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The Role of Teacher Knowledge and Learning Experiences in Forming Technology-Integrated Pedagogy

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Using a multiple-case embedded research design (Yin, 1994), this study examined the nature of teachers' learning during technology professional development activities and the extent to which their subsequent technology-supported pedagogy was innovative. Four English language arts teachers, who ranged in teaching and technology experience, served as contrasting case studies. Results suggested that the power to develop innovative technology-supported pedagogy lies in the teacher's interpretation of the newly learned technology's value for supporting instruction and learning in the classroom; learning experiences grounded in content-based, technology examples were most effective toward this end. Furthermore, teachers with less professional knowledge (e.g., preservice or novice) and/or less intrinsic interest in identifying uses for technology may need guided or collaborative, content-specific technology learning opportunities, while teachers with more professional knowledge (e.g., veteran) may be able to develop innovative technology-supported pedagogy by bringing their own learning goals to bear in professional development activities. Collaborative, subject-specific technology inquiry groups are proposed as professional development that supports all teachers' learning to integrate technology into their subject areas.

We are at a decisive juncture in terms of technology use in elementary, middle and high school education. There is educational promise in the accumulating technological resources that are increasingly available to teachers

and school children that contribute to innovative practice and learning across subject areas (e.g., Chen & Armstrong, 2002; Duhaney, 2000). Simultaneously, technology is being used in ways that replicate traditional instructional strategies and learning (Cuban, 1993, 2001). Given the community support for technology use in the classroom (Starkweather, 2002), it is unlikely, even with Cuban's depictions of uninspired technology use in schools, that technology resources will be extracted from schools. Thus, while education is poised for innovation that will allow students to engage in learning with technology in ways they, their teachers, and their parents have never experienced, we still need to reflect on how to make those practices a reality in classrooms today.

Indeed, increasing the effectiveness of technology-supported content area teaching has been a national goal (Riley, Holleman, & Roberts, 2000). Yet, only one-third of public school teachers feel "well prepared" or "very well prepared" to integrate the use of computers into their teaching (NCES, 2000), and professional preparation for practicing teachers to integrate technology resources in support of subject area learning has been scant (Milken Exchange on Educational Technology, 2000). An essential question concerning this issue lies in how some teachers learn to infuse technology innovatively into subject area instruction and learning while other teachers adopt technologies in ways that do not significantly change student learning or instruction. Thus, we need to better understand how to best support and promote technology integration among subject-matter teachers in both informal and formal learning contexts. The current study builds upon relevant literature on teacher learning and the factors that may enhance the likelihood that teachers will use technology innovatively to support subject matter learning.

LITERATURE REVIEW

Teacher Learning

There are many teachers for whom the use of technologies for educational purposes is unfamiliar and, in some cases, a daunting prospect. Technology integration requires practicing teachers to assume a learning stance. From a constructivist perspective, "teacher-learners" engage in learning that is a "constructive and iterative process in which the person interprets events on the basis of existing knowledge, beliefs, and dispositions" (Borko & Putnam, 1996). The goal of professional development, then, is to help teachers make meaning of new constructs and experiences (technology, in this case)

to determine its impact on education, including learning processes, access to content, and instructional methods. Ultimately, we hope such learning experiences will change teachers' practice in that they are better prepared to integrate technology to support subject-matter learning by their students.

Teachers' prior knowledge mediates future learning (Borko & Putnam, 1995, 1996; Bransford & Schwartz, 1999). In learning situations, teachers interpret, question, or evaluate new knowledge through their previously acquired knowledge and experiences (Bransford & Schwartz). In addition, an important part of teachers' life-long learning is the "expansion and elaboration of their professional knowledge base" (Borko & Putnam, 1995). Overall, knowledge is essential because teachers use it to determine actions in the classroom. Thus, it is strategic to identify the relevant knowledge base teachers draw on and develop when learning to teach with technology.

The conceptual categories of subject matter knowledge, pedagogical knowledge, and pedagogical content knowledge (Grossman, 1988; Shulman, 1987) form a useful framework toward this end. Subject matter knowledge is the depth and breadth of knowledge in a content area such as English, physics, or algebra; teachers know facts and concepts of the discipline, frameworks for explaining such disciplinary facts and concepts, and the path new content takes to become part of the discipline. General pedagogical knowledge, such as learning theories, individual cognitive development, and classroom management, serve teachers across all subject areas for general pedagogical choices. Pedagogical content knowledge is specific for each content area; teachers within a discipline make pedagogical decisions about instruction and learning based on what they believe to be the purpose(s) for teaching the content, what knowledge they believe students should be developing (noting what has been taught in previous and subsequent grade levels), what discipline-based teaching materials are available, and what representations or activities have been successfully used in their past teaching.

Teachers who learn about technology may connect it to their subject matter knowledge, pedagogical knowledge, and pedagogical content knowledge (Drier, 2001; Dun, Feldman, & Rearick, 2000; Margerum-Leys & Marx, 2002). To facilitate innovative subject matter teaching with technology, capitalizing on connections with subject matter or pedagogical content knowledge seem particularly appropriate. Yet, it is unclear how different learning environments or experiences may trigger teachers' development of or connection to any or all of these types of knowledge. Thus, the literature on the nature of effective learning experiences may reveal insight into possible relationships between the learning experience and knowledge development.

Nature of Effective Learning Experiences

Cognitive constructivist learning perspectives and teacher change literature acknowledge the need for awareness of one's own beliefs in order to begin questioning beliefs or considering change. People, situations, or internal reflection can provide "potentially alternative ways of thinking or acting" (Richardson & Placier, 2001) that lead to "cognitive conflict" (Pressley & McCormick, 1995). For example, Sandholtz, Ringstaff, and Dwyer (1997) documented change in instruction and beliefs when teachers, who were aware of their own beliefs, had exposure to "alternative belief systems and experience positive consequences of those alternatives" (p. 48). King (2002) reasoned that inexperience with technology created "disorienting dilemmas" for teachers that prompted enrollment in technology-learning experiences, which, in turn, can "cause adults to question their knowledge base and to change their actions" (p. 287). King documented occurrences of "perspective transformations," such as shifts from teacher-centered to student-centered perspectives, development of a worldview of education, or changes in instructional preparation. We may anticipate that learning experiences that provide opportunities for teachers to access and acknowledge their prior knowledge as well as provide alternatives or dilemmas may impel teachers toward questioning and potentially changing their beliefs and knowledge.

Few teachers have access to quality professional development opportunities that offer thoughtful, subject-matter-based technology use. In 1999, teachers received only 5.9 hours of teacher training on "integrating technology into instruction" (Milken Exchange on Educational Technology, 1999). These minimal training hours are predominantly organized as short-term, one-shot workshops focused on learning software without specific content-based examples of their use (McKenzie, 2001) and without pedagogical and curricular connections (Zhao, Pugh, & Sheldon, 2002). A shift toward content-based technology preparation is beginning to occur in inservice education, and descriptive accounts (e.g., Crohen, 2001) are now available. Providing content connections may be more successful due to its implicit or explicit reference to teachers' subject matter knowledge and the content they teach, for teachers report a desire for grade-specific content and curriculum integration ideas (Snoeyink & Ertmer, 2001/2002). Approaches that emphasize content would target teachers' subject matter knowledge and pedagogical content knowledge in contrast to when technology is learned as a separate, unrelated skill. Thus, we may expect that teachers who learn about technology from a content perspective may be more likely to use it to support content learning, whereas teachers who learn it as a skill may have greater difficulty using the technology for educative purposes. Thus, to

effectively interpret the impact of professional development, one must consider the outcome—specifically, teachers' technology integration efforts and technology-supported pedagogy.

Technology-Supported Pedagogy

The variation in technology-supported pedagogy may be captured through three categories; (a) technology functioning as replacement, (b) amplification, or (c) transformation. Technology as replacement involves technology replacing and, in no way, changing established instructional practices, student learning processes, or content goals. The technology serves as a different means to the same instructional end. Technology as amplification capitalizes on technology's ability to accomplish tasks more efficiently and effectively, yet the tasks remain the same (Cuban, 1988; Pea, 1985). Technology as transformation may change students' learning routines, including content, cognitive processes, and problem solving (Pea, 1985) or teachers' instructional practices and roles in the classroom (Reinking, 1997). Technology in education has the potential to innovate, as in transformative uses, but also can maintain the status quo, as in replacement or amplification uses. Currently, teachers are employing technology in ways that are least distant from their practice, choosing to sustain rather than innovate current pedagogy (Cuban, 2001; Zhao et al., 2002). Crafting transformative technology pedagogy may require learning experiences that inspire reflection, are grounded in content, and provide ideas and alternatives for technology use. Yet, the research has not examined the role that learning experiences or teachers' knowledge may have in the degree of innovation of teachers' adopted use of technology.

PURPOSE OF STUDY

This research extends this discussion by researching how teachers' knowledge is employed and possibly changed within the technology learning activities they experience and the extent to which their subsequent technology-supported practice is innovative. The research questions guiding this project include:

> What is the nature of practicing teachers' educational technology learning experiences?

How do practicing teachers use technology to support their practice?

What role does teachers' prior knowledge and learning experiences play in the building of technology-supported pedagogy?

Specifically, do teachers have the professional opportunity to examine and reflect on content-based technology alternatives or dilemmas? If so, is their subsequent technology-supported practice transformative?

METHOD

This study used a multiple-case embedded research design implementing an exploratory research strategy (Yin, 1994). For each case, the primary unit of analysis was the practicing teacher, and the embedded subunits of analysis were (a) technology learning experiences and (b) technology-supported practice in the classroom.

Participants

Multiple cases were chosen to serve as contrasts in accordance with theoretical replication (Yin, 1994). Potential participants, drawn from university contacts and a listserv advertisement, participated in a phone interview during which they briefly described their technology use, teaching experience, technology-learning experiences, and site-based technology resources, as these were variables that the literature review revealed might precipitate contrasting results. Four teachers were selected and agreed to participate. All cases involved the English Language Arts content area. Table 1 summarizes the cases' contrasting features.

Data Sources and Analysis

Three life-history interviews, adapted from Kelchtermans and Vandenberghe's (1994) cycle of three semi-structured biographical interviews, were conducted that focused on education, career history, technology experience and use in the classroom, technology learning, curriculum, and instructional approaches to teaching English. Interviews were tape-recorded and transcribed. Three direct observations, focusing on the use of technology in relation to instruction and student learning experiences were completed. Field

notes were written and any materials given to the students (e.g., handout) or used in instruction (e.g., PowerPoint presentation) were collected. All sources of evidence were compiled into a case database that facilitated data analysis.

Table 1
Theoretical Replication within Multiple Cases

	Nell	Doug	Roger	Laura
Grade Taught	7th & 8th	5th	9th	9th
Teaching Experience (Years)				
Veteran	✦(26)	✦ (25)		
Mid-career			✦ (6)	
Novice				✦ (3)
Types of Technology Learning Experiences				
Informal (e.g., self, peer, books, etc.)		✦	✦	
Formal (e.g., inservice, higher education)				
Both Informal and Formal	✦			✦
Computers in Classroom (Number)				
Multimedia & Internet Generation[a]	0	2	2	1
Older Generation[b]	0	6	7	0
Computers in Lab/Library (Number)				
Multimedia & Internet Generation[a]	29	0	20	35
Older Generation[b]	40[c]	0	0	0

Note. [a]This category included machines that supported multimedia (CD-ROM and graphics/animation) and Internet-based activities. [b]This category included computers that could not support advanced multimedia and Internet due to hardware or processing limitations. [c]These 69 computers were separated into three labs.

The analysis used explanation-building strategy (Yin, 1994) to build a set of hypotheses (Glaser & Strauss, 1967) related to the relationships between teachers' knowledge, learning experiences, and practice. Overall, each case was analyzed independently, then cross-case conclusions and theories began to form, rival conclusions were considered from the literature, and developing theories were modified or further explained.

The embedded units of analysis (learning experiences and technology-supported practice) were analyzed first and interpreted at a single case level. Field notes and interview transcripts were coded for "instances" of (a) technology use that involved a technology (software or hardware peripheral)

being used during the teaching of English language arts and (b) technology learning (e.g., inservice, independent study, manuals, peer, etc.). Each technology use was coded for the user of the technology (teacher or student), intended and enacted use (general pedagogical or content-related), software/hardware involved (open-ended), and the degree of innovation (replacement, amplification, transformation). Each learning instance was coded for what technology was learned, type of learning situation, and if English subject matter and/or general pedagogy were involved.

Each teacher's past technology use and technology-learning were reconstructed through timelines, diagrams, lists, metaphors, and narratives. During the second interview, participants examined the timeline for verification, additions, and corrections, while a list of all the technologies they had used was presented in the third interview for a structured participant reflection.

RESULTS

The four cases (Nell, Doug, Roger, and Laura) illustrate that the nature of and degree to which a learning experience activated teacher's professional knowledge played a crucial role in the learning process and impacted how the teacher used technology in his/her practice. Each case is presented, and then cross-case analyses are described.

Nell

Educational technology learning experiences. Nell recalled beginning to learn about technology 13 years into her career. She described learning the following seven technologies: word processing, hypertext technologies (i.e., web page authoring, HyperCard, and StorySpace), PowerPoint, listserv communication, and chat software. Although Nell described learning through instances involving (a) playing around, (b) observing students, (c) coaching by technology specialists, (d) presentations or communication (e.g., teachers, conference, listserv), (e) graduate courses or formal inservices, and (f) assisting other teachers in summer course. Nell acknowledged that her most productive learning occurred through playing with technologies or receiving coaching. Regardless of the manner in which she learned, there was always an explicit presence of her content area, literacy, within each learning experience.

Literacy content was tightly connected to each technology Nell described learning. When Nell learned word processing, hypertext and listserv

technologies, the connection to literacy content was provided by the learning situation. For example, at a Writers Workshop conference in which participants focused on literacy, Nell learned about writing process theory but also began to use the word processor on her new computer, concluding that one cannot "truly practice the writing process without a computer because of the ease of revising, revisioning the text" (Interview 3, p. 31). Similarly, Nell learned about postmodern literacy theory and hypertext, computer-based texts that are read in a nonlinear fashion and that are organized on multiple dimensions, in a graduate-level rhetoric class in which an assignment required the construction of electronic hypertexts with web-authoring tools. She learned listserv communication with colleagues by participating in a national writing project.

However, the literacy emphasis was not only made by teacher-figures but also by Nell, as a learner. When Nell learned PowerPoint and chat technologies, she imposed the literacy connection as she learned and experimented with these new technologies. For example, when she observed PowerPoint used by a colleague, she wondered, "…how could I use that to my advantage in the classroom?" (Interview 2, p. 14). As she learned it, she developed potential ideas for its use as a medium for her students to engage or extend their literacy learning. In a similar way, an overview of chat software systems at a conference presentation piqued Nell's interest in its possible support of literacy goals. Nell explained that the presentation "really got the wheels turning for me…the kinds of things you can do with chat…" (Interview 2, p. 8). She thought chat had the potential to support literature-based discussions that had not always been successful in her classroom. Overall, Nell's technology learning was anchored in the literacy content area, whether through a guided, literacy-focused learning experience within a formal learning context or through informal learning contexts during which she identified literacy connections.

Classroom-based technology use. Over the course of Nell's career, she described using the technologies she learned, with the exception of HyperCard, in 11 different ways. Her use of the technology ranged in degree of innovation, and she primarily put the technology into her students' hands as 9 of the 11 instances entailed students using the technology.

There were four instances in which Nell used word processing, PowerPoint, and chat software as a replacement of traditional educational methods. For 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 looped repeatedly while students worked on another project. This activity replicated writing the poem on a poster for the wall, with an unchanged goal

for students to read and appreciate it. The use of PowerPoint did not provide any advantage, and Nell reported the PowerPoint and chat activities were less successful than a traditional, nontechnology approach.

Nell used word processing and Internet searching in three ways that amplified instruction or learning. For example, Nell's students edited peers' stories typed in the word processor. Peer editors typed comments in all CAPS within the word processor file, much like they would have with handwritten editing. Yet, the author's ability to easily revise based on the peer's comments was amplified, for the student avoided completely rewriting the story to accommodate changes.

Nell's use of hypertext software, PowerPoint, and listserv communication led to four instances of transformation. For example, Nell's students used StorySpace and web authoring software to write hypertext slave narratives and colonial biographies. Hypertext was not required content in traditional eighth grade English language arts according to the state standards. Yet, Nell expanded her English goals to include hypertext writing. Students used StorySpace and web authoring tools to visually understand the intertextual roots of hypertext and to write their own hypertexts. In summary, Nell crafted technology-supported activities that elicited student use of the technology and ranged across replacement, amplification, and transformation.

The interaction between professional knowledge, technology learning, and practice. Nell's learning experiences that were grounded in the English content area provided new content or pedagogical approaches, such as hypertext or writing process, connected new ideas within the established content area, offered technological tools for intellectually engaging with the new content, and led to technology use in the classroom that was either amplification or transformation. Nell sought these learning experiences to become a more creative and theory-based literacy teacher, and the primary focus on literacy appears to have expanded her subject knowledge (e.g., hypertext and intertextuality) and her pedagogical content knowledge (e.g., a perspective that teaching process writing requires word processors), and established an ongoing method for learning about her craft (e.g., professional listservs).

The other learning experiences that were not grounded in content or pedagogy but rather, focused on providing an overview of technology tools (e.g., PowerPoint and chat software), at first, contributed to replacement technology use in the classroom. Nell was not satisfied with these outcomes and began identifying more potential uses for the technologies in her curriculum. In these learning experiences, Nell's extensive professional knowledge functioned in two important ways. First, she accessed her knowledge to

identify promising uses for the technology. Though her initial integration only achieved replacement, the ways she used them were very connected to literacy learning (e.g., using chat to facilitate sentence combining skills). Second, she used her knowledge to interpret the success of her integration attempts—in this case, she believed the technology-based activity did not meet the intended outcomes, and she continued to identify other potential uses. Because Nell was not afraid to introduce the technology into the classroom prior to her mastery of it, her students used PowerPoint, StorySpace, and web authoring even though Nell, herself, did not understand all features.

Overall, Nell's technology-supported pedagogy achieved more amplified or transformed educative use in the classroom after she learned technologies framed within literacy content and pedagogy. Yet, she also was able to identify promise for technologies she initially learned as technology tools. Nell's extensive professional knowledge and experience, gained through twenty-six years of literacy teaching, enabled her to independently develop, experiment with, and evaluate ways to use technology to serve literacy learning goals. However, many of her initial attempts to use these technologies merely replaced her traditional practice; thus, the path toward amplified or transformed educative uses appeared to take more experimentation, reflection, and time.

Doug

Educational technology learning experiences. Doug was a veteran teacher with 25 years of experience. Nearly 20 years ago, he began trying to understand new technologies and their potential for education. He learned five technologies, including LOGO programming, word processing, e-mail, HyperCard, and HyperStudio, (a) with colleagues, (b) by consulting books or journals, (c) through conference presentations, and (d) through self-study. Common across all Doug's technology learning instances was the preliminary introduction to the technology by a colleague's demonstration or suggestion.

Though colleagues initially introduced all the technologies to Doug, these introductions varied in the degree to which that introduction involved examples of educative uses related to content, curriculum, or pedagogy. For example, two of the five technologies—LOGO and HyperCard—were introduced as a new technology only, without discussion of connections to literacy learning or teaching. Yet, the other three technologies—word processing, e-mail, and HyperStudio—were introduced as a technology that could facilitate writing activity. Colleagues introduced only one potential use for the

word processor and e-mail and provided a range of uses for HyperStudio during their respective introductions. Thus, these learning experiences did not offer a range of alternatives for using technology in transformative ways, yet they did provide at least one content-based example. Doug subsequently was in the position to decide if he wanted to pursue learning these technologies based on these initial introductions. His learning was sustained if he recognized technology's capacity to support particular aspects of the English curriculum.

Classroom-based technology use. Of the five technologies that Doug described being introduced to him, he used LOGO as an after-school, elective activity (due to Doug's inability to determine a curricular use for it), used e-mail and HyperStudio in his literacy teaching, and did not use HyperCard. The initial e-mail and HyperStudio activities served as springboards for other related activities using Draw software, encyclopedias, and video resources. In total, Doug integrated technology into his classroom in 11 different ways that ranged in their degree of innovation. Doug's students used the technology in 10 of the 11 technology-based activities.

Four of the ways Doug integrated the word processor and draw program into his teaching served as a replacement. For example, Doug's students practiced recognizing parts of speech by highlighting or underlining examples within paragraphs in a word processing file, just as pen and paper might have. Doug used e-mail, HyperStudio, encyclopedias, and cable access in five technology-supported projects that held amplified effects. As an example, in Doug's first partnered e-mail project, he identified people around the world with whom his students could correspond, as Doug described, "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" (Interview 2, p. 13). E-mail facilitated frequent correspondence that motivated and inspired the students to write, provided more writing opportunities, and prompted students to examine differences among people whether it be geography, experiences, beliefs, religion, or race. E-mail amplified the writing activity that students would have been able to accomplish with handwritten, mailed correspondence, yet it did not change the learning or writing outcomes.

Doug also developed two ways of using technologies that transformed instruction and student learning. For example, Doug used web resources, listservs, and e-mail for professional development. He found teachers around the U.S. that, otherwise would have been unavailable, with whom he coconstructed class projects. This range of teachers provided the opportunity to learn about ideas that Doug had never thought about at any length and

to contact teachers "outside [his] little sphere," a shift from the cloistered environment of many schools. As a result, the content of, not to mention the nature of the interaction supporting, his professional development was fundamentally altered. This professional development led to the focus on partnered projects within Doug's curriculum. It was one of these projects—an electronic fieldtrip—that also transformed the way the students learned and wrote about local history.

The interaction between professional knowledge, technology learning, and practice. Doug's learning of technology emerged from colleagues' recommendations. Neither a curricular problem nor insatiable personal interest in technology drove Doug's learning. Rather, Doug understood technology's presence in education and was interested in considering options that came under his radar. This passive approach limited the potential for developing transformative technology-supported pedagogy in that Doug was reliant upon others' technology suggestions that varied in their suitability for educative purposes in his classroom. Doug had a challenging learning-to-practice situation, for Doug's learning experiences varied in the amount of information provided about the technology and the technology's educative value; thus, Doug had to determine the possible value for technology as well as how to subsequently use the technology.

In every learning situation, Doug had to make a decision about the worth of learning and using the technology in his classroom. Doug's wealth of knowledge and experience from a 25 year career as a teacher and a very functional perspective concerning technology facilitated this process. Doug explained, "I want to be able to get it, to use it, to facilitate what I'm doing" (Interview 1, p. 1). The two technologies—LOGO programming and HyperCard—that were introduced as a technology alone, without connections to curriculum or education, were not integrated into Doug's classroom because he was unable to see an immediate benefit or value.

The three other suggested technologies—word processing, e-mail, and HyperStudio—were introduced to Doug along with some discussion of curricular benefits that revealed their value. Understanding their value and using them in his own classroom launched Doug into developing, refining, and expanding the technology use, especially the notion of partnered projects at a distance. Doug began to draw on his general pedagogy and pedagogical content knowledge in order to develop projects that would lead his students toward a better understanding of and interest in writing. Yet, these three learning experiences provided only one way of using the technologies in education and did not provide multiple, alternative views for their use nor were

they intimately connected with content. Doug developed a "spice up" philosophy for technology-supported pedagogy that went unchallenged. For Doug, exposure to technologies that exuded clear value for writing curriculum was essential for him to learn and integrate it into his classroom. Once he saw the value for a technology, he launched into developing a variety of technology-supported projects aimed at spicing up his writing curriculum, a predominantly pedagogical endeavor. This spice led to a variety of innovation because at times the motivational effects of technology were fore-grounded (replacement) and at times the writing content was fore-grounded (amplification and transformation). Multiple, diverse perspectives on technology use may have spurred Doug to consider his "spice up" perspective.

Roger

Educational technology learning experiences. Roger's interest in technology had roots in his adolescence, and he continued to learn new technologies when he became a teacher. In his six-year teaching career, Roger described learning Internet searching, HyperStudio, electronic portfolios, ProQuest database, PowerPoint, Visual Page, chat software, and database software. Roger's approaches to learning tended to be informal, for he described learning technology predominantly through (a) playing around and (b) working with colleagues. Some work with colleagues included professional development projects, such as investigating portfolio assessment, that were organized at the school-level. He also mentioned that a few school-sponsored inservices were offered, but he found that they "never progressed" as they taught the same software (Microsoft Works) every time. The informality of most of Roger's learning experiences made Roger responsible for deciding what and how he would learn.

In each of six learning instances, a particular curricular issue spurred Roger to identify and learn a new technology. For example, for several years Roger wanted to include more current events in his integrated English-history block. When the ProQuest database became available at his school, he quickly taught it to himself and then immediately included it in a debate unit on current topics in the state legislature. In this example, the content and research experience he wanted his students to experience drove Roger to seek options, such as ProQuest, that might support the curricular goals. Roger described several curricular challenges that he was currently searching for possible technological solutions. For example, he wanted his students to access and use their research more prominently during their debates. He described

how laptops and databases might enhance students' access to information during a debate, "The other group is talking and while they're talking, they're pulling files up and doing sorts [sic] to help them present. Wow!… It's here, up in my head, but probably implementation is a year to two years" (Interview 1, p. 18). Roger's investigation of HyperStudio, electronic portfolio options, ProQuest, PowerPoint, and databases emerged from curricular issues in the classroom. In these learning experiences, Roger grounds his learning of technology within his curriculum and content areas, which necessarily requires Roger to be cognizant of his own content and pedagogical knowledge. Yet, these learning experiences do not provide a range of alternatives or ideas for using the technology beyond what Roger identified.

In two other learning situations, Roger learned the technology first without connections to content and then, later, thought about ways to use the technology in his curriculum. He learned Visual Page and chat software in this way. Roger loved to play with computers, and he avidly learned any available technology. For example, he learned about chat systems without any particular curricular use in mind. Yet, in time, he started to develop ideas such as, "I would love it for, to set it up for like book clubs…you could even set up where like in school and at home, parents could communicate, you know. The potential is just unbelievable. I don't know where I'm going to go with it" (Interview 3, p. 20). These experiences offered little more than technology tool learning, as they were not grounded in content or pedagogy nor did they offer multiple ideas for the technology's use in education. Overall, Roger was responsible for his own technology learning. In most cases, Roger used content or pedagogical challenges to spur technology learning, but in some cases, also allowed new technologies to capture his attention without necessarily knowing the technology's potential educative value.

Classroom-based technology use. In his six years as a teacher, Roger described using the technologies he learned, with the exception of Visual Page and chat technology for which he was still identifying purposes, in nine different ways that primarily functioned as amplification. Eight of Roger's nine technology-supported lessons put the technology into the hands of the students.

There was only one instance of technology functioning as a replacement, and this occurred when Roger's students used PowerPoint software to present the main ideas of sections in a book. As a jigsaw, small groups of students were responsible to teach the rest of the class about their section. The use of PowerPoint did not provide any advantage over oral reports and posters. Unfortunately, in this instance the students had focused on learning

the software rather than *using* the software, distracting students from learning the content.

Roger used six technologies in ways that ultimately amplified instruction, learning, or the literacy content. For example, students had the option to do their writers workshop daily writing using word processing software. The use of word processing for Writer's Workshop amplified both the student learning process and the teacher assessment. Since Roger encouraged students to work on one piece of writing for the entire year, he explained how fundamental the computers were since students were given time for editing and revising their writing. In addition, Roger claimed that collecting students' writing on disks helped him assess it quickly and easily.

Roger's two technology-based activities that proved transformative in nature included the use of HyperStudio for representing ideas and the development and use of electronic portfolios. For example, when Roger's students used HyperStudio to gather, organize, and present information in their English 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. As students constructed hypermedia-based presentations, Roger was able to guide them in this structural analysis of their writing and organization. HyperStudio's card 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.

The interaction between professional knowledge, technology learning, and practice. Because Roger's technology learning experiences were initiated and coordinated on his own, Roger chose technology topics that were of interest to him or supported a curricular issue he had identified in his teaching. The close connection between content and technology that Roger maintained in his technology learning experiences offered the chance for Roger to expand primarily his pedagogical content knowledge—in other words, the pedagogical tactics specific to the English discipline that would engage his students in learning.

His learning experiences did not challenge or expand his subject matter knowledge, for he did not seek or create such an experience for himself. Instead, the technology-supported pedagogy that Roger developed grew out of Roger's established curriculum and pedagogy. Since his learning experiences did not expose him to alternative perspectives that used technology in innovative, transformed ways, it is not surprising that his technology-supported pedagogy was predominantly amplified. Finally, Roger's two learning

experiences that focused on technology tools had not yielded actual classroom-based technology use. Thus, the technology tool learning approach was less productive toward developing technology-supported pedagogy.

Laura

Educational technology learning experiences. Laura had taught for three years, and in that time, she learned about educational technologies through (a) playing, (b) assistance from others, (c) school inservices, (d) technology manuals, and (e) repetition and practice. Though she specifically stated that her teacher preparation did not prepare her to use technology, she did describe learning about and using technology during childhood through college. These technologies, such as word processing, BASIC, HyperCard, e-mail, web surfing, database, and spreadsheets, were learned in the context of personal interests or job-related tasks, not teaching. When Laura became a teacher, she considered how her knowledge of word processing, Internet use, and e-mail could be useful in an education setting. She also learned about new technologies, primarily administrative, and productivity tools that were present in her classroom.

All of Laura's learning experiences introduced technology as a general tool, without explicit connection to literacy content. For example, Laura learned word processing software by consulting manuals and colleagues during a summer position at an insurance company. Laura learned about e-mail during matriculation into college, and she discovered it was an inexpensive, simple, and fast mode of communication with her family. Even in content-based professional development, such as a National Writing Project seminar, Laura described learning web page development as a set of technology skills taught by computer technicians. School inservices had been provided for teachers to learn technology tools contained as part of the high-tech teacher desk that included video cameras, TV monitors, a computer, VCR, satellite access, phone system, Internet access, and a school-wide program that compiled grades and attendance. These inservices strictly covered operation of these primarily administrative tools. Due to focus on technology skills in Laura's learning experiences, she was responsible for identifying how these technologies would be used in her own classroom. Since Laura was accustomed to technologies and found technology to be a tool that assisted her in many ways, she eagerly sought ways to use these new technologies to improve teaching and learning in her classroom.

Classroom-based technology use. Laura, the most novice teacher in the study, avidly used technology in her classroom. She described 18 different ways she used technology in her classroom—17 of which were used as amplification. She used technology in 14 ways while students used the technology in only four activities.

There was only one instance in which Laura used word processing as replacement. Laura aimed for her students to create a class newspaper. Though the intention was for small groups of students to write sections and layout the newspaper using the word processing program, in the middle of the project, the use of the technology shifted to Laura. Laura perceived that her students' word processing skills were not developed at a level that was productive, so she typed up their hand-written notes for the class.

The other 17 ways Laura chose to use technology amplified her instruction or administrative duties. For the most part, she controlled the technologies in use in her classroom. For example, the word processor was used extensively in Laura's instruction. It amplified her instructional preparation as she produced handouts, tests, and other student materials for her English classes using a word processor. She explained that creating these materials on the computer served as an archive, in which she could easily and efficiently change the materials for future activities. As another example, Laura used her immediate access to the Web at her high tech teacher desk in her daily teaching to support student questions. One day, students had difficulty understanding Edgar Allan Poe's "The Cask of Amontillado." 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. 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, which had very limited resources. In addition to these examples, Laura used e-mail and telephone, PowerPoint, ceiling-mounted cameras, grading, attendance and student information search programs, and library resources such as ProQuest database and Encarta encyclopedias in ways that amplified instruction and student learning. Laura did not use any technology as transformation.

The interaction between professional knowledge, technology learning, and practice. Laura's learning was focused on technology skills and her practice with technology had little connection to English subject matter and was teacher-centered. Although Laura was very skilled with technology, the focus of her learning had been on how to operate the technology. Learning about technology did not challenge her nor provide ideas about the use of

technology for teaching and learning English. Therefore, identifying how to integrate the technology was her responsibility. This presented the most challenging learning-to-practice situation among the four cases. Not only did Laura experience learning situations that were devoid of content connections and integration ideas, she, as a novice teacher, also possessed the least professional knowledge with which to develop technology-supported pedagogy.

Beginning teachers struggle with classroom management and a sense of survival (Feiman-Nemser & Floden, 1986) as opposed to exploring new curriculum, content, or ways of learning. Laura's most accessible professional knowledge was general pedagogy, a specific focus within initial licensure programs. Laura tended to use technology for general pedagogical purposes to support her teaching rather than student learning. In this way, she maintained management of her classroom as we might expect from a beginning teacher. Likewise, Laura expressed her need to appear knowledgeable and competent in front of her students. Therefore, she wanted to become completely comfortable with technology before she actually used it in her class. For example, she practiced using her high tech desk prior to the school year, and she did not use technologies unless she was comfortable with them. Overall, Laura established a technology-supported pedagogy that was teacher-centric and amplified instruction or administrative activities.

Cross-Case Analysis

Across the four cases, patterns emerged related to the teachers' learning experiences and their technology-integrated pedagogy. First, predominantly informal learning experiences facilitated these teachers' access to and use of technology. Though Nell reported formal learning sessions to be important, she reported it was the informal guidance provided within them that made the difference for her. She also learned through listservs and conference presentations. Likewise, Doug reported that his learning was instigated through colleagues' informal recommendations and demonstrations. Roger spearheaded his own learning, deciding how, when, and what to learn. Finally, Laura used manuals, colleagues, and independent practice, though she also took part in more formal inservices provided at her school. Informal learning sufficiently facilitated these teachers' awareness, familiarity, and understanding of technology.

Second, content-focused learning experiences yielded content-based technology integration in the classroom. There were two variations within this pattern. There were the experiences Nell had in graduate courses and

content workshops in which she was exposed to new literacy content knowledge or content-based pedagogy by an instructor or teacher-leader. She ultimately learned new content (e.g., hypertext) and, out of the experience, developed transformative technology activities. On the other hand, there were experiences when the teacher-learner established the content-focused learning experience, such as when Roger's content and pedagogical challenges impelled him to search for possible solutions. He discovered technological solutions and implemented them in his classroom, though the activities ranged across the levels of innovation.

Introductions to new content and innovations in instruction, as in Nell's experience, may lead teachers to rethink their teaching. Yet, Nell was a veteran teacher disposed to learn new content, and other teachers who lack such a perspective could find this learning situation and topics outside their "innovation" comfort zone (Zhao et al., 2002) and will not learn. Roger's "problems of practice" approach may be more comfortable due to its basis in the teacher's content and curriculum while still maintaining a content-base to technology learning. Teachers with more awareness of their curriculum, content, and students' learning will be able to identify these challenges that can instigate technology learning. The degree of technology innovation would be dependent on the types of challenges and technologies identified and examined by the teacher.

Third, learning experiences that focused on teaching technology within general educative examples demonstrated technology's general educative value that, in turn, inspired teachers to explore the possibilities for the technology in their own classrooms. Doug explicitly stated that he needed to see a value for technology through these examples and demonstrations. After his initial use of technology in which he replicated the examples he was provided, Doug expanded beyond these ideas to develop new, innovative ideas that led to amplification and transformative use. Nell also viewed educative examples for the technologies demonstrated but instead of replicating the examples in her own classroom, as Doug did, Nell determined better-aligned uses for the technology, in accordance with her teaching. The technologies she implemented through this learning approach served as replacement and amplification in her classroom.

It accords that the more content-specific the example, the more likely the teacher will see value and learn it. Doug, who had literacy-based examples, learned these technologies that led to a series of expansions based on the initial example use. However, the farther the example is from the teacher's content area, the lower the likelihood that the teacher would spend time developing other possibilities for the technology. Nell actually was willing

to invest time toward devising ways to use it. Thus, she used her knowledge of literacy to determine possible uses.

Finally, Roger, Doug, and Laura all had learning experiences that focused solely on technology with no connections to education or their content areas. These experiences may not lead to innovative technology-supported pedagogy. In these instances, Doug did not see any immediate educative value for the technology, and he did not pursue learning or using them. Roger, on the other hand, learned any new technology to which he had access and if it was not immediately useful for teaching, he stored it as an option in his mind until the appropriate situation presented itself. The path to actual use was much longer in this case, as Roger described learning two technologies in this way that he had yet to integrate in his classroom. Unlike Doug, Roger was willing to spend time accessing his professional knowledge in order to explore and determine educative purposes for the technology that may support his students' literacy learning. Laura, like Roger, was willing to figure out how to use the technologies she had learned, for technologies had assisted her across her lifetime. Unlike Roger, though, Laura was a beginning teacher whose foremost concerns were pedagogical in nature such as keeping her class managed and developing productive instructional strategies. From these learning experiences, her technology-supported pedagogy emerged as either instructional or administrative during which she maintained control of the technology. This type of learning situation may lead to innovative technology-supported pedagogy only for those teachers with more teaching experience and knowledge and an inclination to spend time determining best educative uses for the technology.

DISCUSSION

These case studies reveal the role that teachers' professional knowledge has on teachers' engagement in technology learning and in crafting technology-supported pedagogy. Indeed, the power to develop innovative technology-supported pedagogy lies in the teacher's interpretation of the technology's value for instruction and learning in the classroom. This interpretation is mediated by past experience and accumulated knowledge (Bransford & Schwartz, 1999).

The literature indicates that instructional or content alternatives and dilemmas might impel teachers to question or reflect on their practice and potentially change their beliefs and practice. In this set of cases, this actually occurred only in Nell's formal content courses that spurred revisions within her middle school literacy curriculum to include topics such as hypertext

and writing workshop. Yet, more alternatives and dilemmas can be built into the content-based examples used during technology training to help leverage participants' reflections. For example, Doug was introduced to the idea of using e-mail in his class through an e-mail correspondence project between his 5th graders and a group of preservice teachers. The colleague who introduced this idea to Doug might have also presented other alternatives for e-mail use for 5th grade literacy activities such as collaborative, cross-cultural conversations or Internet writing by kids for kids in KIDCAFE (Garner & Gillingham, 1996). The cross-cultural conversations activity could inspire Doug to reflect about the types of cultural activities his students experience or more generally, the role of culture in the literacy content area, opening an area of his curriculum to thoughtful examination. Learning activities that provide such alternatives or dilemmas provide a direct path toward change—as long as the teacher is willing to consider and reflect on the dilemma or alternative that has been presented—which is not assumed. Verloop, Driel, and Meijer (2001) noted that "teacher cognitions have taken years to take shape and are, consequently, not easily changed" (p. 454), while Zhao et al. (2002) noted that technological innovations perceived to be far from teacher's own practice are less likely to be established. Though this approach has promise for introducing innovative technology and inspiring reflection and possibly change, all teachers may not willingly engage in such reflection and change. Further research is warranted to understand what characteristics should be included in the alternatives and dilemmas as well as with whom and in what situations these are most successful.

These cases show how content-based technology learning leads to content-based technology pedagogy. The content connection was essential for teachers, like Doug, who require a clear content connection prior to investing time learning the technology. Snoeyink and Ertmer (2001/2002) echoed the importance of including grade-specific content and curriculum integration ideas in technology learning opportunities. Yet, there are several ways to create these content connections. The colleague or inservice leader can provide these connections, as they were for Doug when his colleague not only introduced a new technology but a classroom activity that used the technology. This approach actually provides an opportunity to include examples that may push the teachers' to consider new ways of teaching or new uses for old technologies. It also provides a chance to scaffold novice teachers to consider technology use for more than management and instruction. For example, Laura might have benefited from seeing the way Roger used PowerPoint to teach the structure of English language and composition. This example potentially would have expanded her concept of PowerPoint beyond a tool for supporting lectures. On the other hand, the teacher-learner

can create these content connections through problems-of-practice, as when Roger immediately knew that the ProQuest article database could be used for students to study current events, a neglected area in his curriculum. This problem-of-practice approach more likely ensures applicability of the technology learning to the teacher's practice. However, the identification of problems-of-practice may be limited by the scope of the teacher's knowledge as well as their ability to access that knowledge. In this situation, experienced teachers may have an advantage over novice teachers. As teachers gain experience, their professional knowledge is further developed, and they are more aware of the knowledge they possess and how that knowledge influences their practice (Carter, 1990).

The results of these case studies have implications for professional preparation of teachers. Collaborative, subject-specific technology inquiry groups may be a professional development approach that supports teachers' ability to learn to integrate technology into their subject areas in line with the findings of this study. In inquiry groups, teachers of similar content areas and grade levels use their knowledge of the discipline, curricular goals, and specific school or district goals to identify problems-of-practice or other subject-matter related topics to guide learning of educational technology as possible solutions. Small, collaborative inquiry groups have been shown successful for teacher learning because this approach (a) focuses on supporting teachers in sharing their knowledge and questions, (b) connects learning to contexts of teaching (site and subject-specific), and (c) promotes active engagement with others over time (Zech, Gause-Vega, Bray, Secules, & Goldman, 2000). Contrary to common assumptions asserting that beginning teachers more easily integrate technology, experienced teachers (who often have less technology experience) are more poised to integrate technology simply because they possess more knowledge with which to connect. Veteran teachers' expertise can offer a subject matter or pedagogical-based focus to technology explorations that beginning teachers may not be able to do independently. For example, veteran teachers like Nell and Doug independently developed a range of amplification and transformative, literacy-based, instructional and learning activities for technologies they learned. On the other hand, the novice teacher, Laura, independently developed general pedagogical, teacher-centered uses for technology that had an amplification impact. It is for that reason that it may be valuable for preservice teachers to be involved in such inquiry groups during their initial licensure program. The content-based, technology inquiries that occur within such groups are in line with recent research that found "that professional development should focus on deepening teacher knowledge in order to foster teacher learning and changes in practice" (Verloop et al., 2001, p. 443). Future research can

examine the process of establishing and supporting subject-matter technology inquiry groups, the knowledge participants learn and develop, and the impact of their learning on their teaching practice and students' achievement.

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