Technology Integration Practice as a Function of Pedagogical Expertise

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Abstract
This study investigated how teachers at various levels of technology use and teaching abilities used technology and how technology use related to general teaching practice. Data from case studies of exemplary technology integrators, representing categories of teaching and technology ability, resulted in assertions about the ways these teachers taught with technology, including the existence of teachers' personal definitions of technology integration, distinctive planning habits when planning for technology inclusion, strategies for teaching about technology that matched teacher learning strategies, management of student computer use, and altered perspectives on assessment. Differences observed among technology use were associated with individual levels of teaching expertise. (Keywords: computer use, expertise, integration, levels of technology use, teacher development.)

Society has embraced computer technology and allowed it to reinvent the ways in which we create, find, exchange, and even think about information. Unable to ignore such a deeply permeating innovation, school districts often bow to societal pressure to fund technology without having a thoughtful plan for implementation. This lack of foresight leaves an evident disparity between instances of classroom technology use, with teachers who are attempting innovative integration ideas sprinkled throughout a selection of users and nonusers. The existence of success in isolated pockets prompted this study of how teachers at various levels of technology and teaching abilities used technology and how technology use related to general teaching practice.

NEED FOR THE STUDY
Expert Performances
The motivation and learning techniques of experts have long been explored to understand the development of expertise, beginning with deGroot's (1965) seminal work on expertise in chess. This line of research has repeatedly produced a series of expert characteristics, summarized in Eysenck, Ellis, Hunt, and Johnson-Laird (1990), to include having a structured procedural knowledge base, more efficient domain-related work habits because of routines of automated tasks, increased mental capacity to dedicate to solving complex or unusual problems, the ability to make decisions based on past experience, and the ability to regulate personal learning. Experts are distinguished by a lifelong pursuit of complex problems for the purpose of enhancing personal learning (Bereiter & Scardamalia, 1993; Ericsson, Krampe, & Tesch-Romer, 1993). The development of expertise can be traced through five notable stages, beginning at the novice stage, where beginners operate by following rules of the domain without any real procedural understanding, and leading to the expert stage, in which
years of experience allow for skilled pattern identification across dissimilar situations (Dreyfus & Dreyfus, 1986).

It has been shown that pedagogical expertise develops with characteristics comparable to those of expertise in general. Expert teachers take time during planning to use their knowledge about students and their experience of past teaching events to set goals for student learning (Berliner, 1994). They make a greater number of contingency decisions than nonexpert teachers and consider management and instructional strategies ahead of time (Dunn & Taylor, 1990; Housner & Griffey, 1985; Livingston & Borko, 1989; Westerman, 1991). With an organized store of knowledge, experts employ a set of routines to automate recurring teaching practices (Berliner, 1986; Carter, Sabers, Cushing, Pinnegar, & Berliner, 1987; Kagan, 1992; Leinhardt & Greeno, 1986; Leinhardt, Weidman, & Hammond, 1987; Westerman). Routines allow teachers to concentrate on unusual dilemmas, thereby managing cognitive responsibilities. Past experience supplies both insight into student learning needs and confidence to incorporate student input to tailor lessons. Expert teachers can monitor multiple classroom events at once, perceptively analyzing situations at deeper levels and focusing on the critical elements necessary to propose solutions (Behets, 1996; Claridge & Berliner, 1991; Gonzalez & Carter, 1996; Sabers, Cushing, & Berliner, 1991). The development of pedagogical expertise can be assessed with a five-stage model derived from the general expertise model (Dreyfus & Dreyfus, 1986), proceeding from the novice stage to the expert stage for select teachers (Berliner, 1994).

Teacher Adoption and Use of Computers

Integrating technology tools into the curriculum is becoming an inseparable part of good teaching. Both the personal characteristics of exemplary technology-integrating teachers and factors involved with the schools in which they teach have been examined. Findings reveal that exemplary technology-using teachers not only spent a good deal of personal time working with computers but also had more extensive computer training and teaching experience (Becker, 1994), as well as high levels of innovativeness and confidence (Marcinkiewicz, 1993). These teachers were surrounded by colleagues who used computers for meaningful activities, enjoyed school- and district-level support for technology use (Becker; Hadley & Sheingold, 1993), and had sufficient staff development opportunity (Ritchie & Wiburg, 1994; U.S. Congress, Office of Technology Assessment, 1995; Yaghi, 1996).

Teachers who were experienced at using computers for instruction shared such teaching practices as planning for regular computer use and consistently using technology as a tool in a variety of instructional projects (Evans-Andris, 1995). They maintained higher expectations for student learning, believed they could use computers to address individual learning needs, and were willing to shift focus toward activities that were student centered (Hadley & Sheingold, 1993; Swan & Mitra, 1993) with less whole-group instruction and more independent work (Waxman & Huang, 1996). Finally, these teachers made conscious decisions to alter established curriculum, relying on their professional judgment to guide student choice in learning activities and promote varied grouping schemes (Becker, 1994). Although the literature on technology inte-
igration does not refer to exemplary practice as expertise, two models exist that
chronicle the process of teacher technology adoption through five stages
(Dwyer, Ringstaff, & Sandholtz, 1991; Rieber & Welliver, 1989), beginning at
a low level where technology was obtained but not regularly used and progress-
ing to an advanced, intuitive stage in which educators redefined teaching and
learning roles to better solve educational problems.

The review of the literature led to a series of research questions: What role do
exemplary technology-using teachers perceive for the computer technology in
their classrooms for themselves and their students? In what ways do they plan
for computer use, and what routines do they establish to facilitate and manage
the use of computers in instruction? What strategies do they use to teach with
and about computers, and how is learning assessed? And finally, in what ways
are the practices of exemplary technology-using teachers comparable to indica-
tors of pedagogical expertise?

METHODS

The initial research questions about exemplary technology use in relation to
general teaching practice indicated a qualitative method of inquiry. My intent
was to provide both a rich, descriptive account of teachers’ use of technology
and to uncover patterns that might suggest a relationship between technology
use and teaching practices. Ultimately, the case study approach used here was
nested within a larger comparative case effort.

Sampling

A quickly growing school district that served a range of socioeconomic subur-
ban areas and ethnic groups was chosen for its history of commitment to pur-
chasing computers and maintaining a technology staff development program.
Elementary teachers with primarily self-contained classrooms who were identi-

fied as exemplary technology users were selected to provide the best data to an-
swer the research questions. Because there may not be a realistic way to identify
teachers who are truly expert (Berliner, 1986; Peterson & Comeaux, 1987), a
process was devised to allow for as consistent a selection as possible.

In early fall 1998, I sought guidance and recommendations for teacher selec-
tion through a process of interviews with the district director of technology, two
teachers on assignment for technology, school media specialists, and principals.
This sequence produced a list of 24 teachers who were contacted to obtain
agreement to participate in the study. In all, 16 teachers were observed for the
screening interview.²

¹ Six recommended teachers were not approved by their principals for various reasons, and eight
others who participated were nominated by their principals but not by the district. This did, in es-
sence, allow principals final veto power, giving their opinions the greatest weight. Because the goal
was an inclusive list of teachers to screen, I decided this distinct risk of sample bias was a necessary
toll to pay to gain access to the schools.

² Three teachers in the initial pool agreed to participate in the screening observation but were un-
able to continue further. I gained consent to participate from two others, but for reasons specific to
each, observations could not be scheduled. Two responded to the participation request but later de-
clined. Finally, four teachers never responded to the informational letters.

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To select a smaller number of case studies, each of the 16 teachers was observed from a half day to a full day to gain a coherent view of classroom routines and technology use. It soon became clear as the initial pool of participants was screened that, although these teachers had all been recommended as exemplary technology users, the group was not homogeneous. They instead represented a range of combinations of levels of teaching abilities and technology use abilities, with some more skilled in technology use and others more effective as teachers. The goal of the study, therefore, changed from examining only those teachers who were exemplary technology users to comparing the interplay of different levels of technology use and teaching abilities.

A framework that loosely intersected levels of teaching expertise (Berliner, 1994) with stages of teacher technology adoption (Dwyer et al., 1991) proved an effective way to understand the abilities of the teachers in this sampling pool and at the same time gain a richer insight into the relationship between teaching abilities and technology abilities. When I examined the models more closely, however, I realized that I would not likely be able to find teachers from each of the five categories in such a small sample. Experts, in particular, are so rare and difficult to identify (Berliner, 1986; Peterson & Comeaux, 1987) that it was improbable that anyone from my sample would be classified as a true expert. To investigate the variety in the sample yet avoid prematurely pigeonholing participants, I devised a more generic framework comprised of composite categories of teaching ability and technology ability. Adequate in this framework is a composite of the lower-level characteristics of each model, whereas Exemplary is a composite of the higher levels.3 Participating teachers were fit into the framework according to supporting data and then compared to others within each category. One teacher was finally selected as the best representative of each category. Table 1 introduces the three case study teachers, illustrates the

3I modified the intent of the Dwyer et al. (1991) model at the higher levels, as it proved difficult to use to isolate technology use abilities from changes in teaching abilities. To better understand how varying levels of technology abilities relate to varying levels of teaching abilities in this particular sample, I infused into the model basic technology competencies.

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Table 1. Relationships among the Categories of Technology Use and Teaching Abilities

<table>
<thead>
<tr>
<th>Teaching ability</th>
<th>Adequate ¹</th>
<th>Exemplary ²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adequate</td>
<td>Category 1:</td>
<td>Category 2:</td>
</tr>
<tr>
<td>Exemplary</td>
<td>n/a ³</td>
<td>Steve McDonald ⁴</td>
</tr>
<tr>
<td></td>
<td>Category 3:</td>
<td>Category 4:</td>
</tr>
<tr>
<td></td>
<td>Jill Nichols ⁵</td>
<td>Sheila Turner ⁶</td>
</tr>
</tbody>
</table>

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Table 1, cont.

Adequate Technology Use. Describes teachers with enough technology skill to troubleshoot common technical challenges, use computers to simplify administrative duties, and teach students to operate hardware and software. Teachers at this level are developing strategies for teaching with technology; however, the classroom computer is primarily used to replicate traditional activities.

Exemplary Technology Use. Includes teachers with exceptional personal and professional computer knowledge. They devote a great deal of personal time working and experimenting with computers and share that passion with students and colleagues. At this level, teachers use computers as a part of daily learning activities yet still may occasionally find difficulty identifying appropriate technology–curriculum connections.

Adequate Teaching. Classifies teachers with an experiential base that allows them to see patterns in classroom events and use that knowledge to identify and solve instructional problems, make informed decisions, and set reasonable goals. Their experience provides insight into critical teaching choices, such as timing and instructional sequence, giving them a sense of responsibility for decision outcomes.

Exemplary Teaching. Identifies seasoned teachers who possess the intuition to recognize patterns across unrelated activities and have contingency plans for the unexpected. Exemplary also describes those few highly motivated learners who interpret their environment in fluid, almost subconscious ways and act in anticipation of what is needed.

No teacher was selected for Category 1, as it represented the lower portions of both teaching and technology skill levels.

Steve McDonald. Steve was chosen to represent Category 2 because of his strong interest in technology, demonstrated with personal time spent using computers, display of technology-related information in his classroom, and pursuit of network certification outside school responsibilities. He assisted colleagues by conducting inservices and helping informally when needed. Professionally, he used his computer for regular e-mail communication with colleagues and parents and for administrative tasks, and his instructional use of computers was primarily limited to weekly computer lab visits. His teaching approach was largely traditional and teacher centered, and he taught the whole class together, by subject, and according to the textbook. Overall, his technology skills were more prolific than the others in this category, but his teaching appeared uninspired after five years of experience.

Jill Nichols. Jill was selected over the others classified in Category 3 because of her greater number of years teaching, the committed and informed way she planned for student learning, and the motivated way she learned from her experience. Her classroom was filled with learning opportunities, and routines for regularly occurring activities were in place, making the day appear to move along effortlessly. She taught students in groups of varying sizes and encouraged student choice in activities and working environments. Although her interest in technology was high, she was just beginning to explore instructional uses of computers. She used her one laptop computer for occasional e-mail and productivity needs, and students used it during free times to play Solitaire or use drawing software. Weekly computer lab visits were reserved for learning specific software skills. Although she was recommended as an exemplary technology integrator, she was still developing personal computer proficiency.

Sheila Turner. Sheila was the most representative of Category 4 teachers because of her high personal interest in technology and her project-based and reflective teaching approach. Students used various forms of technology, including computers and video cameras. She had five computers in her classroom, two provided by the district, and three she had acquired herself. Various projects occurred simultaneously throughout the day, with students moving frequently between whole-class, small-group, partner, and individual work. The other two teachers in this category had every indication of strong technology and teaching skills, however Sheila’s more habitual and varied use of technology promised greater access to data.
relationships among the four categories, and defines the category labels of technology and teaching abilities.

Data Collection

All data were collected during approximately one month per case study classroom over the course of one school year. Every attempt was made to gain a valid picture of teacher practice in relation to the larger classroom and school contexts by collecting multiple sources of data.

Two in-depth interviews were conducted with each of the three teachers. The first was a semi-structured interview occurring at the beginning of the observation period to determine personal educational philosophy and teaching style and to describe typical uses of technology by teachers and students. The second, more structured and customized for each teacher, took place at the end of the observation period to elicit information on each teacher’s perceptions of personal computer use, as well as to clarify events observed in class. I additionally engaged in countless informal conversations with participants. Interviews were audiotaped and later transcribed for analysis purposes.

Classroom observations were focused by cues offered during the beginning interviews, and data collection for the second and third cases was additionally guided by observations made in the first classroom. Full days of observation in each classroom gradually gave way to more focused times as classroom routines became apparent. Observations were recorded in field notes and later reviewed and expanded.

Before the observation of a selected technology activity, each case study teacher was asked to “think aloud” as he or she planned the lesson, recording thoughts and any special considerations of technology usage or management. Each teacher was also asked to keep a log of his or her personal and professional computer use for one week. I additionally collected and analyzed teacher-, school-, or district-created documents related to technology use, such as teacher-produced directions for student use of technology and the district technology curriculum.

Data Analysis

Field notes were reviewed and analyzed soon after leaving the classrooms every day. At the end of the first classroom observational period, all field notes, interview transcripts, think-aloud transcripts, documents, and memos were arranged in sequential order. Through repeated readings of the entire data record for this first teacher, potential themes of teaching and technology use were informally noted and then grouped into larger, related categories. The process was repeated by modifying, combining, and even discarding existing categories to fit the emerging themes from the second and third teachers. Memos were written to advance tentative explanations about the meaning of the data, to speculate about the relationships between ideas, and to tie empirical data in the field notes and transcripts to larger concepts of teacher practice and perceptions.

*The names of all teachers have been changed to protect their confidentiality.
(Miles & Huberman, 1994). The analysis process resulted in a series of assertions that explained what was happening in the three case studies. A systematic search through the data record for concrete examples "established the warrant" (Erickson, 1986) for each assertion, and a reading of the written accounts by each teacher provided member checks for the representation of data.

INTERPRETATION OF FINDINGS
This study was designed to understand how teachers at various levels of technology and teaching abilities used technology, as well as how technology use related to general teaching practice. Through interpretive analysis, emerging patterns in the data led to the formulation of five assertions that illustrated the ways these teachers taught with technology.

Assertion 1: The ways technology was used determined the teachers' personal definitions of technology integration.
Three generic statements, ostensibly similar but in actuality quite different in meaning, will serve to organize the discussion of the individual definitions of technology integration according to which each of these teachers operated.

Steve: "We're going to do the computer."
Steve recalled the way computers played a role in his past by saying, "I've just always done computers." Teaching with computers represented somewhat of a dichotomy between his desire to share his personal computer interest with students and his struggle to connect technology to his fourth-grade curriculum. He organized activities in terms of particular software he wanted students to explore, rather than by the content on which the activities were based, focusing on how rather than why.

It was Steve's own enthusiasm for computers that was the driving force behind computer-involved projects he chose. A good example was his teaching of Web page creation to publish the results of students' research. He expressed in an interview other goals, however, that he had for the project: "Well, I always like to make home pages. You know, something about the Internet really intrigues me ... I want to show them that making a Web page is simple." The inference to be made here is that, although the project was indeed a publishing outlet for student writing, his underlying intent was to share an intriguing computer application. The point is further exemplified through comments Steve made about his use of the Internet personally for entertainment and professionally to find relevant Web sites for students. The Web provided a way to enjoy himself and to simultaneously use his own computer skills and experience to provide a curricular connection to what students were learning in class. Seen together, Steve's computer uses and statements demonstrated the clash between his desire to show students how to do things that were entertaining and the need to relate projects to the curriculum. Computers were an activity unto themselves for Steve, and as long as he could claim some connection to a content-based lesson, he viewed what he was doing as technology integration.
Jill. “We’re going to use the computer to do an activity.”

Jill perceived technology integration as a pairing of two opposite uses of computers. First, she taught structured, step-by-step software lessons in the computer lab, comfortable with the structure so students could learn specific skills. Then, students could select the computer as one of several free-choice activities when other work was finished. In between specific software assignments, Jill had not yet tackled the management issue of individualizing learning using computers, so she allowed students to simply play. To this end, she was proud to say that her students used the Internet, although their use was limited to “surfing” for Web sites of personal interest. There was indeed a generous amount of student choice built into Jill’s classroom; however, the relevant difference is that other choices were designed to meet specific learning goals. Jill was not fully convinced of the computer’s ability to transform teaching. When asked if her teaching strategies would be different without computer access, she responded, “No, things wouldn’t change. Learning will still go on, reading would still go on.” Her comment says a great deal about the value she placed on computers. She welcomed technology as an inevitable part of education, but she remained confident that her own teaching practices would prevail.

Sheila: “We’re going to do an activity.”

Whereas Steve emphasized the use of computers as an inclusive project and Jill emphasized the use of computers as tools to complete assignments, Sheila placed emphasis on the assignment content. With five classroom computers, she was in a better position than either Steve or Jill to weave computers into the fabric of daily learning. Students had frequent opportunity to word process various written projects, to write software commands to enhance problem-solving abilities, and to use drawing software to explore geometrical properties. Sheila considered the content objectives first and then capitalized on how the unique properties of technology could demonstrate the concept. The computer was the tool, not the topic. Sheila was strongly opposed to having students play computer games, although she approved of the use of certain educational software programs for certain student needs: “I have a specific objective in mind, and I’ll say, Okay you need to be using this piece of software to do this only.” Goal-driven technology use was also the reason behind Sheila’s surprising stance toward Internet use. Her frustration at slow Internet access at her school caused her to make a conscious decision not to have students use the Internet regularly. Technology integration to Sheila involved using the most appropriate electronic tool available when and if it was necessary.

Assertion 2: Teachers at the lower levels of either technology or teaching abilities altered their planning habits when planning for technology inclusion.

Planning for technology use showed varying levels of resemblance to each teacher’s previously established planning habits according to their individual definitions of technology. The Category 4 teacher, Sheila, employed similar planning strategies for the use of both technology and nontechnology tools. She began her yearly planning by reviewing the district curriculum guides and her
brimming file cabinets for inspiration, although she never planned exact duplicates of past lessons: "I'm very reflective of what I'm doing and what I would do differently. I know a lot of people are talking about, well, why reinvent the wheel. I kind of like reinventing the wheel!" She found success with involving her students in the planning process, believing that this type of participation allowed students greater benefit from both the technology and nontechnology aspects of a project. Technology was used so pervasively in Sheila's class that there was effectively no distinction between her planning strategies.

Five years teaching fourth grade gave Steve a familiarity with the curriculum, yet he preferred to follow the scope and sequence as presented in the textbooks. Without an established guide that explicitly stated how to integrate technology, he was forced to make his own technology-use decisions. In interviews, he described preliminary plans for activities involving computers, and his personal experience and well-developed technology skills allowed him to later improvise in ways he normally did not when teaching a lesson in one of the traditional subject areas. Unfortunately, although Steve's personal interest led him to put more preparation into technology-aided lessons, his level of experience raised obstacles for successful teaching. The more expertise a teacher has, the more he or she can imagine how a planned lesson will be implemented (Westerman, 1991). Steve demonstrated in his planning thoughts that he was not consistently able to envision what would happen in the computer lab. His knowledge of software and hardware operation was not sufficient to ensure an effective lesson or to connect technology use in a pedagogically sound way to other classroom learning opportunities.

Jill had taught second grade for long enough that she rarely referred to the curriculum guide. Instead she sorted out materials she had used before, reflecting on what she knew would work and what she would like to try differently based on her experience with the topic and with her students, rarely planning with more than a few words to prompt an entire lesson. Her relative inexperience with computers made her more cautious in what and how she was willing to teach with technology. Her plans were more deliberate; although she did not go so far as to script the exact words of her presentation, she did create a list of the items she wanted to demonstrate during a lesson. She also used the district technology curriculum literally, such as including exact indicators such as "identify and use special keyboard keys" or "change font size" on her lesson agenda to make sure they were addressed. One is struck by the way Jill's relative inexperience with using technology forced her to regress to a more conscious level of planning, from a more confident and practiced long-range planning habit to the conscious, deliberate plans a less expert teacher might have devised.

**Assertion 3: Teachers taught with and about technology according to their own personal learning strategies.**

The methods each of these teachers used to teach with and about technology reflected the ways in which he or she learned best. To learn something new about technology, Steve's personal strategy was primarily experimental, preferring to progress through the basic steps and figure procedures out for himself.
through trial and error rather than to refer to a help screen or a manual. His learning style with computers involved “playing around,” so when it was time to teach his students, he employed a similar strategy. Steve’s overall teaching style was largely casual; however, when introducing a new software program, his vocabulary became even more conversational, as if he was speaking with personal friends: “I just share my experiences with the computers a lot of times with them. You know, hey, I was at this really neat Web site. . . you know, look at this new program, and hey, check it out.”

When something intrigued Jill enough to want to learn more, her habit was to gather a wide selection of information in front of her so that she could decide the best way to learn for that situation. Her approach to teaching her students with and about technology mirrored her own organized learning strategy. She introduced individual software programs according to a sequence of steps. Worried about losing control of students with the unfamiliar dynamics of the computer lab, she structured activities carefully so that most were “pretty foolproof.” She presented technology lessons in planned, distinct segments, with precise vocabulary of program features, making clear to students exactly how she wanted the software to be used: “The first thing you’re going to do is, I want the title, and I want it in the center. Do you see how that’s in the center? That’s what I want.” When Jill taught something she was already familiar with, the planning thoughts behind the lessons were less obvious, hidden in a fluid presentational style, whereas, when teaching with computers, she relied on a structured sequence of steps.

Sheila learned about technology through a variety of means, from attending university courses and conference sessions to experimenting on her own at length and searching for guidance in the help features and manuals of programs. The methods she employed to teach her students about technology were as eclectic, with the goal for students not to merely learn a list of steps but to gain a true understanding of the whole concept. Sheila aimed to instill in her students a knowledge of how to be independent learners by finding the answers, developing this information-seeking behavior by referring regularly to the software and hardware manuals. Other directions she provided students with were presented in the first person, asking them to notice how she was going through the procedure: “When I click on that, you see I have a new window.” Sheila was a very hands-on teacher, frequently helping students herself, if appropriate, or encouraging her students to help each other. This highly participatory teaching style modeled for students that she was still learning through what they were learning.

Assertion 4: Teachers’ individual definitions of technology integration directed their management of student computer use

In summarizing the body of literature on classroom organization and management, Doyle (1986) proposed: “The key to a teacher’s success in management appears to be his or her (a) understanding of the likely configuration of events in a classroom, and (b) skill in monitoring and guiding activities in light of this information” (p. 424). Carried further, this theme suggests that, for teachers to
be successful in managing a classroom environment containing computers, they must understand how those computers will affect classroom events and have a plan in place for monitoring and guiding activities that involve computer use. Data collected on the teachers in this study revealed a relationship between the ways they managed and monitored students’ use of and access to computers and their individual definitions of technology integration.

Sheila viewed technology as an invaluable learning tool, so it made sense that her students used computers whenever needed for specific purposes. It was common for her to designate the older computers for word processing while leaving the newer, more powerful computer for research or multimedia work. Priority for student computer use was a negotiation among assignments that were most in need of being finished. Computer use was largely student initiated, dependent on the activities at hand rather than on an artificial management system regulated by a set time or schedule that students cycled through. Indeed, there were times in Sheila’s classroom when none of the five computers were used, a tribute to her perception that not all learning activities required the use of technology.

Being relatively new to technology, Jill saw the potential for computers but had not yet found a meaningful way to include them in her regular classroom routines. Students initiated use of the laptop computer when their morning class work was finished, and then only if they were in the one group out of five that had the computer listed as a “learning center” choice that day. The required, or “important,” work was completed first every morning before the supplemental center work, like the computer, could be chosen. By using the computer as a center activity, Jill was able to apply familiar classroom management routines and thus make the use of technology more workable. It seemed that by organizing computer use with this amount of freedom, Jill was operating under the impression that the computer was an option for learning simply because it was available as a choice.

In Steve’s class, a structured management plan was in place for student use of the sole desktop computer. Students received coupons each nine-week period for 15 minutes of computer time, which generally could be used after lunch during story time. The process for using a computer coupon required a student to ask Steve to use the computer, quietly and independently select a software program, set the egg timer for 15 minutes, and when the timer went off, close the program and join the rest of the class. Steve’s perceived role for computers as a form of entertainment clearly influenced this approach to computer management. By giving students coupons, he was giving them a “treat.” The coupon approach additionally made the computer a more manageable option for Steve because it neatly segmented computer use into specified time blocks and because students could regulate use independently.

Assertion 5: Teachers at the lower levels of either technology or teaching abilities altered their perspective on assessment when assessing student use of technology. Each of these teachers had established procedures for both required and more informal assessment measures. Sheila used consistent assessment strategies when
assessing students' performance with and without technology; however, the Category 2 and 3 teachers, Steve and Jill, made certain modifications to the focus and practice of their assessments.

To Sheila, the subject matter was of utmost importance, and she made it clear to students that she was grading on content rather than on the technology skills themselves: “I will not be giving you a computer grade. But, tomorrow, I will give you a math grade on your shapes that you will be drawing on your computer.” Assessment strategies fit various learning activities, regardless of the level of use of technology: informal observations, traditional paper-and-pencil tests, individual reading comprehension tests, student self-assessment according to rubrics, or customized assessments such as reading contracts. She kept no formal checklists of student progress on the technology curriculum skills, a practice attributed to a conceptual concern she had with the goal of student “mastery” of the listed skills.

I can’t say that the students by the end of the [project] have mastered all the skills of how to use [a particular software program]. A skill that I can use today because I needed it for this project is not necessarily a skill that will just come to me when I come back to it in two months’ time.

Sheila instead relied on her own experience with computers to intuitively judge learning as steps in a process rather than the end toward which all instruction was building.

On a daily basis, Jill assessed her second graders’ progress and adjusted instruction accordingly in a manner similar to that of Sheila. Assessment was seen as an iterative step in the planning and instruction processes, with anecdotal records and performance assessments used for future planning. Her approach for assessing performance with technology was noticeably more structured. Anecdotal records remained the foundation of her assessment approach, though she relied to a greater degree on district-prescribed checklists. Students printed and submitted specific examples of procedure-related actions with the assessment focused on the technology itself rather than the lesson content.

There was a distinct emphasis on test taking in Steve’s class, communicated to students through both his words and his actions. Most activities were introduced with the test in mind: “Expect one of those [on the test] this week.” Tests were used as summative evaluations to judge student performance at the end of a unit. There was a marked shift in Steve’s stance toward assessment regarding activities in which students used computers. Rather than having students progress toward the goal of taking a test, there was almost no assessment of computer activities whatsoever. Steve mentioned that he “really just makes mental notes” about what skills students were exhibiting, confident that he had a “pretty good idea of where all the kids are.” There were no set criteria; he was instead interested in giving students time to explore. He expressed some reservations about using checklists as a form of assessment of technology skills, worried that specific assessment criteria would “make students hate tests and hate technology.” The inclusion of technology in his teaching gave Steve license to break away from tra-
ditional test-type assessments; however, progress on neither the content nor the technical skills covered during computer activities was recorded.

DISCUSSION

The comparisons drawn among the strategies these three teachers employed when teaching with technology versus teaching without technology proved most interesting. Evidence presented in this study suggested that these variations in technology use were closely linked to the teachers’ respective levels of general teaching expertise.

The Effects of Pedagogical Expertise

Category 2: Steve

Steve’s reliance on textbook planning, his teacher-centered approach, and his lack of motivation to modify teaching practices demonstrate his settling into a state of experienced non-expertise (Bereiter & Scardamalia, 1993) in which experience is not capitalized on to continue developing knowledge or a fluid level of expertise. In some respects, teaching with technology prompted positive change in Steve’s teaching. He gave more thought to lesson planning and taught with enthusiasm. His plans and teaching demonstrated, however, how his technical expertise did not automatically result in higher-quality teacher performance. Many experts in a particular domain are not able to instruct others effectively because they cannot articulate how they do what they do (Berliner, 1994; Bransford, Brown, & Cocking, 1999). Steve’s technology skills were developed before his teaching skills, and, as his teaching had remained somewhat stagnant past his initial pedagogical learning, he had thus far been unable to link his technology expertise to his teaching. Consequently, technology remained a separate activity with regards to planning, management, and assessment; it, furthermore, was not connected in a pedagogically sound way to other learning opportunities. Future progression along this line would not likely result in Steve using technology in any concerted or meaningful way to improve the learning of his students.

Category 3: Jill

Jill had in place established routines and highly organized mental schema for what she considered to be “teaching.” She was able to recognize patterns across different subjects and was able to use such knowledge to present fluid, flexible lessons. Technology, however, was a novelty to her. In spite of her interest in learning about technology, she did not recognize technology as being similar to other tools she typically used in her teaching. Expert knowledge has been shown to be contextual and domain specific (Berliner, 1994). Perhaps Jill needed to recognize the place of technology use as related to her general teaching practices before it could become an integral component of her repertoire. By perceiving technology use as a practice distinct from her teaching practices, Jill essentially slipped back into novice teaching habits when teaching with technology. Her plans for technology use remained conscious, deliberate thoughts that were largely separate from other subject-matter plans. Others have sug-
gusted that expertise is not directly transferable to other situations (Berliner, 1994; Huberman, 1985) and, in fact, must be “reinvented or adapted” (Huberman, p. 256). The adaptation process for Jill involved seeking ways to use technology within the framework of her prior knowledge about teaching.

**Category 4: Sheila**

Because technology was used so pervasively in Sheila’s classroom, there were few notable distinctions between the ways she viewed planning, management, and assessment of technology use and her comparable strategies for more traditional learning activities. She made conscious decisions based on her knowledge of both the content and her students to use or not use technology tools under certain circumstances. Routines facilitated much of the student computer use, making Sheila available for novel circumstances requiring her attention. On the whole, Sheila’s uses of technology were not only the most prolific of the three teachers but also the most closely aligned with the content-area curriculum.

**Definition of Technology Integration**

My study demonstrated how the term *technology integration* connoted three very different concepts for three different teachers. Literature on exemplary technology-using teachers characterizes them as using more student-centered learning, viewing computers in terms of function rather than application, and using more complex project-based activities in their classrooms (e.g., Becker, 1994; Hadley & Sheingold, 1993). In my study, only Sheila could be described by these indicators.

The disparity between the operational definitions of technology integration in this study and those in the literature suggests that the term may be being used too freely. Schools are so eager to purchase and have teachers begin using technology, that they mistake simply having and turning on a computer as integration. The word *integrate* is defined in Merriam-Webster's Collegiate Dictionary as “to form, coordinate, or blend into a functioning or unified whole.” The findings from this study suggest appending to this basic definition an understanding of technology use as a component of what is done by an expert teacher with students as a key part of the curriculum, rather than a finite activity with a distinct set of rules.

Yet, this definition remains vague and not readily usable to the classroom teacher as it stands. It is neither possible, nor necessarily desirable, to arrive at one indisputable definition of a term that is so dependent on the variability of educational beliefs, technological availability, and even community expectations. I propose instead that such a concept be locally defined, using available research models and national standards as a foundation, so that it is understood by all stakeholders and can be planned for, implemented, assessed, and generally understood.

Additionally, understanding can be found in a theoretical definition of technology integration derived from the literature on expertise in teaching. Researchers (Berliner, 1986; Leinhardt & Greeno, 1986; Shulman, 1986; Wilson, Shulman, & Richert, 1987) agree that expert teachers possess both content
knowledge and pedagogical knowledge, the intersection of which is described as pedagogical-content knowledge, or knowledge about specific learners, curriculum, and the various and most useful ways to represent the particular subject matter being taught. The findings of the present study suggest another component to the model, that of technological knowledge. This knowledge would include not only basic technology competency but also an understanding of the unique characteristics of particular types of technologies that would lend themselves to particular aspects of the teaching and learning processes. A teacher who effectively integrates technology would be able to draw on extensive content knowledge and pedagogical knowledge, in combination with technological knowledge. The intersection of the three knowledge areas, or technological-pedagogical-content knowledge, would define effective technology integration. Figure 1 illustrates the possible relationships among the types of teacher knowledge.

![Figure 1. Relationships among content, pedagogical, and technological knowledge. Section A represents knowledge of content-related technology resources. Section B represents such knowledge as the methods to manage and organize learning technology use. Section C represents the intersection, or technological-pedagogical-content knowledge, which is true technology integration.](image)

**CONCLUSION**

Our society does not simply need teachers who know how to use computers. We need exemplary teachers who know how to effectively use all the tools at their disposal for the learning benefit of students. According to the proposed definition of technology integration, technology in the hands of a merely adequate teacher will lack the experienced and thoughtful motivation necessary to embed it within a context of sound teaching practice. Conversely, technology in the hands of an exemplary teacher will not necessarily result in integrated and meaningful use. Unless a teacher views technology use as an integral part of the learning process, it will remain a peripheral ancillary to his or her teaching. True integration can only be understood as the intersection of multiple types of teacher knowledge and, therefore, is likely as rare as expertise. Educational lead-
ers would be well served to look beyond mere technology purchases and focus efforts instead on creating environments that are conducive to continued growth in pedagogy as well as in technology use.

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