[5] (FN, 5/11/99) denotes this comment or observation came from Field Notes recorded on the date 5/11/99.

Patterns

The patterns are summarized in Table 3. Nell learned in two starkly contrasting ways. On one hand, she learned productively with coaches guiding her in using the technology. On the other hand, she also learned through "playing" or "fiddling." In both cases, Nell's impulse to learn the technology was driven by ideas about and connections to literacy; she did not seek out or learn technology for technology's sake or for personal interest. She integrated technology only when it supported English curricular goals.

Table 3

Summary of Patterns Across Nell's Learning and Practice

Lens	Teacher Learning	Teacher Practice
Rational Why?	**Nell learned** technology when facilitated exploring ideas in literacy.	**Nell used** technology in practice only when it supported English curricular goals.
Technical How?	**Nell learned** technology through guided coaching and by "fiddling" and "playing" with it on her own.	**Nell taught** her students technology by providing ample "play time" for them to explore the technology or by steering them individually, with meticulous exactness.

Consistent with her own preference for "playing around," Nell offered students time to explore and play with technology. The way that Nell supported students' learning of technology using a one-on-one basis also had a parallel in her learning experience. However, in helping a student, Nell oftentimes took control of the mouse and the computer away from the student. The student watched as Nell solved the problem or clicked through a series of the steps. Nell was, perhaps unconsciously, trying to help students in the very ways that frustrated her as a learner. Nell's inclination to integrate technology before actually knowing it completely most likely required Nell to sit down

and play with the program itself in order to determine the appropriate next step or an answer to the student's question. Yet, she did not seem to realize that she was replicating the very practice that frustrated her as a learner. This replicative behavior was all the more surprising in light of Nell's recognition of her own need to jump in head first, "If I had had to wait to know it [all] before I went in, I'd never be in there" (2, 16). Her own frustrations and needs as a beginning technology learner had not been utilized in developing her approaches to supporting her own students' technology-learning.

Roger Karpenter

Teacher Learning

Why? Roger learned technology partly due to a life-long interest and partly due to his commitment to offer many technological opportunities for his students. Roger's interest in technology can be traced back to guitars and amplifiers, 8mm video, video games, film, and television, public broadcasting, and finally computers. During high school, Roger was interested in computers, but he "was one of the outsiders in the school... I wasn't allowed to touch them. 'Cause they were technology and only certain good, pure students were allowed to touch... to go back in that room. We stared through the glass [window] and looked at them" (1, 8). He finally learned technology when his mother purchased a Commodore 64 for him after high school. Since then, Roger has continually been learning many technologies. As a teacher, he learned all technologies available.

How? Roger learned technology primarily through playing, but he also consulted colleagues, friends, books, and manuals on occasion. Perhaps it is a personal predisposition or perhaps out of necessity (having no other learning venues), Roger

learned technology through playing. Before his teaching career, learning about computers often was a joint venture for Roger and his friends. He and his friend, Brian Norman, editor of the university newspaper, really challenged each other by combining photography and animation to produce "cool" advertisements. Roger reported, "We were just, it was just a lot of playing. It was a great time. It was really cool. Because we were playing with it and learning..." (2, 7). Play dominated his recollections of early experiences with technology.

Roger's experiences in and after high school led to facility and comfort with various technologies. He continued to play with software, as Roger explained, "I basically learned everything by just sitting down, looking at the computer and doing it" (2,9). For example, when Roger heard about his library's access to ProQuest, an on-line database of journal articles, he "[went] in and putzed...I had played with it a bit" (2, 18). In another instance, he described, "Oh, I got this new program called Visual Page. They give me the book. I said this time, I'm gonna sit down with the book and I'm gonna do it. Have I? No. What'd I do? I just sat down and played with this" (2, 9). He acknowledged that he skimmed through manuals but was not comfortable with the linear approach to learning that manuals and courses offer. He explained why he had never taken a computer course before:

> ...they're going to present it very linearly and as you watch this unfold, you're going to find out my use of computers is not linear whatsoever. Nor is my learning. And I'm afraid I'll go into classes where they're going to present computers in a linear fashion, and I'm used to this holistic way of learning and

doing it. I think I need it, but I, I think I need that linear to help me fill in the holes because there's holes. But I don't know how well I'm gonna cope with that. (1, 10)

Though Roger seemed to acknowledge that a more disciplined and orderly approach to learning, like a manual or course, might help him become more knowledgeable, he had yet to try such an approach. Rather, the "play" or exploration was present throughout Roger's descriptions of his learning of technologies as a teacher.

Roger also learned through collaboration with colleagues. During one year, six teachers, including Roger, from different content areas accepted an hour of release time each day to develop lessons that shared two critical features—they used technology and met the outcomes and standards in a particular curriculum framework, such as math, science, or English. With these colleagues Roger learned about different educational technologies like HyperStudio. The district technology representative, Matthew, also assisted Roger in fixing various glitches and problems with technology. Matthew was one of the main individuals from whom Roger sought advice or help with projects. For example, Roger wanted to have his students store information in databases and access the information instantaneously *during* a debate project. Roger was not exactly sure of the best way to organize this, and explained that Matthew was the person from whom he would seek advice.

Teacher Practice

Why? The computer ban that Roger experienced during high school motivated him to provide many opportunities with technology for his own students. Playing with and learning computers changed his world. He moved from being a janitor to a public relations officer to a teacher. Roger explained how his experience guided his teaching:

> ...that idea of that locked room frustrates me. Part of it is: I don't want that. Part of it is: I'm a little kid. I play like you wouldn't believe. I mean, it's music, it's guitar, it's this, it's that, and I love to play. Computers are one of the things I love to play with. Computers gave me something by them existing and coming into existence when they did. And other technologies. I mean, I was doing video and doing all that. It gave me a way to express myself that they didn't before, that I didn't have before. And I think it does it for kids, too. (3, 31)

Roger's own world changed so drastically when he finally came to have computer learning opportunities – he saw and realized potential in himself. He moved from being "dead," going nowhere, to attending and graduating from college.

This idea of potential is important, he said, "And it just, I love potential. I love to look at something and have an idea, wow, it could go here but I can't fathom where it will go. It just, it overwhelms me and I like that. ..." (3, 32). This overwhelming aptitude for potential pushed Roger to provide all he could for his own students, unlike his experiences in school. He explained:

> It's more, yeah, and it's more the opportunity than it is, you know, anything. I hate kids losing opportunities. I hate kids that lose an opportunity. And... And so, in my teaching I try to make sure that those, those kids who end up with me have those opportunities because, because it's what makes... it means so much. It does. I just... I just, yeah. (3, 31-34)

His passion and commitment to provide students opportunities was almost too much for him to communicate through words. Roger's prior experience certainly shaped this philosophy and, in turn, his students' opportunities with technology.

How? In teaching, Roger organized learning opportunities with technology for his students in ways that mirrored his own technology-learning experiences. He did not teach about technology using a step-by-step approach. Rather, he offered simple overviews and modest directions and then allowed his students the freedom and flexibility to learn more about the technology as they desired or needed, and he was always available for consultation and assistance.

For example, before Roger's students used ProQuest, he shared an overview of the program and the first few steps. After students conducted their first search, Roger circulated through the class, ensuring that students understood the difference between an abstract and a full article. He also resolved log-in problems and helped others begin searching the topics. As students discovered new features of the program, such as expanding their searches by using other words or phrases, Roger shared these ideas and approaches with the whole class. As research progressed, Roger continued to circulate, showing students these advanced search features, if they had not already found them. As might be expected with a large group of students dispersed over a large space, Roger did not circulate in an organized or sequential fashion (especially when computer problems tore him away). Thus, not all students received the same level of guidance.

Despite Roger's effort to prepare his students for computer-based activities in the library, they were often confused with the ProQuest database functions and how to interpret the information the database yielded after searches. For example, two students, Brenda and Eileen, did not understand which search options – search by word, publication, or topic – to use. Later, when Brenda received search results and clicked to see an abstract, she read it and exclaimed with disapproval, "It is so short!" (FN,

2/26/99). She then saw the list of related subject headings and clicked on "Quality of Education." This opened a new page with a new list of articles. At this point, Brenda explained she was confused and didn't know how to get back to the original list of articles. Other students had similar problems. Mandy's partner, Helen, searched on "sports" and "drug testing." When looking at her search output (a list of hotlinked article titles), Helen exclaimed, "Why didn't it give me an article?" She expected the computer, after searching, to show her a full-length article on the topic of sports and drug testing. She was confused by the list of article names. Mandy, who was also confused, advised her to click on a related subject heading, which brought them to a new, entirely different set of articles and caused further confusion. Another pair, Missy and Gabriella, looked at citation information of articles found in a search on "death penalty." Missy asked Gabriella, "Who or where did this article come from?" Gabriella had no idea. These two girls could not find who wrote the article or where it was published – information that appeared in the full citation at the top of every screen displaying information about that article.

Similar to ProQuest, Roger started a project that involved the use of PowerPoint by demonstrating some of its capabilities. Before the students began working in small groups, he used a classroom computer to demonstrate (actually to remind them about) how to open a background design in a PowerPoint presentation, as he had already shown them the day before. Student groups then created a PowerPoint file and started looking at different backgrounds. Roger characterized the first day of any project as a "mess day," where students were able to mess around or play around with the technology or the topic of study. In a sense, students were able to explore the technology until they felt ready to

begin the main activity. Roger described this first PowerPoint use as a "mess day." He explained that he was predisposed to "playing around," the approach through which he saw learning accomplished. He acknowledged that he could "blab, drone on, pound in," but he does not think students learn using that method of instruction (FN, 4/29/99).

Patterns

Table 4

Summary of Patterns Across Roger's Learning and Practice

Lens	Teacher Learning	Teacher Practice
Rational Why?	**Roger learned** technology because he was generally interested in technology. As a teacher, he learned it to find tools to support his curriculum and offer his students opportunities to use technology.	**Roger used** technology in practice to offer his students opportunities to learn about technological tools.
Technical How?	**Roger learned** technology primarily through playing with it; secondarily, through consultation with friends and colleagues.	**Roger taught** his students technology by providing ample "mess time" for them to explore the technology.

For none of the teachers was the link between personal learning and teaching practices more transparent than with Roger. As summarized in Table 4, he learned technology by playing around with computers outside the classroom walls – including in his basement, at friends' houses, and at his place of work. In his own classroom, he tried to recreate the active and driven atmosphere of those playful "outside of the classroom" opportunities yet still connected the technology use to content. To support his approach to learning, Roger viewed his students as "adventurers" and organized instruction and student work time to offer flexible time to "play" with materials, books, and learning tools. Students in Roger's class worked in pairs or small groups and, especially during

what Roger and his students call "mess" time, discovered new functions of the technology. Roger provided just enough scaffolding to begin and allowed for growth, as he explained, "...as they want to, they grow with it [software programs]. There's a whole bunch in there that I don't talk about" (2, 10). Roger's playfulness came at a price, though: some students were confused about using the technology and completing school assignments.

Doug Logan

Teacher Learning

Why? Doug learned technology because he had a general interest in it and because such a pursuit "spiced up" his teaching career. Though technology was interesting to him in a general sense, he also learned it because of its potential to assist teaching. His first learning experience with computer programming communicated the importance of considering the connection to subject matter (specifically because it did not). Doug reported, "I got turned on to it [LOGO programming] and started doing it and enjoyed it" (1, 3). After learning programming, Doug found "there was no transition to the classroom" (2, 5). Doug learned that not all technology would support his curriculum directly. He came to realize that, "One of the problems I feel with technology is that we put it ahead of curriculum. That there are so many people that don't understand what it really is and should be used for, that they literally are forcing it on as a curriculum" (3, 19). LOGO did not seduce Doug. He did not force it into content areas where it did not belong, nor did he add a new "computer" curriculum.

From that point on, Doug saw the need to examine the extent to which a technology would benefit his teaching or students' learning. He still looked for

technologies to learn that interested him, but he wanted to learn technologies that had potential to complement his curriculum. As he began to learn and assess more technologies in terms of teaching and learning, he began deciding earlier — before he committed significant time and energy to learning technology – if the technology had educational potential and relevance.

For example, word processing interested him because, "I saw a way this was going to help me. And the way it helped me was I have horrible penmanship and I'm a pretty pathetic speller...Somebody showed me a word processor. And bang, the light went off. I saw a means to help Frank get better... That's when I started seeing, how am I going to get this in my classroom..." (1,2). At the same time, he foresaw a connection to his students' writing, and he decided learning it was a worthwhile endeavor.

How? Doug learned and applied many technologies in his teaching in an organized manner. Doug took a very conservative approach to his own learning. He tended to apply himself to learning and examining the breadth and depth of how one particular technology could support curricular functions before learning another technology. For example, after his students began using E-mail with a set of preservice teachers in a local university, Doug explored a new idea that still involved E-mail – connecting with people across the world. He explained, "...I want to talk to someone outside [the] university. I want to see how this stuff works. So he [colleague] got me a woman in Australia" (1,9). Doug continued to explore other applications of E-mail and developed relationships with many teachers around the world and the United States, but then focused on "one or two really good ones and just work[ed] with them, hard and strong" (2, 9). He was deeply focused on one technology at a time and knew his learning

limits. When colleagues encouraged him to learn a new software package called HyperCard, Doug explained, "People are saying, you know you've got to check out HyperCard. Well, you know what, no offense but I'm handling this right now, and I can't even look at that because I don't want to try to learn something new" (2, 15). Doug learned technology in a focused, slow approach.

Doug had assistance from others when he learned. From the first inkling of interest in technology, Doug's learning had been inspired and developed with his colleagues. They helped him learn both the technological tools and the ideas and approaches to integrating the technology into his curriculum.

For example, Peter, a colleague at his school, was the first to help Doug learn. Together, they learned more about computer programming. Later in his career, Doug's collaboration with John, the reading specialist and a doctoral student, played a crucial role in his learning and eventual integration of technology in ways that were supportive of his subject matter goals. Doug described how John guided his learning:

> I was doing stuff, but I couldn't see how I was going to bring it into my classroom. And then a guy named John walks into the building... The guy is phenomenal, phenomenal. He understands the stuff. And he understands how it works and he understands how to apply it in a classroom. (1, 9)

With John, Doug learned E-mail, found distant E-mail partners, and wrote and won a grant that supplied Doug's classroom with an Internet-capable computer, software, and peripherals.

Access to the Internet and E-mail in Doug's classroom opened the door for more learning through peer collaboration. Doug used educational web sites to locate other

teachers with whom to collaborate, an activity he claimed was a "big break-through." He was able to "find somebody that's right on your same wavelength" (3, 26). His work with distant partners exposed him to new uses for technology but also to a wider array of educational issues than he might not have had encountered, "You go out and talk to someone in a school in California and you find out wow, multi-age classrooms. Cool. Or, block scheduling - what is that? And they tell you, and you say, 'Wow.'" (1, 12). Doug worked harder and closer with these distant teaching partners than with the colleagues in his own school.

In addition to the on-site colleagues who taught him the basics of computer use and his distant partners who expanded his conceptions of teaching, Doug interacted with colleagues at state technology conferences and through listservs. By attending presentations at these conferences, Doug learned about contemporary technologies and how fellow teachers were using them. On listservs and online conferences, he was able to talk with educators from across the country about issues. Doug reported that the conference "was really kind of neat to do because I learned while I was doing. I was seeing what could be done with this technology stuff" (2, 2). He learned technical knowledge and applications of technology simultaneously.

Teacher Practice

Why? Doug used technology in his classes in an attempt to "spice up" his curriculum. His main focus remained teaching language arts, but Doug felt students needed change in daily activities. He explained, "So that's the underlying theme - to continue their writing. On the same token, it is going to get boring after awhile, so you've got to spice it up. So you spice it with a project here and there" (2, 13). Though his major

agenda was to spice up the curriculum, he chose activities that he felt would enhance the students' learning of English language arts.

For example, Doug discovered that communication with peers around the world enhanced his students' learning in several ways. First and foremost, "it gives my kids an audience and it gives them, it takes what we do and it brings it to a bigger level, a broader level. It's not just, doesn't end at this doorway" (3, 20). The students had a different audience than writing just for Doug, which Doug felt gave the students a purpose. They learned about unknown ideas and places from their distant peers and immediately wanted to research and write about them. Doug described an incident:

> One kid [in Australia] talks about the Gold Coast in Brisbane. What did my kid do when he got the letter? [He asked,] "What is this?" Wow. The kid wants to use research, do research to find this out. They are self motivated. When you are self motivated, get out of my way. (1, 12)

These students' motivation to learn more was inspired by ideas, comments, and communication with their peers.

How? Students used technology in the classroom either as a part of large group projects or individually when completing shorter activities. In either case, Doug always prepared them in an organized and planned manner. Doug was instrumental in leading the large projects, such as developing video or HyperStudio representations of "All About Allendale," their hometown. Doug led students in brainstorming topics to research for the video project. He orchestrated the students into research groups. He communicated with parents and sought their participation. He and the students taught each other how to use the video cameras and considered what visual information was most important in

capturing in order to communicate the important information for their Newfoundland partner class.

In addition to these longer, cross-curricular projects, the students completed shorter activities within a day's work. When Doug wanted to do a short computer activity, he organized instruction into three rotating centers because he had only seven computers in his classroom. One of the centers involved computer activities, such as language arts skill activities, research, writing, or typing practice. Doug introduced the center activities the day before students would cycle through them. Doug demonstrated the goals and nature of the computer-based activity, ensuring all the students understood to prevent confusion the following day. For example, he would show the students the location of the computer file they would work on, what the activity involved, and what computer skills they needed to have in order to complete the work successfully. For student research on planets and the solar system, Doug set up bookmarks on the Internet and an electronic encyclopedia to NASA and other solar system information for simple navigation. As students became comfortable with these technologies, like word processing and research tools, Doug encouraged students to access them during the school day. Some students elected to use them, such as a set of students who wrote their "young author books" using the word processor.

Patterns

Doug learned technology predominantly through collaboration with and guidance from colleagues. The relationships he developed with these individuals and the products of their collaboration — knowledge about technology and its use to support subject matter instruction — spiced up Doug's professional life. In turn, the projects and

activities Doug and his colleagues developed provided spice in what the students experienced in their English curriculum (see Table 5).

Table 5

Summary of Patterns Across Doug's Learning and Practice

Lens	Teacher Learning	Teacher Practice
Rational Why?	**Doug learned** technology because he had a general interest in it.	**Doug used** technology in practice because he saw that technology-based projects "spiced" up his curriculum.
Technical How?	**Doug learned** technology conservatively, one technology at a time, with heavy assistance from colleagues.	**Doug taught** his students technology by guiding them through planned and organized technology introductions.

When learning, Doug focused on learning one technology at a time. In his classes, he did not establish high expectations for his students' technology uses. He exposed and supported them to use technology in ways that he thought suitable and supportive of the curricular goals with much support. He may have provided this heavy support due to his own learning experience – that he sometimes would forego a new learning opportunity to assure his own sanity. Yet, he did not allow his approach limit his students.

Laura Yates

Teacher Learning

Why? Laura learned new technologies because they were everyday aspects of her life. Just as a reader occasionally buys a new novel to read and enjoy, Laura occasionally learned new technologies to use in her daily life. Laura was accustomed to technologies because she grew up with them. She had used technology in her life from childhood onward and became more and more comfortable with them. Most important, perhaps, Laura found technology to be a tool that assisted her in many ways. For example, E-mail

provided her with an inexpensive, simple and fast mode of communication with her family (who live in another state). A database file she created recorded the books she had read over the past several years. With it, she had simple access to multiple types of information she had compiled about the book. These capacities drove Laura to learn new technology. She always looked for tools to improve her life.

How? Laura learned technologies using various resources, such as colleagues, practice, manuals, and inservices. In her three years as a teacher, Laura had learned many new software programs and hardware devices. Bancroft High School recently moved into a new building and each teacher's classroom had a high tech teacher desk that included video cameras, TV monitors, a computer, VCR, satellite access, phone system, Internet access, and WinSchool, a school-wide program that compiled grades and attendance. The school offered many inservices that taught teachers how to use these resources. For example, inservices had been provided for teachers to learn about using PC machines (the former school had Macintosh platform), about the software that controls the video cameras, satellite access, and videotapes, and about WinSchool, the grade and attendance programs. These inservices strictly covered operation of these tools. It was left to the teacher to decide when and how to use them with students.

To learn a new technology well, Laura preferred to consult the manual. She also appreciated having a colleague available to assist her. Finally, she practiced and used the technology before using it in her teaching. Laura explained, "I would say a lot of the time, yeah, [I focus on manuals], unless somebody else offers to show me how to do it or somebody that I know is willing to spend the time showing me something" (2, 5). While

learning to scan, Laura explained how her colleague did not help as much as she had hoped:

> The graphics guy keeps [saying], "Here, do this, do this" and then he does it for me really quick, and I don't know what he's doing. Or he'll do it on his computer, and then says, "Well, it will be different on your computer when you do it." So, I'm saying, "How will it be different?" and I'm trying to write it down, and I get too frustrated. So, I probably, what I should do is try to find an owner's manual thing and work myself through it....Plus I think I need a couple days in a row just to really mess with it, so that I'm comfortable with it, so it's not figure it out once and then forget it all and have to start all over. (1, 12)

At times, though, a colleague did help in essential ways. When Laura wanted to operate the cameras in her classroom, she could not recollect the steps, as the inservice training had taught. She explained, "I just went and found one of the teachers who did it and said, 'Could you help me?' And she helped me out" (2, 21). These cameras allowed her to videotape her own class, to display any item on a monitor (similar to an overhead), or to video conference between classrooms. A software program on the computer controlled the cameras, and Laura felt nervous about operating all the new devices. She explained, "I didn't want to be in here the first day of school and not know how to run my desk. So I practiced...I messed around..." (2, 22). It was very important for Laura to feel confident and capable with the technology before actually using it in her own classroom.

Teacher Practice

Why? Laura used technology in her teaching in the only way she had ever known — as a tool. Technology had consistently streamlined her teaching processes.

How? Laura used much of the available technology to aid her instruction and administrative duties, such as in supporting class discussions, answering students' questions, storing grades, and reporting attendance. For example, in reading Edgar Allan Poe's work, the students could not visualize catacombs. Believing that she might find some example on the web, Laura searched and found that the Vatican offered a virtual fieldtrip through catacombs in Rome. Laura thought this information helped the students have a better sense of the setting in the story. In a similar way, when a student asked about Stonehenge, Laura explained, "I can tell them about it forever, but they still won't get it. Then, I just went and found a site which took me about a minute. 'Oh, yeah, I know what that is'" (1, 5). The visual image reminded the student. Laura also used the Internet for herself to learn more about the Cold War when the students needed more contextual information to better understand a piece of literature and her explanations were inadequate.

Laura used PowerPoint and Word to plan and orchestrate class discussions and class-generated work. She organized a series of quotes from To Kill a Mockingbird using PowerPoint to scaffold a discussion about themes in the book. Laura also used Word as visual help similar to how one might use an overhead projector. While displaying Word on the monitors, the class developed grading rubrics together. They also wrote together, as Laura explained, "...we were going to try to write a poem as a class. And if you put it up on the board, you end up with squiggly lines everywhere, and it is a big mess. So we put that up on the screen. So I did it in Word and made the screen big" (1, 10).

Laura reported that her students used computers frequently although I did not observe them doing so. The first year Laura taught, she led a newspaper project. Her

students wrote the content of the newspaper, and Laura constructed the newspaper on the computer because she claimed that the students, at that time, had little computer and typing experience. The project would have taken far too long if students had typed it. Laura reported that more recently her class often worked in the computer labs to write and revise their writing. However, she was committed to using the computer lab to compose rather than just to type. She explained:

> I don't like to give them time to go down there, just to type. I want it, I want it to be different than what they would be doing in here if they were handwriting it. So sometimes we will go down there and actually do composing down there 'cause I think that makes them write a little bit differently. Or revision activities or things like that. But it's not just so that I can read their handwriting. (2, 45)

By using the computers to write, the students went through the writing process and realized that revision is more than just recopying work to make it more legible, Laura reported.

Patterns

It is clear that Laura's learning and practice with technology had little connection to English subject matter (see Table 6). In addition, the technology use was teacher-centered. There were several possibilities to explain this lack subject-matter use and teacher-centeredness. Laura practiced and became completely comfortable with technology before she actually used it in her class. There was the possibility that Laura believed that students, also, needed to be "experts" with tools before using them. When she did the newspaper project during her first year, she constructed the newspaper on the computer because her students were beginners with the technology. She described:

> They gave me the information, and I typed it in. The problem was they weren't getting their stuff fast enough in, and they didn't know at that time, they didn't have enough training..... So if I were to do it again, I would either have an aid type the stuff in and teach them some formatting, or I think that the kids have enough training now that some of them could handle it, if I put them in say groups of four and said make a page. I think they could do that now, with some assistance. (1, 8)

Laura felt her students needed much more skill with technology before they actually could use it.

Table 6

Summary of Patterns Across Laura's Learning and Practice

Lens	Teacher Learning	Teacher Practice
Rational Why?	**Laura learned** technology because she saw them as everyday tools.	**Laura used** technology in practice because technology was an available tool.
Technical How?	**Laura learned** technology preferably with a manual on hand. She also consulted friends or colleagues and attended inservices.	**Laura used** technology she felt comfortable with as an aid to her instructional practices in the classroom.

Another possibility that might explain the scarcity of student technology use was the nature and organization of resources in Laura's classroom and the school. Much of the software and hardware in the classroom did not cater to student use because it supported administrative goals and instruction. For example, the high-tech teacher desk also only had one computer and was located in an area of the room where students traditionally do not go. Laura's students occasionally made presentations to the class using the teacher computer, but one computer did not support the whole class or even

small groups working with computers. The school-wide lab accommodated the entire class; however, priority was given to computer courses in the lab, leaving all other classes to vie for the remaining time.

A third possibility existed. Although Laura had learned and used technology since she was a student in elementary school, she focused on learning how to operate the technology qua technology. She had not experienced learning about technology as a tool for teaching English. This focus on learning the technology for its own sake, coupled with her status as a beginning (third year) teacher, may explain her tendency to use technology to support her teaching rather than student learning. Beginning teachers struggle with classroom management and a sense of survival (Feiman-Nemser & Floden, 1986). As Laura becomes a more experienced teacher, she may transform her use of technology from predominantly an instructional tool for herself to a multi-faceted tool serving her and her students.

Discussion and Implications

Discussion

This study examined how teachers, working in circumstances that predict no technology use, developed an approach to teaching with technological resources in the classroom. With no apprenticeship of observation from their former schoolteachers (because the teachers did not teach with technology) and no formal technology training during preservice education, these teachers managed to learn and use technology anyway. Their reasons for learning technology and the ways they learned technology impacted the subsequent design of learning opportunities for their students.

Roger and Laura began learning technology as children. Roger became interested in technology during his youth, and when Roger taught, he made providing opportunities for his students to learn technology was a priority in his classroom. Roger's inclination to learn through "play" is seen in his pedagogical approach of providing "mess days" for students to play around with the technology before putting it to use for a curricular purpose.

Laura learned technology just as she might have learned any other tool designed to improve everyday life. In her teaching, she used technology to facilitate her teaching presentations, but she never extended her own learning to her students. The most plausible explanation of her reticence to involve her students is that she felt she needed a thorough understanding of any technology tool before she would even use it herself, let alone turn it over to her students.

Doug and Nell began learning technology as teachers. Doug developed a general interest in technology, and used technology in his teaching after he saw ways that its use could "spice up" his English curriculum. He took a conservative approach to learning technology, focusing on one technology at a time. For his students, he presented thorough introductions to technology-based projects before they began.

Nell learned technologies that would specifically facilitate the teaching of literacy content, such as non-linear (hypertext) writing or representation of meaning. She used technology in the classroom when the content she was trying to teach was better communicated through the use of technology. She was inclined to play with the technology to learn it, rather than read a manual or even consult others, and she allowed her students ample time to play with the technology with little organized instruction.

Even without the experiences, such as observing their own teachers or taking formal courses about technology in education, that might have provided some guidance about teaching with technology, Nell, Doug, Roger, and Laura still managed to learn about and teach with technology. In lieu of other preparatory experiences, these teachers developed approaches to learning and using technology based on their own experiences. This finding is encouraging in that it indicates that the road to technology integration in schools is not solely a matter of receiving information from researchers and offering "effective" inservice. Teachers can and, as these four teachers demonstrate vividly, do learn on their own. The potential for innovative uses can be legitimately developed outside of researchers' visions. Studying this process requires observing what teachers are doing so that we can learn from them.

This finding also requires a cautionary note. Even among the four teachers in this study, the technology uses varied widely—from Laura's emphasis on a presentation to Nell's study of literary genres. These varied uses can be attributed to the variability in their own experiences and learning.

In fact, Roger and Laura, who grew up using technology as technology, used it in their classrooms in ways that were more distant from the curriculum. Roger's main priority was to provide technology opportunities and secondarily, though also very important, to connect it to English. Laura used technology as a tool and had not developed uses for technology directly connected to English content. Doug and Nell, on the other hand, began learning technology as teachers, and for some reason, developed a commitment to using technology that advanced or facilitated the English curriculum. If our aim is for teachers to use technology in instruction in thoughtful ways, growing up

using technology or taking many technology courses is no guarantee that teachers will develop the skills and knowledge needed to develop thoughtful technology uses. Roger and Laura were surely thoughtful, and they developed legitimate technology applications in their classrooms, but their uses were qualitatively different from those of Nell and Doug.

These findings have led to me to develop a model of the nature of teachers' independent learning (instead of, say through a formal inservice) about technology. The fundamental premise of the model is that differences in technology-learning and technology use can be explained in terms of the kinds of knowledge under development. In this model, I begin with the concepts of content knowledge and pedagogical content knowledge. To them, I add two new knowledge sources—"technology knowledge," (what does a teacher know about technology per se) and "technology pedagogical knowledge," (what does a teacher know about how to use technology to support teaching and learning). The model combines these four knowledge sources in strategic ways. To unpack the model, I will describe each new category, in turn, and explore its properties, function, and connections to the better-known categories —content knowledge, pedagogical knowledge, pedagogical content knowledge (Shulman, 1987). Once the model has been fully described, I will re-examine the patterns of both learning and use among the four teachers.

Shulman (1987) and Schwab (1978), among others, delved into the nature of teacher knowledge and the structure of disciplines. From this work, a better understanding of characteristics of teacher knowledge has been established. Most significant was Shulman's claim that content knowledge and pedagogical knowledge

combined to create a new kind of knowledge, pedagogical content knowledge, that was more than either the sum or the product of its two sources. Transporting these generic categories to the teaching of English, we can ask: What kinds of knowledge do the four English teachers in this study possess? First, they possess knowledge of the English content. As Schwab (1978) and, later, Shulman (1987) indicate, English content knowledge not only includes deep understanding of the subject but also a conceptual understanding of the structure (what are the bounds of content?) and acknowledged modes of inquiry for the discipline (what are productive lines of analysis to create new understandings?). This English content knowledge is represented in Figure 1 on the left side.

Teachers also possess pedagogical knowledge — both general and specific to the English content. General pedagogical knowledge (at top of Figure 1) represents that knowledge of pedagogy (e.g., classroom management and organization strategies) that applies across disciplines. Pedagogical content knowledge (PCK) is knowledge of pedagogical tactics that are specific to a content area. English teachers' PCK would be different than the PCK of science teachers. Different content requires at least some unique pedagogy (though, of course, there can be overlap). English PCK is represented in Figure 1 as the intersection between English content knowledge and pedagogical knowledge.

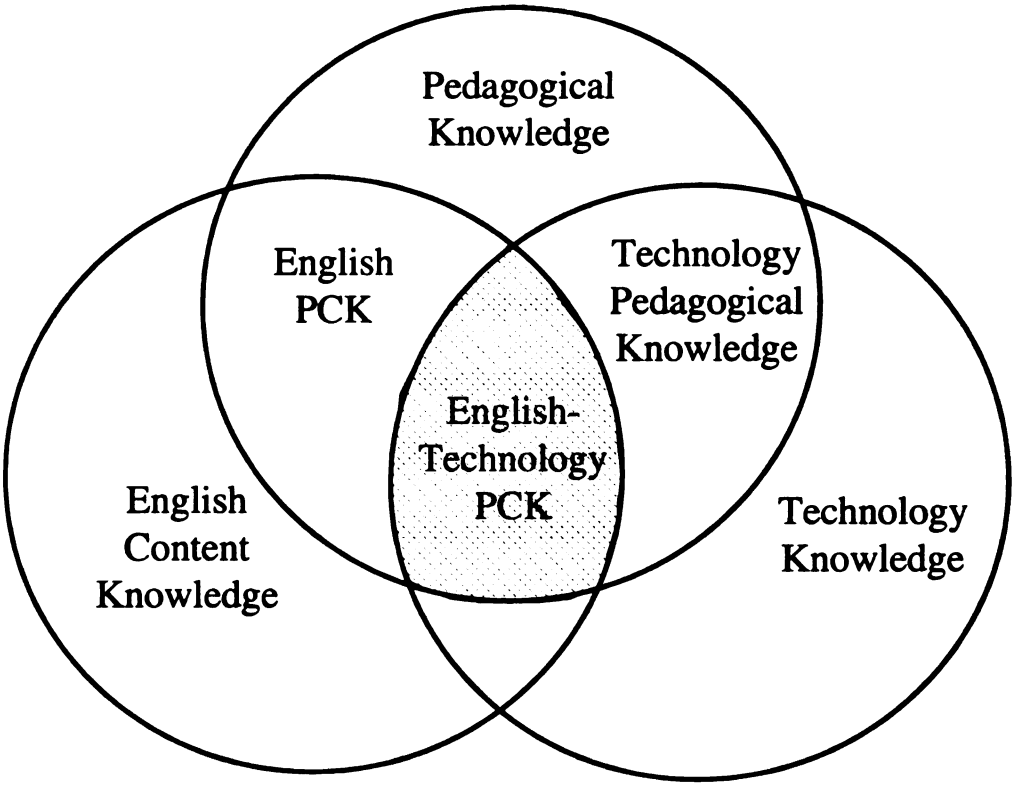


Figure 1

Components of English-Technology Pedagogical Content Knowledge (E-T PCK)

Computer technologies have only recently been pedagogical options (and for some teachers, still are not). As documented in the introduction, practicing teachers have not experienced this blend of technology and English – either during their K-12 education or during their preservice education. The four teachers in this study are among the group who have never experienced or observed this blend of technology-supported English practice. Though we may strive to have technology as an aspect of either general pedagogical knowledge and/or English content knowledge, at this point it is not. Acknowledging this, the following categories of knowledge have been theorized to

account for the knowledge these four teachers developed through learning and using technology.

Technology knowledge (TK) (on right in Figure 1) includes general knowledge of technology skills, software, and hardware. For example, knowing how to use a spreadsheet program, send E-mail, hook up and use a scanner are examples of TK. There has been some fluctuation as to whether technology knowledge is a set of skills, as I have presented it here, or an actual discipline—thus, warranting the name "technology content knowledge." Though educational technology has become a specialized area of study where scholars trace the development of educational technologies (not only computer technologies) over time and have conceptual understandings of and inquiry approaches to the field. The participants in my study do not possess such a broad understanding of educational technology but rather, a narrower band of knowledge focused more on skills than concepts. For example, Roger and Laura, who used technology throughout their lives, possessed TK upon entering the teaching profession. They had used E-mail, word processing, databases etc. On the other hand, Doug and Nell did not have TK as entering teachers but began learning these skills as teachers.

A teacher can possess a great deal of TK but still not understand how to use technology in her classroom. Such knowledge is called technology pedagogical knowledge (TPK) (on right of Figure 1). Having developed this knowledge, teachers know how to use technology to support general pedagogical goals, unrelated to specific content. Examples include using word processors to develop handouts, tests, and worksheets; displaying speaking points in PowerPoint to guide a lecture; and using grading program or spreadsheet to manage and post students' current grades. In the

future, TPK may be subsumed into general pedagogical knowledge. At this point, it is a separate category because, as discussed before, it is highly unusual that novice and practicing teachers are developing TPK through preservice education or from their apprenticeships of observation. Until teachers learn about technology as it supports pedagogy naturally, along with the many other strategies they learn, it will be separated from pedagogical knowledge. All four teachers in this study (even Roger and Nell who had TK) entered the teaching profession with no TPK (see Figure 1). They developed TPK as they learned or relearned technology for use in education.

These four types of knowledge (English content knowledge, pedagogical knowledge, technology knowledge, and technology pedagogical knowledge) combine to form what I call English-Technology Pedagogical Content Knowledge (E-T PCK), a highly specialized knowledge of using technology to teach English.

The cases of Nell, Roger, Doug, and Laura illustrate that, in the absence of an "apprenticeship of observation," each developed his or her own approach to learning TK (the skills in technology knowledge), which, in turn, impacted the development of TPK and E-T PCK. Why and how (the rational and technical framework used in this study's analysis) a teacher learns technology determined if and how TPK and E-T PCK was developed.

As illustrated in this study, in lieu of formal preparation, the teachers' TPK was developed through their experiences learning technology (the technical aspects of teacher learning; see Table 2). Simply put, their approach to teaching technology was closely associated with the ways they were taught technology, not surprising given the strength an apprenticeship of observation (Lortie, 1975). The cases illustrated how Nell, Roger,

and Doug's technical learning (e.g., Nell's need for guidance; Roger's playfulness; Doug's planning) translated into their technology teaching approaches (e.g., Nell's directedness; Roger's license to play; Doug's methodical guidance). Laura, whose case I will address shortly, presents a more challenging case for this analytic approach.

The rational aspects of the teachers' learning (why they learn and use technology) also impacted the nature of their E-T PCK. Nell, Roger and Doug all developed E-T PCK. This E-T PCK manifests itself differently for each of them. Nell's uses technology as a means to engage students in the acquisition of English content. The connection and commitment to English content stands out. To communicate such, I note that she has **English**-Technology pedagogical content knowledge or **E**-T PCK (emphasis added). Roger connects technology use to English content but, in reality, he strives to give his students opportunities to use technologies. Therefore, in his E-T PCK, the **technology** stands out — thus E-**T** PCK. Doug uses technology to teach his English content, as well, but his aim is to spice up the curriculum. He uses technology as a means to target a pedagogical tactic. He believes spicing up the curriculum with, in this case, technology-based activities will engage his students. The **pedagogy** stands out as important for Doug — thus E-T **P**CK. These differences in the teachers' E-T PCK trace back to their reasons for learning technology. Figure 2 illustrates the effect of each teacher's manifestations of E-T PCK (particular emphases) by placing each teacher in that particular space within the Model of Knowledge Development that best characterizes the particular spin he or she gives to technology.

Laura is the outlier. She did learn and use technology because it facilitated her presentations and administrative tasks (e.g., record keeping). She possesses TPK (note

her placement in the model in Figure 2) and applies it regularly in her teaching. But she does not appear to possess English-Technology PCK; her presentational uses, while pedagogically-driven, did not extend to curricular matters. As I have argued elsewhere (Hughes, 2000b), it is almost incidental that her expertise was applied to English teaching.

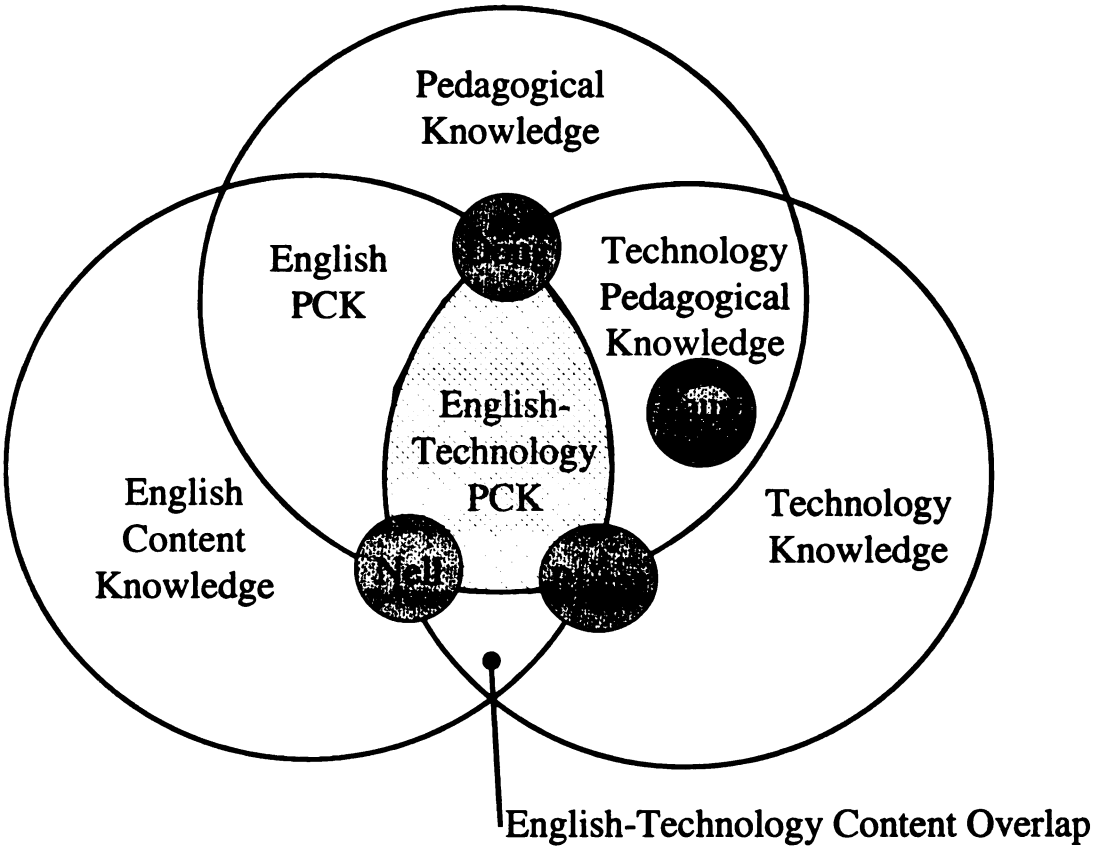


Figure 2

Teachers' Knowledge Emphases

It is likely that the content and nature of the teachers' technology-learning experiences also influenced these different manifestations of E-T PCK. The clearest example is Nell. Her technology-learning occurred within the English-Technology content overlap (see bottom of Figure 2). She learned technology in the process of

learning English content. As just explained, her E-T PCK was English-focused. Whereas Roger, Doug, and Laura predominantly learned technology skills, and later Roger and Doug applied such knowledge to teaching English (and we saw how each emphasized the **T** and **P** of E-T PCK, respectively).

The potential impact of learning technology skills as one learns English content is reinforced when considering the extent to which each teacher transformed instruction, student learning or content. In another study (Hughes, 2000a), I categorized each teacher's technology uses in terms of a taxonomy, identifying if the technology served to replace, amplify, or transform instruction, student learning or content. Figure 3 overlays the percentage of each teacher's transformative technology use. In addition to Nell's practice being nearest the English content side, she also had the highest percentage of transformative technology uses in her practice (33%), versus Roger (22%), Doug (19%) and Laura (0%). This suggests that learning the way Nell did (in the English-Technology overlap) may lead to more content-based transformative technology use in the classroom.

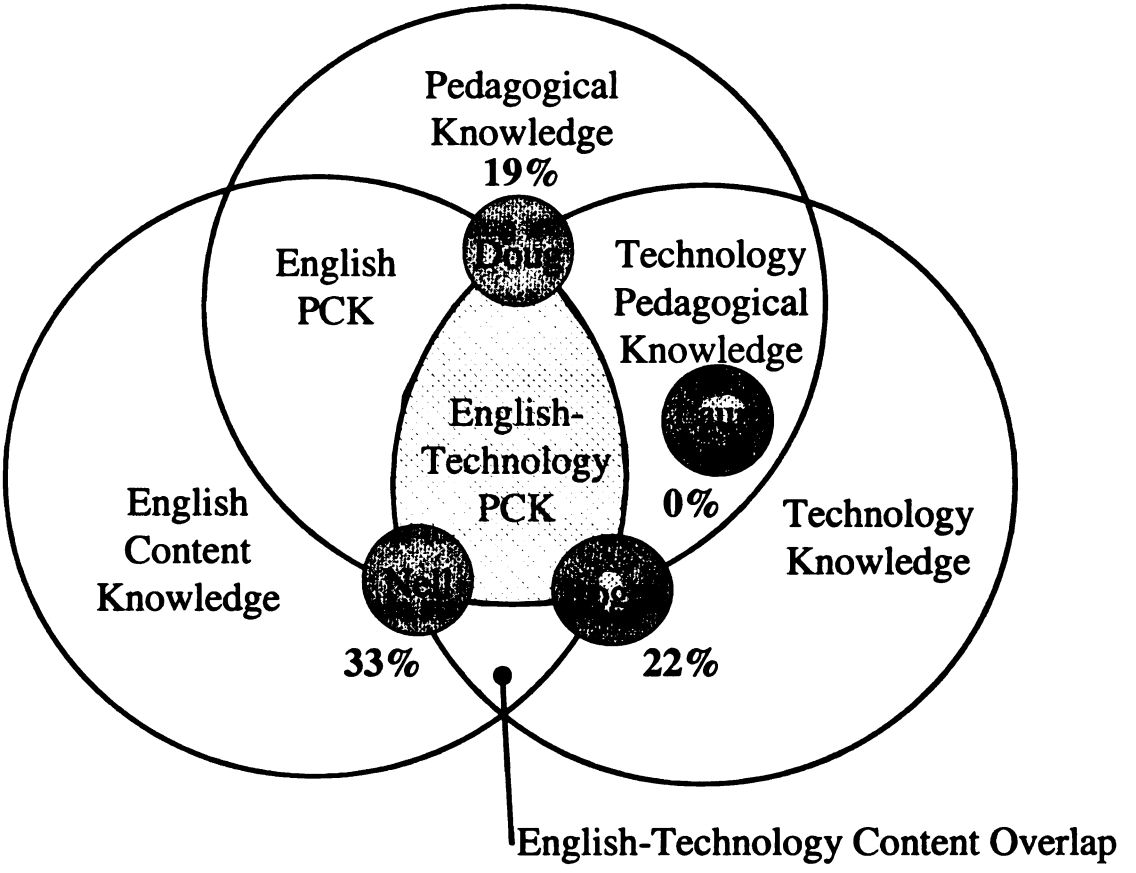


Figure 3

Teachers' Knowledge Emphases Overlaid with Percentage of Transformative Technology Use

Implications

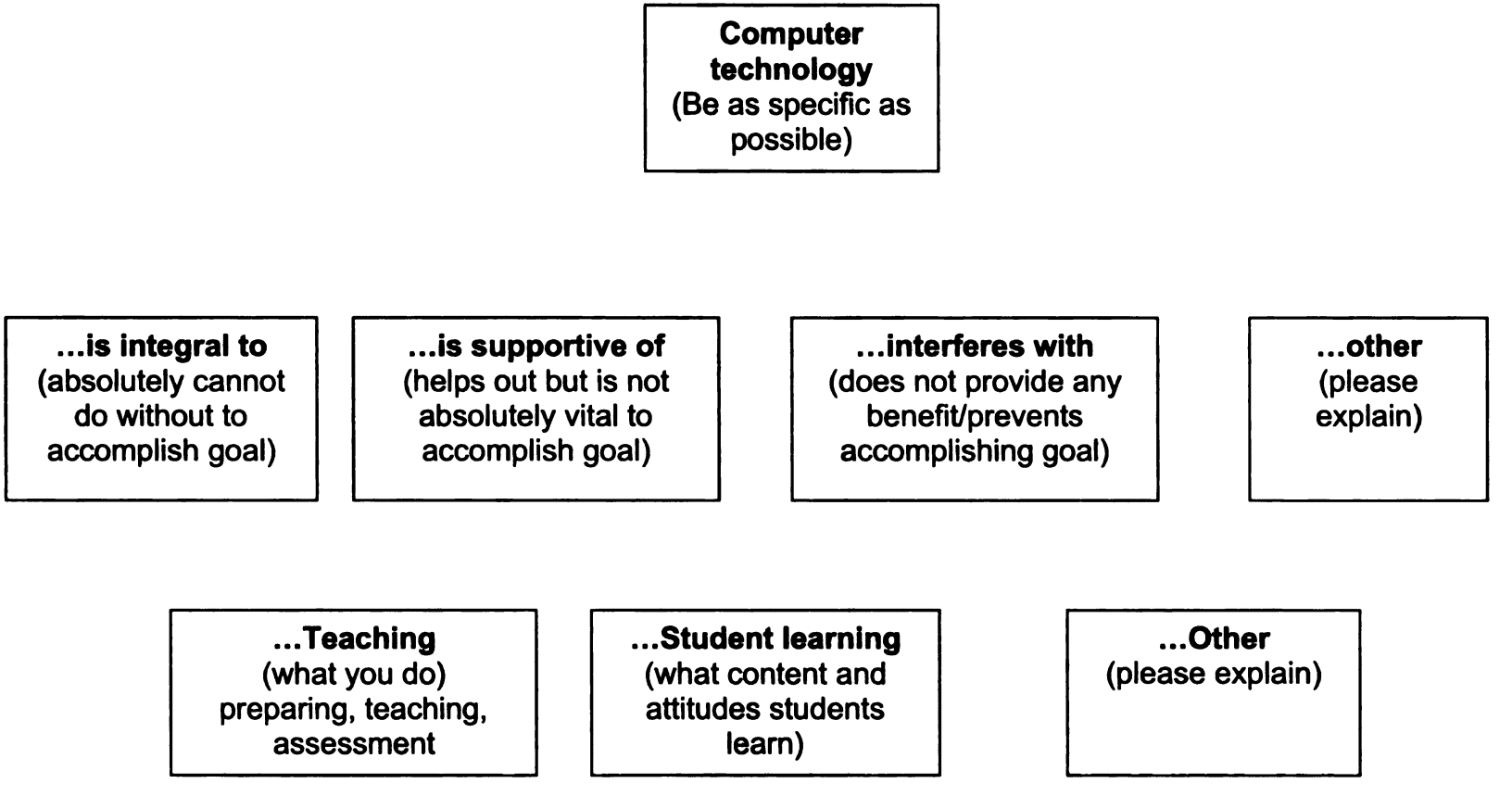
If future research substantiates my hypotheses about the kinds of knowledge teachers develop (as well as the symbiotic relations among them) when learning to use technology for teaching, several implications stand out as important for the professional development of teachers. I have implied that teachers develop E-T PCK that facilitates thoughtful technology use in subject matter teaching. Given this hypothesis, we need to consider how the organization of professional development opportunities might impact teachers' development of E-T PCK.

Professional development that merely teaches technology skills, such as Laura's experience, does not lead to development of E-T PCK. Roger and Doug's learning experiences illustrate how professional development opportunities that highlight connections to subject matter after teaching technology skills reduce the possibility that the English content in E-T PCK is prominent. Continuing to teach teachers technology first and content connections second may lead teachers who, like Roger and Doug, have developed E-T PCK that emphasizes the Ts (technology) and Ps (pedagogy) rather than the Es (English). The substance and form of Nell's learning experiences may be the ideal situation. In her case, teachers learn about technology in the context of learning English content. If there is value in thinking and learning about English content with technology, then it stands to reason that teachers should experience this themselves, a stance already taken in contemporary approaches to professional development. In reviewing research on teacher learning communities, Wilson & Berne (1999) concluded, "what these professional development projects appear to be doing ... is to engage them [teachers] as learners in the area that their students will learn in but at a level that is more suitable to their own learning" (p. 196). As a learner, Nell learned new English content. As she learned, she also considered her $7^{th}/8^{th}$ grade English curriculum, how and if she might teach the new content (hypertext theory), and how students might learn to write non-linearly. It may be that technology's potential for education and English teaching will not be realized unless we emphasis the content as teachers learn and use technology.

In addition, this study also shows how teachers' knowledge is developed out of teachers' past experiences, skills, and dispositions. For example, Roger's passion for tinkering with technology and his belief in technology access for all drove the

development of his TPK and his E-T PCK. As professional developers or preservice educators, tapping into this storehouse of past experiences, skills, and dispositions seems one way to foster the kinds of knowledge development discussed here. However, the success of individual, independent learning in this study provides no mandate to abandon all professional development. Laura's case reveals where one's past experience, skills, and dispositions do not contribute to development of E-T PCK, which has ramifications for how technology is used in her teaching and her students' learning. In short, some teachers may succeed in thoughtfully teaching with technology without formal support and assistance (though Roger, Doug, and Nell all had informal support throughout their learning process), yet many will not. As professional developers and preservice educators, building upon teachers' and students' prior skills, dispositions, and experiences will likely push the Dougs, Rogers and Nells of this world to strengthen their E-T PCK, while also helping the Lauras to begin considering how they can bring both content and students into their sights and ultimately develop E-T PCK.

Appendix A: Sentence Completion Activity



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EPILOGUE

In the work represented in the preceding articles, I sought to explore the territory of English teachers' technology-learning and classroom-based use, an area sorely in need of study. I chose to examine this topic with a wide-angle lens using naturalistic methods. Though I have interpolated implications for professional development and preservice education from my findings, the small number of participants (four) actually reduce the likelihood that these findings generalize to a larger and more diverse population. The findings of this study will primarily serve two purposes. First, they might serve as hypotheses and concepts for future study, using a collection of analytical methods (appropriate to the research questions I ask). I imagine in five or ten years' time this future research will reveal whether the findings and inferences discussed in this body of work actually do generalize. Second, the stories of these four teachers can serve as a reflective tool for current teachers, as a mirror in which they can look to see if they see themselves.

This work separated classroom-based technology use into finer categories. I developed theoretical categories of replacement, amplification, and transformation to analyze teachers' use. These categories highlight significant differences among types of classroom-based use. It seems prudent to share this framework with classroom teachers, administrators, and university instructors, so we all can begin to think more deliberately about the kinds of technology practice we promote and enact. In addition, these categories can be a basis for evaluating the cost-effectiveness of the investment into technology. Clearly, technology used to replace current instruction, learning, or content

will not prove as attractive an investment as technology that amplifies or transforms current practices.

The work also underscores just how hard it is to learn technology. It documents that learning to use technology in the classroom requires more than simply learning a repertoire of technology skills. The content and form of technology instruction for preservice and practicing teachers impacts their classroom-based technology practice. For example, to facilitate more transformative technology uses, we might consider teaching new content knowledge (such as hypertext in the English discipline) and technologies that support the teaching and learning of that content (as we saw Nell do). There is a cycle inherent in these findings: the manner in which teachers learn about technology impacts how they use technology in the classroom which, in turn, impacts students' learning opportunities. The connection back to (or lack thereof) students is the ultimate reason for examining teachers' learning and use.

Roger, Doug, Nell, and Laura managed to learn to use technology with little formal support. The learning model developed in the second study highlights the principal role of prior knowledge and experience in the learning process. On the surface, assuming these four cases are typical, they would suggest that we let teachers learn technology on their own, just as these teachers have. The argument would run something like this: teachers' prior knowledge and experiences determine what, when, and how they learn in the end anyway, so why disrupt the natural process? This approach, though, is ultimately flawed because it would exclude all the teachers who could benefit from an outside nudge, whose prior knowledge and experiences do not provide the natural motivation to learn technology. With these teachers in mind, the model must suggest an

alternative to laissez-faire. An alternative might focus on the need to understand teachers' prior knowledge and experiences. This understanding allows the instructor to tailor instruction to the needs and interests of a diverse array of teachers or to understand why particular teachers may not find the instruction useful. For example, teaching about technology by displaying its "possibilities," in other words, sharing rich cases of technology use in education, would be an excellent approach for teachers like Doug who has a general interest in technology. However, this approach might be less effective for a teacher like Nell, who is committed to teaching English inventively. What are the chances that one of the "possibilities" involves intriguing and inventive English content? Overall, knowing more about a teacher's prior experiences and knowledge will help the instructor design useful instruction and, ultimately, better support teachers' learning.

The findings, suggestions, and implications of this research suggest several directions for future work. The technology use taxonomy and the learning model both require further research (validation and reliability) within a larger population of teachers and across more content areas. A longitudinal examination of progress through the learning phases in real time will allow better characterization of each stage.

In addition, research that maps and assesses the kinds of knowledge teachers develop when learning to teach with technology would be a valuable addition to the field. A better understanding of these kinds of knowledge and how they can be acquired will lead to a better understanding of the design of both preservice and inservice education. Preservice programs struggle to understand how to include "technology" in their required course sequences. If future research confirms my hypotheses about the development of E-T PCK, subsequent recommendations for preservice and inservice would focus on

engaging teachers with new content as they learn about technological tools that support the learning of that content.

Finally, one of the most important pieces of my future work is to examine how technology-supported practice and learning connects to and impacts student learning and achievement. If and when we make this connection, we would be able to determine exactly how different technology uses (replacement, amplification, transformation) and different types of knowledge (e.g., E-T PCK, TPK, TK) enhance or retard student learning. Only then, will we be able to speak confidently about the impact of technology in our schools and society.