A Framework for Understanding Teaching With the Internet

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The Internet is widely used in K–12 schools. Yet teachers are not well prepared to teach with the Internet, and its use is limited in scope and substance. This article uses case studies of three high school science teachers to develop a framework for teaching with the Internet, exploring how the Internet shapes and is shaped by classroom practices. The framework includes five affordances of resources: (a) boundaries, (b) authority, (c) stability, (d) pedagogical context, and (e) disciplinary context. These interact with fundamental challenges of teaching to produce wide variation in Internet use. The case studies suggest that affordances vary because of activity design and characteristics of the resource. Challenges to teachers depend on how they position themselves with respect to the affordances.

KEYWORDS: classroom resources, educational technology, science teaching, teacher knowledge, teaching with the Internet.

In the last decade, researchers have described and demonstrated the potential of the Internet for improving teaching and learning (Owston, 1997; Wallace, Krajčík, & Soloway, 1996; Windschitl, 1998). In science education, for example, a number of innovative and successful projects were launched to support collaboration with peers and experts, access to new and different resources, and multiple representations of ideas and concepts (K. C. Cohen, 1997; Edelson, 2001; Lento, O’Neill, & Gomez, 1998; Linn, Bell, & Hsi, 1998; Schofield & Davidson, 2000; Songer, 1998; Songer, Lee, & Kam, 2001). Success in pilot projects, however, has rarely been matched in scaling up (Edelson, Gordin, & Pea, 1999; Fishman, 2002; Fishman, Soloway, Krajčík,

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Marx, & Blumenfeld, 2001; Zhao, Pugh, Sheldon, & Byers, 2002). Even in schools where technology is readily available and teachers are enthusiastic, well prepared, and well supported, results are uneven (Cuban, 2001; Zhao & Cziko, 2001; Zhao et al., 2002). Teachers' uses of the Internet are far from the deep and engaging activities implemented by research projects (Becker, Ravitz, & Wong, 1999; Davidson, Schofield, & Stocks, 2001; Lento et al., 1998; Peck, Cuban, & Kirkpatrick, 2002; Songer et al., 2001; Zhao et al., 2002). These difficulties in implementation and diffusion echo past experience with educational technology and are attributed to a variety of causes, including lack of teacher training or commitment, inadequate technology or technical support, structural barriers in school schedules and policies, and lack of administrative support (D. K. Cohen, 1988a; Cuban, 2001; Dede, 1998b; Means, Penuel, & Padilla, 2001; Peck et al., 2002).

But these explanations do not satisfactorily answer the question of why successful innovation with technology in general, and with the Internet in particular, has been elusive. This study looks at the question from a different perspective, examining how teachers use their knowledge and skills to engage students with content through the medium of the Internet. The hypothesis of this study is that the work of teaching and the nature of the Internet interact both to support and to inhibit innovative teaching and learning. The study aims to understand that interaction, proposing a framework for future research.

**Background**

A study of teaching with the Internet covers potentially enormous territory. Research on teacher knowledge and beliefs, teacher preparation and professional development, planning, and assessment all can contribute to understanding what teachers do when they teach with the Internet. This study focuses on a small part of that territory, exploring teaching with the Internet as it relates to and interacts with both generic tasks of teaching and particular challenges of subject-specific teaching.

**Challenges of Subject-Specific Teaching**

Prior to the 1980s, it was thought that effective teachers needed primarily a set of general pedagogical skills combined with an adequate base of domain knowledge. Shulman and his colleagues (Shulman, 1986a), however, challenged those assumptions by claiming that there was a "missing paradigm" in research on teaching, which acknowledged the centrality of subject matter. In particular, they hypothesized that teaching required pedagogical content knowledge—knowledge that enabled teachers to create domain-specific representations that connect students with subject matter (cf. Grossman, 1990; Shulman, 1986b; Shulman, 1987; Wilson, Shulman, & Richert, 1987). This kind of knowledge and expertise, they argued, is different from the knowledge of a disciplinary expert, and from the general pedagogical knowledge shared across teachers (cf. Brophy, 2001).
A similar “missing paradigm” characterizes research on the use of technology in teaching: Research has focused on teaching the technologies and on developing advanced technologies that affect student learning, but has been slow to include research on using technology in classrooms in the service of teaching subject matter. That is, we know much more about how to insert technology into the curriculum as a generic topic and about software that affects student learning than we do about the teacher’s role in using technology to mediate students’ learning, in particular their learning of subject matter. We know still less about how instruction with technology might differ across subject matters.

Early recommendations about teacher preparation for teaching with technology included lists of technology skills and techniques that teachers needed, such as familiarity with aspects of hardware use and troubleshooting, and knowledge of particular kinds of software, such as word processing, spreadsheets, presentation software, and, later, e-mail and the Web (Dede, 1998a; Harmon, 2000; International Society for Technology in Education, 2000). Policymakers, teacher educators, and technology advocates wrote about “teacher training,” and it was widely (if implicitly) assumed that, if teachers knew enough about computers and used them with ease, they would be able to use them effectively in teaching. Technology literacy was thought to be key to successful teaching with technology. This generalized approach to teaching with technology spawned workshops and teacher education courses about general productivity tools (Becker et al., 1999).

Recently, attention has turned to integrating technology into the curriculum, recognizing that being a competent technology user is different from knowing how to teach effectively with technology (Davidson et al., 2001; Lento et al., 1998; Margerum-Leys & Marx, 2002; Schofield & Davidson, 2002; Songer et al., 2001; Zhao & Cziko, 2001). Research reporting teachers’ actual experiences teaching with the Internet, for example, suggests that designing and implementing activities that use the Internet are complex, time-consuming tasks that call on teacher knowledge across a wide spectrum of expertise (Burniske & Monke, 2001; Edelson, 2001; Garner & Gillingham, 1996; Means et al., 2001; Wallace, Kupperman, Krajcik, & Soloway, 2000). It is in this intersection, where technology is integrated into the curriculum, that pedagogical content knowledge is required.

Pedagogical content knowledge for teaching subject matter with the Internet can be conceptualized in the terrain laid out by Shulman and colleagues by likening the Internet to familiar resources. Possibilities for teaching with the Internet include using it as a source of information, a means of representing content, a means of communication, or a site for collaboration. Of course, the Internet provides options that are unfeasible, or even impossible, with conventional resources, such as using remote scientific instruments or sharing real-time data across continents. For purposes of conceptualizing pedagogical content knowledge, however, a simplification is used, likening the Internet to conventional resources.
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As a source of information, the Internet can be used like books, library resources, or even a field trip. For representing content, it can be like a television, an overhead projector, or a laboratory. For communication, it may be like a visiting speaker. For collaboration, it can be used to organize small group work. For example, a science teacher trying to help students understand light might know that the information and representations provided by WISE (an Internet-based site for science inquiry, see Linn & Slotta, 2000) would be especially useful for her students. She uses her content knowledge (about the science of light), pedagogical knowledge (e.g., of students' developmental level and prior knowledge, of how to manage collaborative group activities), and pedagogical content knowledge (the existence and usefulness of WISE, the representations it offers, and the collaboration it supports) to decide when and how to use it. Knowledge about how to use the Internet per se is taken for granted, just as it is taken for granted that a teacher knows how to use a television when showing a video. Once a Web resource is identified that meets the teacher's needs, this conception seems right—what is required is not a wide-ranging understanding of technology but, rather, specific knowledge of how this technology can be used with these students to accomplish this purpose.

A significant missing piece, however, is knowledge of what is available on the Internet for a particular subject matter and purposes. With so many different kinds of resources on the Internet, from databases to interactive lessons to chat rooms, it is a daunting substantive and technical task to find appropriate, useful resources. How might a teacher even know of the existence of WISE? The process of finding useful, pertinent resources may call on other aspects of teachers' content knowledge, pedagogical content knowledge, and technical knowledge. Specific knowledge of resources on the Internet that support the curriculum is, in fact, reminiscent of descriptions of the knowledge that expert teachers bring to bear on their teaching (cf. Grossman, 1990; Leinhardt, 1989; Leinhardt & Greeno, 1986; Shulman, 1986b; Shulman, 1987; Wilson et al., 1987; Wilson & Wineburg, 1993; Wineburg & Wilson, 1988), knowledge developed over time in response to students and subject matter (Hogan, Rabinowitz, & Craven, 2003; Sosniak & Stodolsky, 1993).

Generic Tasks of Teaching

As described above, using technology to teach subject matter requires subject-specific knowledge, as well as particular knowledge about technology, curriculum, and the intersection of these domains. There are, however, antecedent steps, including finding technology-based tools and resources, learning about them, developing pedagogical content knowledge, and, finally, using both the tools and that knowledge to create, monitor, and critically evaluate classroom activities.

Teaching with the Internet begins at a point prior to the kind of pedagogical content knowledge described in the preceding section, where the teacher's knowledge includes knowing about WISE and knowing how to use
it in her teaching. For most teachers, resources and activities for teaching with the Internet do not come ready-made, in packages that fit into their curriculum or into their existing practice. Even if useful Internet-based resources exist across domains and grade levels, teachers first must know (or learn) that a resource is available before they can use it in educative ways. With some exceptions (e.g., Internet resources provided by the curriculum or textbook), they find and develop Internet-based resources and activities almost from scratch, figuring out what, when, and how to use them.

Finding and developing Internet resources is necessary in large part because the technology itself does not provide a map for its use, and many interesting and potentially useful resources are not designed for schools. Teachers in effect become curriculum makers, developing parts of the curriculum by using the Internet. Schwab (1978) describes the requirements of creating curriculum materials in terms of identifying and using their “curriculum potential”:

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The methods by which scholarly materials are translated into defensible curriculum are not mere transformations of one kind or style of material into another. They are methods for assessing privations, perversities, errors, and developments in those who are to be recipients of the putative benefits of curriculum; then, methods for discovering in scholarly materials curricular potentials which serve the purposes which have been envisaged in the light of detected student needs; then, assessment of the probable advantages of one potential against others as a means toward educational benefits. (p. 380)
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This difficult process is not usually prominent in teachers’ work, minimized by the use of curriculum materials and textbooks (Sosniak & Stodolsky, 1993; Stake & Easley, 1978).

Teaching with the Internet, then, entails the usual tasks of teaching—planning, implementing or interacting, and assessing—along with the less common tasks of identifying and selecting resources and materials, and fitting them into the curriculum.

Affordances of Technology

As pedagogical content knowledge lies between and combines content and pedagogy, so affordances fall between features and uses of technology. “Features” of technology are the objective collection of functions and options for a specific configuration of hardware and software. “Uses” are what users do with the technology. Hardware or software designers specifically consider some uses; users themselves create others as they adapt technology to their specific purposes. “Affordances” are possibilities for what the technology can do. So, for example, “tracking changes” is a feature of a word processor on a personal computer. Editing documents is a use probably conceived of by designers of word processors. Engaging in a writing process is an affordance of a word processor for teachers and students of writing. The technology
provides a means to draft, edit, and revise; to keep track of the process; and to share documents.

The term "affordance" was defined by Gibson (1979) as what an environment offers to a person:

[An affordance is] neither an objective property nor a subjective property; or it is both if you like. An affordance cuts across the dichotomy of subjective-objective and helps us to understand its inadequacy. It is equally a fact of the environment and a fact of behavior. It is both physical and psychical, yet neither... [Affordances are] properties of things taken with reference to an observer, but not properties of the experience of the observer. (pp. 129, 137)

Affordances are emphasized in this study because of the important distinctions among how technology is designed (its features), what it is designed for (uses), and what it offers to teachers through the lens of pedagogical content knowledge (affordances for teaching).

In summary, we know little about either how tasks of teaching are affected or what constitutes pedagogical content knowledge in teaching with the Internet. It is possible that teachers accomplish tasks in different ways when using the Internet, changing how they allocate time, how they design activities, or how they interact with students. Clearly seen in teachers' responses to challenges that arise in teaching subject matter, pedagogical content knowledge is, by definition, domain-specific, and perhaps tool-specific. Understanding the affordances of the technology may be an aspect of pedagogical content knowledge; that is, knowing the range of potential uses for a technology might be something that informs good teaching. These related aspects of teaching with the Internet—the impact on generic tasks of teaching and on subject-specific pedagogy—suggest the need to look closely at the work of teachers to better understand what knowledge they bring to bear and how they go about their work when they teach with the Internet.

Method

Research Questions

This study was motivated by an interest in understanding why it has been so hard for the promises of the Internet to be realized in classrooms, and particularly whether (and how) the nature of the Internet and the nature of teaching conflict with or support effective teaching with the Internet. Two questions frame the research:

- What problems and challenges do teachers face when teaching with the Internet?
- How do the features and affordances of the Internet support or undermine teachers' work?
The site for this study is high school science, chosen because it is a subject for which many Internet-based resources and projects were developed early in the history of Internet use in schools (Pea, Gomez, & Edelson, 1995). By the mid-1990s, generous funding from government agencies resulted in excellent Internet-based resources for secondary science education, including development and implementation projects for introducing the Internet into science classrooms. Many science teachers were early Internet users, and at the time of the study (1999), it was relatively easy to find science teachers who had used the Internet in their teaching for several years.

Context of the Study

This study grew out of prior research in the University of Michigan Digital Library Project, in which middle school and high school science teachers used Internet-based science resources and materials in their classrooms (Alloway et al., 1996; Wallace et al., 2000). Experience suggested that the fundamental difficulties of teaching with technology could not be revealed with a research staff functioning as teaching assistants. With the ongoing and rapid development of superb Internet resources for use in schools, an interesting and important issue emerged: What would teachers do with the Internet in the absence of project support and guidance?

Through a statewide professional organization for teachers using technology, teachers were recruited who were not receiving special support and resources for teaching with technology. Teachers were eliminated who were (a) early adopters (in the sense of obtaining and trying every new technology); (b) functioning as technology experts within the school; or (c) teaching technology classes. Those selected were teachers using the technology made available to them, but not seeking out new technology. Seven science teachers who were identified in this process were interviewed about their past experience and Internet use and were observed informally in their classrooms. After these informal contacts, three teachers were selected to participate in the study—Ms. Owens, Mr. Robbins, and Ms. Varner—on the basis of their years of teaching experience (at least 3), their access to technology in their own classrooms, and their plans to use the Internet in the time frame of the study.

The choice of the three teachers was also mediated by the desire to have a diverse range of students and teaching contexts represented in the very small sample. The teachers were from two districts and three very different schools. Owens taught chemistry at North High, located in a blue-collar suburb in a large Midwestern metropolitan area. This school was relatively small (700 students), with a mostly Caucasian student body; half of the students typically went on to higher education. The other two schools were in a smaller city that included a large university population along with technical and manufacturing industries. In this district, Varner taught physical science at Central High, a large comprehensive high school (2,400 students), about 80% Caucasian, with a primarily middle-to-upper-middle-class student body. Most
students were college bound. Robbins taught biology at East High, a very small (100 students) alternative high school committed primarily to students who were failing in the comprehensive schools. Its population was largely African American, and few of the students expected to go on to college. All three schools had high-speed Internet access available in the classrooms of the teachers studied.

Methodological Orientation

The study was designed to seek better understanding of the complex relationship between teachers and technology. The nature of the research questions called for a method that could generate theoretical constructs to explain issues of interest. Instead of collecting data to prove or disprove the underlying hypothesis that the work of teaching and the nature of the Internet interact both to inhibit and to support effective teaching, this study seeks to explore and illuminate that hypothesis. In particular, conceptions of teaching with technology, and of the necessary teacher knowledge, missed important interactions between the nature of teaching and the nature of the technology itself. This pointed to looking for data in the intersection, where teachers are teaching with the Internet, in order to develop a theory about why success has been hard.

Methods of grounded theory were employed to generate theoretical understandings. In this method, multiple sources of data were used in a recursive process of data collection and analysis until each construct was "saturated"—that is, until new data began to confirm rather than shed new light on the construct (Strauss & Corbin, 1990). The study results are not proven assertions, but rather a theory—in this case, a framework—that provides insights into the question posed and a starting point for future research.

Because of time constraints and human subjects requirements, a complete, open-ended pursuit of grounded theory was not possible. In classic grounded theory development, parameters such as the quantity and type of data are open to change in light of ongoing data analysis. In this study, the quantity, type of data, and initial analytic categories were specified in advance. Research memos were written to guide the focus of the next day's fieldwork. Other data were collected on a schedule, as described below, and analyzed post hoc.

Although this study was not an ethnography (not necessarily appropriate for theory development), the primary methods of data collection were ethnographic. The author attended classes, talked with students and teachers informally, attended other classes taught by each teacher, and became familiar with the entire context of each class during the data collection period.

Data Collection

Data were collected in the spring of 1999. Each teacher was observed for the duration of a unit (5–10 days). Data collected included pre- and post-interviews; classroom video records; "process video" records from two computers while they were in use; and observation notes. "Process video" is a recording of the

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Table 1

Data by Teacher and Type

<table>
<thead>
<tr>
<th>Teacher</th>
<th>Pre-interview</th>
<th>Observation notes</th>
<th>Classroom video</th>
<th>Process video</th>
<th>Audio post-class notes</th>
<th>Post-interview</th>
</tr>
</thead>
<tbody>
<tr>
<td>Owens</td>
<td>Yes</td>
<td>8 periods</td>
<td>4 periods</td>
<td>2 periods</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Robbins</td>
<td>Yes</td>
<td>6 periods</td>
<td>No*</td>
<td>No*</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Varner</td>
<td>Yes</td>
<td>9 periods</td>
<td>3 periods</td>
<td>6 periods</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

*Robbins’s school did not allow audiotaping or videotaping in the classroom.

computer screen taken while the computer is in use with audio of the conversation of student(s) seated at the computer. This gives a limited student’s-eye view of the lesson, including any discussions with the teacher that occur at the computer. Table 1 shows data collected by teacher and category.

An initial interview was designed to probe the following areas: (a) background and experience; (b) ideas about science and science teaching; (c) training and experience with computers and the Internet; (d) reasons for using the Internet in science class; (e) immediate plans for Internet use; (f) expectations for the future with respect to the Internet in schools. In addition, notes were taken in every class attended by the researcher for each teacher. This included classes before and after the Internet unit. Brief notations made during class were expanded shortly after each observation. Note taking was guided by the developing coding schemes described below, and by research memos written throughout the observation period.

Immediately after observing classes, the researcher recorded audio notes about the classes. These notes, which were expanded in writing later each day, were in addition to notes taken during class, and included descriptions of informal conversations with the teacher. Finally, each teacher was interviewed after all other data were collected. The interviews were customized for each teacher, who was asked to reflect on the Internet activity, on his or her roles, and on student work.

Analytic Methods

The starting point for data analysis was a collection of categories from prior research for understanding teaching and technology. In particular, Jackson’s tripartite division of teaching activities into proactive, active, and postactive or reflective (P. W. Jackson, 1986); Lampert’s (2001) work on the content domains of teaching; and D. K. Cohen’s (2004) work on the terrains of teaching were used as initial lenses for viewing teaching. The categories derived from these authors were expanded and modified by using Nardi and O’Day’s (1999) work on technology as ecology, and three different views of the affordances of the Internet as a technology for education (Owston, 1997; Wallace et al., 1996;
Windschitl, 1998). Analysis proceeded by coding documents seriatim according to these codes through a method of constant comparison. This meant adding and modifying codes on the basis of prior coding and research memos, and, finally, eliminating and collapsing codes to reflect the developing theoretical constructs. An additional category of codes was added mid-study for challenges that were observed in practice. This resulted in five categories: (a) phase of teaching, (b) context, (c) content, (d) actions, (e) challenges. (See the Appendix for my list of derived codes.)

Consider an example that illuminates the process. Initially the category of “boundaries” came from Nardi and O’Day (1999), who proposed that an information ecology is characterized by boundaries that define what is in the system. In coding, it became clear that two kinds of boundaries were at work in defining the local character of classroom: boundaries around resources that the teacher intended students to work on (whether material, such as a chapter of a book, or virtual, such as a particular collection of websites); and intellectual boundaries around the subject matter. Other codes in the primary category of “challenges” were often double-coded for boundaries as well, most notably “teaching more than you know,” “planning for the unknown,” “managing multiple student trajectories,” and “adapting to change.”

All these codes were subsumed under the expanded category of boundaries, and boundaries were noted as a product of both the medium and the teaching. For example, a worksheet is a medium that defines boundaries, whereas a restricted list of websites is a means for the teacher to define boundaries within a practically unbounded medium. Additional coding and recoding of data confirmed this category as an important construct for understanding teaching with the Internet. In early analysis, a wide range of codes was applied to data, significant similarities and correlations were found and explored, and codes were combined and collapsed. In the end, three meta-categories were identified as particularly significant: tasks, problems or challenges entailed by the tasks, and features or affordances of materials and resources that can support or inhibit teaching.

This analysis was carried out in conjunction with rereading and researching for relevant literature to confirm or disconfirm decisions made in the coding process. For example, working on the “boundaries” code led to literature about how teachers use conventional curriculum materials and, especially, how they find and use supplementary materials not prescribed by the official curriculum (e.g., Hawthorne, 1992; Lunetta, 1998; Stake & Easley, 1978; Weiss, 1978, 1987).

Three Cases of Teaching With the Internet

The three teachers in the study—Owens, Robbins, and Varner—provide different views of teaching with the Internet. All were committed to teaching science by using the Internet, had some experience in doing so, and had reasonable access to technology. Their schools and student populations varied, as did their purposes for using the Internet and their approaches to teach-
ing. These case studies are not offered as typical or representative; rather, they are examples of possibilities for teaching with the Internet and, therefore, can illuminate our understanding. We begin with a brief introduction to each teacher and a view of his or her classroom. In each case, the 1st day of observation was typical of the other days, and it is described in detail.

Darcy Owens

Darcy Owens taught in Middletown, a suburb of a large metropolitan area, categorized in census data as “urban fringe.” The school district is primarily Caucasian, serving a population of 22,000 and a student population of 3,000. Middletown is an aging community: In the 1970s, the high school had a population of more than 2,000 students; in the 1998–1999 school year, it was 750. About 40% of graduating seniors go on to 4-year colleges, and another 40% go to 2-year technical or community colleges. Middletown High School offers one advanced placement course, in history.

At the time of this study, Owens was finishing her 3rd year as a teacher, having spent all three years at Middletown High. She was teaching science, after completing college with a major in biology and a minor in chemistry. She had received her teaching certificate after completing college and was taking additional courses for a master's degree. Owens wanted to find ways to get students involved in science and to move away from lecture as the primary mode of instruction:

I like to involve [students] as much as possible. I still talk too much even though year after year that’s my goal, to talk less. I personally think it is because in my K-through-12 education, and then through 12 and beyond, was lecture, lecture, lecture, and now given that’s what you’re used to because that’s what you had year after year. You have this model and that’s what you’re so accustomed to, but now in education courses they tell you that’s wrong, that’s wrong, that’s wrong, so you have to switch gears. (Interview, 4/14/99, transcript lines 44–46)

The class observed for this study was an 11th-grade chemistry class of 17 students, considerably smaller than Owens’s average class size of 25. Her classroom had 16 on-line computers for student use and another at her desk. It was a large classroom, with 30 student desks as well as wet and dry lab tables, computers, and other lab equipment and storage.

Goals for Internet Use

Owens felt an obligation to use computers, in part because few classes had them. She wanted her students to be fluent computer users and to have access to current information about science:

I think it’s good practice if they get used to surfing the Web because my kids are middle class, low income, and a lot of them don’t have computers at home, so they don’t know how to surf the Web so I
think it’s good to get practice. I think the number one reason [for using the Web in my science class] is to become familiar with the Internet and how to use it. And how to find things. And second would be just to get the most up-to-date information. And a variety of information. (interview, 4/14/99, transcript lines 60–64)

Although Owens graduated from college in 1996 and started using the Internet in 1995, she felt poorly prepared to use it in her teaching: “I mean [in my teacher education courses] I never had to do any lesson plans that had to do with the Internet. Not one. I was never trained in the Internet ever in college” (interview, 4/14/99, transcript line 378).

In January of 1999, Owens enrolled in a master’s-level course to learn more about using the Internet. Spending hours searching the Web, she planned to use the Internet in a unit on nuclear chemistry, a subject she had not studied herself and would teach for the first time: “I don’t have much experience with it [nuclear chemistry] but I think it’s important for the kids to know. So, I looked in a lot of different chemistry textbooks that we have. Just like high school textbooks. And I also looked on the Internet a lot for information” (interview, 5/28/99, transcript lines 5–6).

She planned to begin the unit by having students first read their textbook’s chapter about nuclear chemistry for homework and then, in 3 or 4 class periods, search the Web for good and bad effects and uses of radiation. This would be followed by a debate about radiation. She hoped this would motivate them to engage in the textbook work to follow: “I’m hoping if they just research things like nuclear weapons and nuclear energy they’ll be more interested to learn the science behind it. If they know a little bit about it and maybe raise some curiosities in their minds. We’ll see if that works at the end of the year. But, that’s what I’m hoping,” (interview, 5/18/99, transcript lines 14–15).

**The Internet Unit**

On the 1st day on the Internet, Owens asked students to find 50 facts about radiation: 25 that could be categorized as good uses or effects, and 25 as bad. In preparation for the debate, they were to record the 50 facts on individual index cards, including the sources of the information.

[I’m asking them if] they think radiation is a good thing or a bad thing. So, what I tell the kids, well you’ll hear me say it today, is of course there are good points and bad points and they’re going to have to research both. Because most of them think, like, when they hear radiation they think, “Oh, it’s bad.” But there’s tons of good points to it also, so they’re going to have to research both sides, and then I’m going to assign them a side and then they’re going to have to debate it. (interview, 5/18/99, transcript lines 11–13)

While students worked on the Internet, Owens moved around the room, interacting with them about their work. In a typical day of the 3 full days spent on the Internet, Owens had 34 separate interactions with students.
during the 35 minutes that they worked on-line (Table 2). Fourteen of those interactions were monitoring; 8 were social or disciplinary, unrelated to the science content; and 12 were specifically about the science. Of the 12 specifically about science, 9 were very brief (less than 30 seconds), and 3 were extended interactions about science, lasting more than a minute each (see Table 2 for examples of each type of interaction).

This pattern of interaction meant that students talked infrequently with Owens about science. Working primarily on their own, they found a wide range of content, including information on weapons manufacturers, smoke detectors, radiation therapy, and police radar guns. Throughout their explorations, Owens urged students to consider the source of information and assess its validity. She closed the class, saying,

Please be careful. I've been telling some people, be careful on the websites that you look at to see who produced the website, because I know a lot of people think—including me when the Internet first came out—whatever's on the Internet has to be true and that's not always the case. Like, Dave and those guys saw a website that was put out by Pantex, which is the only nuclear weapons manufacturer in the country, so their information could be a little slanted. You have to take it with a grain of salt and see if you can kind of verify it maybe somewhere else, or if something sounds crazy then it probably is.

(audiotape of class, 5/18/99, transcript lines 349–351)

Owens's content interactions, both short and extended, took up one of three aspects of content: (a) what students found on the Web; (b) how they might assess the truth or believability of what they found; or (c) the underlying science of nuclear chemistry (as in the extended example in Table 2). She made few connections across these interactions. Consider the "quick content" exchange in Table 2. Rather than asking a science question—"How do smoke detectors use radiation to detect smoke? How much radiation do they emit? Why does plastic absorb radiation?"—Owens briefly summarized what the students reported and moved on.

When it came time for the debate 4 days later, Owens assigned students to a side, selected three judges, and gave the class 15 minutes to prepare. Once the debate started, students argued about radiation. Although some students used the facts they had gathered on their index cards, most of the arguments were not evidence based.

After the debate and the conclusion of the nuclear chemistry work, Owens reflected on the unit. Overall, she was disappointed with students' encounters with science on the Internet, and with the lack of impact that the Internet work seemed to have on their enthusiasm for studying nuclear chemistry.

Because my goal is—you know what they [say you] should do in education classes—let the kids explore and figure it out, but I haven't figured out a way to have the kids get so motivated to be able to jump in there and work through things and figure them out. I guess the big thing was just them understanding the science better. Even when I,
<table>
<thead>
<tr>
<th>Type of interaction (number of occurrences)</th>
<th>Example</th>
</tr>
</thead>
</table>
| Monitoring (14)                             | T: Are you guys finding what you need?  
S: Uh hum. (5/18/99, lines 264–265)          |
| Quick content (9)                            | T: How are you guys doing? Oh, this is a good one. Smoke detector. That is a good one that I didn’t mention.  
S: Yeah, but it doesn’t let out much radiation and then most of it’s absorbed by the plastic.  
T: Okay, so it’s a good use of it then. Used to make smoke detectors. (Moves on to next interaction.) (5/18/99, lines 256–258) |
| Extended content (3)                        | S: Hey, do you want to explain radiation again please?  
I don’t understand it. (Teacher moves around the room getting everyone going, then returns to this student, takes out a paper and pencil, and makes a schematic drawing of a cell.)  
T: Okay. If we were to catch this piece of paper on fire, what is being rearranged? Is it the nucleus, the protons and neutrons?  
S: Well, it’s turning to ashes.  
T: Okay. Particles. Like what type of particles?  
S: Whatever you think. I don’t know.  
T: How about if something’s bonding. When sodium bonds with chlorine, what is being rearranged?  
S: The electrons. Protons . . . . (additional explanations and questions).  
S: So then that’s like the same thing as radiation or . . . ?  
T: No. This is something totally different because now, with radiation, the nucleus is actually changing. Before here, with regular bonding—  
S: The change was in the electrons?  
T: Exactly.  
S: In radiation, protons change?  
T: With radiation now we have a nucleus with protons and neutrons. This is getting broken down. Not necessarily in half but it’s losing some protons, it’s losing some neutrons. When that happens, energy is given off. Right? Because these two are being held close together. When they break apart, energy is going to be given off. So that energy is in the form of radiation. (excerpts from a 5 1/2-minute interaction; 5/18/99, lines 179, 187–193, 211–217) |
| Other (8)                                    | T: Make sure you have stuff to do for tomorrow. Be all conscientious. Oh, band. Band practice.  
S: Yeah, neither is Laura. Neither is Cassy.  
T: How about Thursday?  
S: Thursday—I’ll be here. (5/18/99, lines 359–362) |
| Total: 34                                    |         |
not only in the debate but when I walked around, I just got the impression that they didn't understand it as well as I wanted them to. And, I wish somehow maybe they would have been more excited and interested in it when they were on the computer. Like maybe if I would have brought in a couple of stories of people that have been cured of cancer or specific stories of people in Chernobyl and what had happened to them, maybe that would have sparked more interest, but I wish they would have been—I thought they were semi-interested on the Internet, but I wish they would have been more interested while they were on the Internet. (interview, 5/28/99, transcript lines 85–95)

On the positive side, Owens pointed to evidence that some students were interested—for the first time that year—in what was happening in science class. And she was proud of their growing ability to use the Internet. In retrospect, she felt that her goals had not been clear and that she had underestimated the difficulty of finding useful, relevant information:

It's hard for me even to articulate now [what my goals were], so that's part of the reason why I'm saying I probably should have had more clearly defined goals for myself. But I would say one is to get them more interested in [nuclear chemistry] and two, to get them more familiar with searching on the Web. Those were my two main goals. Because I mean, you've even heard them say, "I hate this, I hate the Internet, can't we just go look it up in an encyclopedia?" and I thought that part of the purpose of that was just to keep searching and searching and searching and kind of get used to that. But, I wish I knew better techniques to give them hints so they could become better searchers, but I don't really know those techniques. Like, probably if I did it next year, I would try to learn those techniques and teach them to the kids. (interview, 5/28/99, transcript lines 49–51)

Uncertain about the impact of the unit, or why it did not go as she expected, Owens's only solution was to teach search skills explicitly the next time she did such a unit. She identified her students' failure to connect Internet information to science as an important problem, but she did not know how to help them make that connection.

Mark Robbins

Mark Robbins taught at South High, which opened in 1995 to serve students struggling at other schools in the district. In 1999, the student body consisted of 110 students in five grades (8–12). Students attended the school for as long as necessary to prepare them to go back into the regular schools, anywhere from a semester to several years. The school featured small classes in small classrooms, individualized attention for every student, and family involvement in the life of the school. Students in the school were 80% African-American, in a district with 18% African-American students overall.
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Robbins was a science teacher with 18 years' experience. He taught biology, and, during this study, his students were working on a unit that emphasized independent work, completing sets of questions about infectious diseases and writing short research reports. Robbins had 12 computers on-line in his classroom at all times, and he considered computer use to be an integral part of his teaching. He viewed the Web as "another tool" for students, and tried to integrate it into the routine work of the class. When they were doing research, students used the Web just as they used books, CDs, or library resources.

Goals for Internet Use

The focus of Robbins's work as a teacher was on teaching his students to be responsible, successful students. Science was his medium.

I describe myself as someone who is trying to teach my kids to be successful in life, and hopefully along the way they learn some science. I want my kids to be able to develop the skills to study and be successful. So I'd say that's one goal, which for me means making sure my kids get to school; they've got their materials; they do their homework; they ask questions if they don't understand. And then I guess the most, my biggest objective for my kids, and I tell them all the time, is I want them to be able to read, write, think, and use the tools that are available to them to enhance their skills. And that to me is far more important than do they understand the difference between DNA and RNA. (interview, 4/22/99, transcript lines 130–132)

He made seamless use of the Web. It was one of many resources available to students, not singled out for special attention or given special time. Students always sat in front of computers as they worked, sometimes using them for word processing or other applications, sometimes for the Web, and sometimes not at all.

Robbins used the Internet, and computers, for two primary reasons. First, he felt it was important for his students to have a chance to learn about and use technology:

I think it provides more opportunities for the kids than relying primarily on a textbook. I think that the Web allows them to go out and see things that the book just can't show them. If they want they can go out and see excellent schematics of the human cell. They can go out and see excellent photographs of cells. They can spend all day looking underneath a microscope and never see a cell as nice as they can find online because they put the best ones out there. (interview, 4/22/99, transcript lines 186–188)

Second, at South High, the computer resources were better than other resources (such as lab equipment and supplies), so he depended on computer technology, and in many cases the Internet, for things that might have been done in a science lab in other schools:

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Our technology stuff is much better than our lab stuff. And I like the fact that the kids can see the results a lot quicker sometimes. Especially for my kids, that works well. And . . . I like the fact that I give them more exposure to working with the computers. (interview, 4/22/99, transcript lines 118–120)

In the unit observed, students had four different assignments: a research report on a contagious disease, answers to a list of questions on genetics, a “fact sheet” about an assigned topic in genetics, and a personal journal evaluating their own work and participation.

This was Robbins’s 3rd year of teaching the unit, which made a difference in how he prepared.

The framework of the lessons may stay the same but I find myself sitting down and rewriting my lessons every year. I think that initially, yes, initially when I started using on-line stuff, it probably greatly increased the amount of time it took to prepare. [Now] I’ve got some sites that are pretty stable. (interview, 4/24/99, transcript lines 219–221)

Although his planning time was not substantially different, Robbins saw a big change in how he used class time: “[Last year] what I thought was going to take a day took 2 or 3 days. I’m still learning about working with the kids on computers. It takes longer than I guess I had anticipated, and I sometimes think that I’m spending more time. Seems like I’m giving up science time to allow more computer time” (interview, 4/24/99, transcript lines 222–223).

The Internet Unit

As the unit began, Robbins encouraged students to use whatever resource made the most sense to them: a textbook, something from the library, a CD, or the Internet. Students had 6 days to complete the assignments, which they did with varying levels of success. During class, Robbins sat with students, interacting with them as they worked. He knew several useful websites, but he did not direct students to those sites unless they asked for help.

Over the course of the 6 days, Robbins’s interactions with students varied within three primary categories. He sometimes dealt with student behavior, from brief reminders to stay on task, to reprimands. He helped students decide on appropriate resources, often steering them away from the computer and toward a resource book or textbook. And he worked with students to find and make sense of websites. For several reasons, accurate counts of the various types of interactions were not obtained. First, no electronic data collection was allowed at the school, and thus retroactive coding was not possible. This meant that, as categories of interaction emerged during the data collection period, it was impossible to go back and recode data. Finally, the pace of his interactions was very fast, moving from student to student sentence by sentence, and was consequently difficult to parse in real time.

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Wallace

In several interactions with students working on the Internet, Robbins used a strategy of modeling his own actions to help students. Consider a typical interaction:

A girl was looking for information from the Web to answer a question from the assignment sheet about muscles. From across the room, Robbins said to her,

“Go to InfoSeek, enter ‘muscle fiber’ and when you get there, search within there for ‘fast twitch’ and ‘slow twitch.’”

Searching “within there” meant choosing an option in the InfoSeek search engine, which searches only the sites already returned from the previous search, but the student did not know how to do this, so she asked Robbins for more help. He got up and came across the room to help her.

He said, “OK, you’ve got a million hits here, so let’s see if we can get it down smaller. Here enter, ‘fast twitch slow.’”

She entered it and he said, “Now you’ve got 5,000 hits, let’s see if any of them are useful.”

Next he started reading the titles of the hits on the first page. One of them was called ‘Muscles, an Introduction.’ He said, “That sounds good.” For others he said, “No that’s not good.”

He moved down the entire page, reading each title and a little bit of the summary that was provided, judging whether it was a good hit or a bad hit.

Then he said, “OK, let’s go to this one,” going back to the first site on the search list. He clicked on the link and began to read it aloud. He read the first part of the first paragraph, and then skipped to the second paragraph. He skimmed down the page reading short excerpts and, several paragraphs into it, found a paragraph about muscle twitch. He told her to use that page, and went back to his seat in the middle of the room. (5/4/99, observation notes)

Robbins used the same technique on other occasions, replicating and modeling for students something he had already done himself and knew would be successful. In another instance, he directed a student to the Centers for Disease Control website and talked him through a series of links that he had already used to find information about a particular disease.

To help students find the right resource, he pushed them to look first in the textbook to find background information or possibly the complete answer before launching into a Web search. In one case, he asked a student to bring her question sheet to him, and he talked through each question, giving her both a recommended source for the answer and a reason why that source would be the best starting point: “Last year we found this good site that had everything you needed right there on-line, but I don’t know if it’s still there. . . . That one you’ll have to go on-line for, here’s this one right here (looking at the biology book, using the index to find the right page)” (5/4/99, observation notes).
Repeatedly, Robbins let his students explore the materials—printed and virtual—but when asked for help, he took them to a resource he knew well, and modeled his own thinking about its use.

Directing the class from his seat in the middle of the room, Robbins engaged in continual conversation with students about what was required, what would constitute acceptable work, and whether their assignments and grades were up to date. Much class time was taken up with disciplinary interactions: reminding students to keep working, going over what work they were missing, arranging after-school meetings with parents, and reprimanding students for misconduct. He made all of his interactions about content and discipline public, available for every student to observe and learn from.

Robbins was a careful observer of each student. Using a detailed and documented assessment of each student’s progress, Robbins tracked what they had turned in, how many points they had received, and what was missing. Use of the Internet was instrumental to completion of assignments, not an assignment per se, so he did not specifically track their Internet use. Continuous feedback, with ample opportunity to make up work and constant reminders of progress, was an important part of teaching his students to be successful in school.

At the end of the unit, Robbins’s students had not done as well as he expected:

Kids aren’t taking advantage of some of the resources I pointed out to them. They’re not helping each other out as much as they realistically need to help each other out to be successful at it. The work’s not coming in at the pace it should be. The answers don’t indicate the level of thought and work that they [can do]. Some of the questions are very straightforward. Some require some thought and some time. And it shows in the answers. So it’s time to reevaluate the unit. (interview, 5/19/99, transcript lines 291–295)

Although he was not sure what to change, or whether to drop the unit in favor of something different, Robbins was certain that he could do better by his students.

Lucy Varner

Lucy Varner taught five sections of accelerated physical science at a large comprehensive high school. In the section observed, she had 30 sophomores who were heading for advanced placement science classes in their junior and senior years. In two semesters, the class completed a semester each of chemistry, physics, and earth science. Varner described her students as hard workers, determined to succeed and motivated to get good grades.

In her 6th year of teaching earth science, Varner had an undergraduate degree in land use planning and a teaching certificate in earth science,
chemistry, general science, and geology. A year earlier, Varner had taken a class from the American Meteorological Society (AMS) to learn about their on-line resources for secondary teaching. This year, she planned to use AMS resources for the second time, focusing on their DataStreme website (American Meteorological Society, 1999). It was her 4th year using the Internet in her teaching. The Internet activity came at the end of a month-long unit on weather.

Varner did not ordinarily have computers in her classroom, but she had a high-speed Internet connection and access to a cart with 12 laptops and a hub (for multiple connections) that could be connected to the Internet. On other occasions, Varner took her class to one of the school’s two computer labs, where they did research on specific topics. Teachers were discouraged from using large blocks of lab time and could sign up only 2 weeks in advance. In this first-come-first-served sign-up system, teachers could not rely on having Internet access when they needed it. The laptop cart was easier to schedule and worked well for Varner’s purposes.

Varner used her 1st-hour planning period to prepare for the day, getting the computers set up, checking out the day’s weather, and writing questions. Days on the Internet were intense and exhausting, much more demanding than her usual days:

Physically, it is really draining. I think it’s a combination of both physical and mental—I’m just drained. In labs and with the computers you have to watch out for safety things. Watch out and make sure they’re not screwing around with the equipment, and that sort of thing. They’re on their own a little bit more and this year’s group especially are very insecure with being on their own. They are so paranoid of being wrong. (Interview, 5/27/99, transcript lines 46–55)

These students were high achievers, concerned about their grades and about being prepared to excel in future classes. With mostly traditional classes in a highly tracked system, they were unaccustomed to the freedom that they experienced in the Internet work.

Goals for Internet Use

Varner used the Web in her classroom in two ways. For projects in astronomy in the fall and natural disasters in the winter, she took students to the lab to do research on specific topics and create presentations for the rest of the class. Then, in the spring, she did the weather unit. She reported using the Internet for three reasons: as a source of variety and motivation; for content not otherwise available; and as a resource to help students learn to evaluate information and improve their critical thinking skills.

They enjoy doing things where they can show off talents other than taking tests. I see more enthusiasm coming from kids I don’t usually see. It’s definitely different than the typical textbook, video sort of
thing. They're more on their own, which I like and they like. The astronomy stuff, for example, comes right from Jet Propulsion Laboratory. Their data sites, NASA sites, the Volcanic Survey Organization. So they get that and they get the things that are in the news right now. For example, [the volcano] down in Montserrat. That's not going to show up in textbooks for a few more years. In the collection and evaluation, what do they consider good data? [I expect them to] evaluate what's worth putting in and what's not worth putting in their projects, narrowing down their topics, just making judgment calls. What is and what isn't relevant or important. I teach this] as they come to me [with questions] or I walk around. (interview, 4/9/99, transcript lines 260–270)

Varner was not trying to change her teaching by using the Web but, rather, saw it as another tool in her repertoire:

[The Internet] is not used enough to change the overall climate [in the school]. Other than when I tell them it's coming up, they do perk up. When [they do research reports] they enjoy what they see from the other kids. They're actually enjoying what they see. I don't think it's going to overhaul [education]. Maybe it's just my attitude that it's another tool. (interview, 4/9/99, transcript lines 347–349)

The Internet Unit

Varner used the AMS website to teach students to read and interpret weather maps and make simple forecasts. She did this in conjunction with a tool called “The WeatherCycler” (http://www.weathercycler.com/) that functioned like a slide rule (by fixing two variables and reading resulting values of a third variable) to show how fronts, pressure, and temperature can be used to predict weather. Students completed worksheets that came with the WeatherCycler, providing 30 questions each day.

For students' work at the computers, Varner created a daily worksheet with 10 items about the weather, which she posted on an overhead projector. Students wrote responses in their notebooks and handed them in at the end of the unit. For example, on May 11, 1999, she posted the items shown in Table 3.

Because both resources were limited—12 computers and 20 WeatherCyclers for a class of 30—students took turns at the computers, moving between their desks and the computers (which were set up on lab tables in the back half of the class). Varner monitored activity in both parts of the classroom, and when a computer became available, she called out for another student to take the vacant spot.

Varner was in constant motion, moving from student to student, both on the computers and off, answering their questions and pushing them to explain what they were doing. In the 55-minute class on May 11, she had 82 separate interactions with students. As shown in Table 4, her interactions were of six types: The most frequent interaction (26 instances) was to assist students with a procedural issue. She helped them find the right link on the computer, gave
### Table 3
**Varner’s Worksheet Items for May 11**

1. Daily summary—A good day for bad weather, . . .
   Two more F5 tornadoes—when, where, number of deaths.
2. Isobars, fronts, etc.
   Time of map, EDT.*
3. Detroit conditions (temp, press, winds).
4. Where is yesterday’s stationary front?
5. Note the nearby cold front. Describe weather ahead of the front.
6. Describe the weather behind the front.
7. Find the front in N. Dakota. What type of front is it?
8. Toward what direction is it moving?
9. Describe the weather conditions in Charleston, SC.
10. 24-hour forecast for Detroit (temperature, cloud cover, possibility of precipitation).

*Eastern Daylight Time.

### Table 4
**Interactions in Varner’s Class, 5/11/99**

<table>
<thead>
<tr>
<th>Type of interaction (number of occurrences)</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Give answers</strong> (15)</td>
<td></td>
</tr>
<tr>
<td>Teacher directly answers student’s question.</td>
<td></td>
</tr>
<tr>
<td><strong>Monitor</strong> (10)</td>
<td></td>
</tr>
<tr>
<td>Teacher checks in to see how a student is doing, without a substantive interaction.</td>
<td></td>
</tr>
<tr>
<td><strong>Explain</strong> (14)</td>
<td></td>
</tr>
<tr>
<td>Teacher explains a concept, symbol, or process to a student, beyond a simple answer to a question.</td>
<td></td>
</tr>
</tbody>
</table>

*Student 1:* Is there something you have to write for the daily summary besides (inaudible).
*Varner:* Just the F5’s.
*Student 1:* Thanks.

*Varner:* Okay. Let’s see, how we doing
*Student 2:* I’m doing pretty good.

*Varner:* What’s that, Mike?
*Student 3:* Number 2?
*Varner:* Um, yeah, what is Eastern Daylight Time for us?
*Student 3:* No, like isobars, fronts, data, what does that mean?
*Varner:* That is, Oh that’s right, you missed part of yesterday didn’t you. Okay, well then you deserve an explanation. Okay, this is the thing here. Okay, this is the title of the map that you went to there (pointing to link on the DataStream main page). So right now, for Detroit, what are our conditions? Oh, the daylight time (pointing to a current weather map).
*Student 3:* I already got it, you subtract four from Zulu.

(continued)
<table>
<thead>
<tr>
<th>Type of interaction (number of occurrences)</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Prompt (13)</strong></td>
<td><strong>Varner:</strong> Yeah, yeah. So then for local conditions they're right there (pointing to the local weather station on the map). <strong>Student 3:</strong> So we just get local conditions from this. <strong>Varner:</strong> Yeah, yeah, the temperature, cloud cover, wind speed.</td>
</tr>
<tr>
<td><strong>Assist with process (26)</strong></td>
<td><strong>Student 4:</strong> What's a pink front? <strong>Varner:</strong> What's that? <strong>Student 4:</strong> What's the purple? (Different student interjects.) I think it is occluded. <strong>Varner:</strong> Go to the weather map symbols. <strong>Student 4:</strong> The stationary front is the pink one, right? <strong>Varner:</strong> The stationary is the alternating red and blue. Go to the weather map symbols if you don't remember. (5/11/99, lines 387–410)</td>
</tr>
<tr>
<td><strong>Other (4)</strong></td>
<td><strong>Varner:</strong> Okay, reload. Let's reload. First thing it'll do, there you go. <strong>Varner:</strong> (to whole class) Okay folks, when you get to the weather map page, make sure you press reload because your time ought to be about 132 right now. (5/11/99, lines 60–62) <strong>Varner:</strong> Janic, don't get him in trouble. (5/11/99, line 533)</td>
</tr>
</tbody>
</table>

Total: 82

instructions to the whole class about using the website, or answered a question about the assignment itself. She also did quick monitoring of student work (10 instances), checking to see how they were doing. In a few instances (4), she had a social or disciplinary interaction with a student.

A majority of Varner’s interactions with students, however, were substantive (see Table 4): answering questions about the content (15), explaining a concept or process (14), or prompting them to help them find an answer for themselves (13). Varner pushed students with questions, trying to get them to think for themselves. Her familiarity with the website, with the day’s weather, and with weather forecasting meant that she knew what to expect as students navigated the assignment. Varner was actually able to answer questions from across the room without looking at the computer screen.

The Internet and WeatherCycler activity lasted 3 days. Expressing concern about grading students’ work on the Internet, Varner did not track their progress explicitly but, rather, expected them to learn the content and demon-
strate their knowledge on the unit test. She checked off (for completion), but did not correct or grade, their worksheets and questions, and she gave them points for participation.

As far as the individual questions, I’ve got copies of the [questions from the] overhead. I know generally what to expect, and if they’re pretty close they get their three points [for each day]. [Unless] they were screwing around, most kids will get the full thing. I always see some glaring—this guy’s just way off base or didn’t do what I know he was supposed to do. They get the points. Me, I’m more interested in that they were looking at the stuff and being exposed to it. (interview, 5/27/99, transcript lines 129–130)

At the end of this work, students participated in a graded weather game, in which teams of students posed and answered questions about the weather. Then they took a written test on the entire weather unit that included a map from the DataStreme site and questions similar to those they had answered using the Internet. Varner was pleased with students’ work during the unit and with their exams:

I think they did pretty much what I expected. The WeatherCyclers kind of gave them the basics. The weather map [on the Internet] gave them what really happens. They got to actually see a stationary front this year, for example, sit over Ohio for 3 days. And they saw that and looked out the window and it was gray and rainy. (interview, 5/27/99, transcript lines 41–42)

She intended to do the same unit again, with few changes. Even though she wanted a better way to track student work on the Internet, to be sure they were learning, she felt the final test was an adequate measure, albeit too late to help them. The Internet work fit well with her teaching style, which was, like the website that she used, subject-matter focused and fast-paced.

Challenges of Teaching with the Internet

These teachers faced common challenges, manifest in different ways in the three cases. Four challenges were prominent: (a) knowing the subject matter, (b) knowing what students know and can do, (c) keeping track of student work, and (d) developing a coherent progression of ideas. Clearly, these are issues that occur to varying degrees in all teaching, they are newly exposed and configured in relation to practice in teaching with the Internet.

Knowing the Subject Matter

Teachers’ knowledge of their subject matter is always an important factor in teaching and learning (Shulman, 1987; Wilson et al., 1987). Often, the knowledge that teachers need is closely tied to the curriculum materials and textbooks they use. Offering a map for teaching, curriculum materials provide
subject matter appropriate to the age of students and true to the discipline itself. In many cases, teachers rely on a textbook alone for defining the scope of a year's work, relieving them of the work of finding, selecting, and organizing information.

Subject matter on the Internet is different. Most content is neither designed nor selected for teaching purposes. The teacher does this work herself, relying on her own knowledge of the subject, along with knowledge of the curriculum, of her students, and of the Internet. In the three cases presented above, the teachers each took a different approach: Owens did not select any specific materials; Varner used one website; and Robbins referred students to a small collection of sites when they asked for help. Developing from different purposes for the Internet work, these three approaches resulted in varied demands on subject matter knowledge.

In the case of Owens, although her knowledge of nuclear chemistry was weak, she expected her otherwise strong background in science to serve her well as she learned alongside her students. The Internet, however, did not support either her learning the content she needed or her engaging with students to help them learn. By creating an open-ended assignment, without restriction on what websites students might use or what topics they might pursue, she made it likely that she would encounter content that was new to her. Responding to what students found entailed huge demands on her subject matter knowledge, far exceeding what she had anticipated or what she knew. The mismatch between her knowledge and what students found resulted in interactions that remained superficial, obscuring the science content she wanted them to learn. Her "adventurous" teaching proved difficult and unsatisfying (D. K. Cohen, 1988b).

Varner used the Internet in a more limited way, favoring a narrow focus on content as compared with the openness of Owens's assignment. The nature of the assignment and features of the AMS website combined to enable Varner to interact with students about the specific subject matter she intended them to learn. She constructed an assignment that evenly matched her subject matter knowledge and the content that students used, while taking advantage of an important feature of the Internet, access to up-to-date information.

Robbins let students search freely and use information from any site, but when they asked for help, he directed them to sites he knew well and used those sites as the basis for engaging with them about subject matter. He managed unknown content by moving students to websites with content he knew.

By looking at these three cases, one sees that the Internet can cause problems for teachers with respect to their content knowledge or be managed in a way that matches the teachers' knowledge. Whether or not the teacher goes beyond the bounds of her knowledge, how she chooses to handle new or unfamiliar concepts, and the success of these efforts depend on her purposes and her design of Internet assignments. In any interaction with students, on or off the Internet, a teacher can find herself dealing with unexpected or unfamiliar content. For example, a student's response to a question may be new to the teacher; an experiment or project may lead down unfamiliar paths; close
reading of a textbook may reveal something about which the teacher is uncertain. Such surprises, however, are not built into the nature and characteristics of a textbook as they are on the Internet. The very things that make the Internet desirable also lead to routine encounters with unfamiliar content: it is up-to-date, responsive to change, wide-ranging, and at the same time, it is unreliable, unpredictable, and changing. For the teacher, this can mean dealing with new content at unexpected times and in unexpected ways.

Knowing What Students Know and Can Do

Expert teachers are familiar with how their students are likely to think, while remaining open to hearing unusual ideas that students contribute (Carter, Cushing, Sabers, Pamela, & Berliner, 1988; Huberman, 1993; Leinhardt & Greeno, 1986). Teachers develop a base of knowledge about their students, building on formal and informal knowledge of student development. Teaching with the Internet makes special demands in at least two ways: First, such teaching is still relatively new and unfamiliar. Knowing what to expect from students is in part a function of having seen it before, but with the Internet, both the medium and the content can be novel to teachers and students alike. New computers, new modes of Internet access, different service providers, and changing websites are examples of contextual changes that make teaching with the Internet novel. Second, it is difficult to anticipate students’ responses to content that is changing. With both the context and content in flux, it may be hard for teachers to develop knowledge of what students know and can do with subject matter on the Internet.

Robbins solved this problem by limiting his interactions with students to a few specific sites where he could predict what they would see and how they would respond. He focused his teaching on processes of using the Internet rather than on science content, with the result that changes in content were almost irrelevant to what he was teaching. He demonstrated the same procedures with several different students each class period, creating a routine for using the Internet that both helped students to learn a process for finding and using Internet information, and allowed him to build on students’ prior knowledge and skills.

Varner also designed her lessons in a way that took advantage of her knowledge of students. Doing in a different medium the same thing she had done for many years, Varner knew what her students would be able to do and learn. The Internet gave them current data with real feedback, but it did not change the essential content and processes in which they were engaged.

In contrast, Owens was not at all sure what students knew when they started the Internet work, or what they took away from it. This is not surprising, as she was the teacher with the least amount of experience. In her interactions with students, she did not use their prior knowledge or understandings and was not sure what they already knew about nuclear chemistry. In Owens’s case, the important variable may not have been the medium itself but rather the nature of the assignment. However, evidence suggests that
teachers using the Internet often do what Owens did, giving students open-ended assignments to “do research” (Becker & Anderson, 1999). Knowing what students know—with its implications for being able to help them learn more—could well be as problematic for many teachers, especially those who are branching out and trying innovative assignments.

As with subject matter knowledge, the challenge of knowing students depends on features of both the Internet and the assignment. The Internet does not inherently offer solutions or strategies for meeting this challenge (nor do many other curriculum materials). Again, the important observation about the Internet is not that it is radically different but that, in many uses, a teacher’s lack of knowledge about students’ capacities is exposed with no built-in supports or solutions.

Keeping Track of Student Work

Knowing what each student is doing and what he or she has done can be difficult in any kind of small group or individualized work. To the extent that groups are doing different things, the difficulty increases. Moreover, if they are using materials unfamiliar to the teacher—either in terms of content or in terms of how students will interact and interpret them—yet another kind of difficulty is entailed. The problem is compounded on the Internet, where the environment is virtual, allowing the teacher access to students’ work only one screen at a time.

All three teachers identified assessing student work as a specific challenge when using the Internet. Varner focused on students’ learning the content, and, in the end, assessed it through a test that specifically asked questions similar to those the students had answered by using the Internet. She was uncomfortable with the part of her grading scheme that gave credit for the Internet work itself, because she did not have a good way to evaluate what students actually had done, only whether they were diligent and completed the task. The assignment provided the structure that she needed to ensure that, in the end, she would know whether students had participated. Only at the end of the unit, when the assignments were turned in and the tests taken, did she discover that some students had not learned from their work on the Internet.

Robbins was entirely focused on the very issues that Varner was uncomfortable with. He assessed students on the basis of their participation and completion of the work, monitoring them throughout their time on the Internet. The challenge as Robbins saw it was to keep students on task, and he used grades to do that. What he did not track, however, was their science learning.

Owens wanted her students to learn subject matter from their Internet work, but she had no routines or tools in place either to hold students accountable for their work on the Internet or to evaluate what they actually had learned. As she moved around the room answering questions and offering help, she did not evaluate what each student was doing or assess the progress of the class as a whole. In the end, Owens did not hold the students accountable for what they did on the Internet.
These teachers pursued different strategies and had different goals for assessing student work. The Internet and the hardware through which it is available did not provide inherent support for solving the assessment problem, and they made it difficult for the teachers to apply their usual routines for tracking student work. This challenge was probably the most consistently troublesome: None of the three teachers managed to assess student work while they were on the Internet, and only Varner tested what they had learned.

Developing a Coherent Progression of Ideas

One problem inherent in Internet use is that the configuration of information does not readily lend coherence to a topic. It combines some of the well-known problems of hypertext (Dillon, 1994; Foltz, 1996; Marchionini & Schneiderman, 1988; Rouet, Levonen, Dillon, & Spiro, 1996), with the additional problem of being unbounded and large. Some websites have been designed to meet the needs of students in a particular grade or subject. On the Internet as a whole, however, it is more likely that teachers will find and use sites that have not been carefully constructed either to meet the needs of learners or to avoid the problems hypertext can entail. In those cases, it is up to the teacher to use the Internet in ways that provide curricular coherence, helping students experience a reasonable progression of ideas that contribute to their learning.

Each of the three focal teachers addressed this problem in a different way. Varner used the AMS weather site as a tool for delivering maps. Students used a single map each day. In form, this was the same thing Varner had done before she started using the AMS site. It was a longstanding element of her pedagogy, improved by the fact that the maps reflected the current weather.

Owens used the topic of radiation as the link that was meant to connect what students were doing to the science she wanted them to learn. In the end, she felt that the topic was too broad and ill defined, and did not give students the grounding she wanted for their study of nuclear chemistry. She knew she wanted a tighter connection between the kinds of things they found on the Web and the science she wanted them to learn, but she did not know how to provide those connections. She felt that she had not successfully helped students to understand connections between science and "the real world," as she had hoped to do.

Robbins's goals were not closely tied to subject matter. He sought coherence in student behavior and in their learning to use the Internet rather than in subject matter. He modeled searching, scanning search results for useful sites, and skimming websites to see if they were helpful. He constructed a progression for learning about the Internet, rather than learning from the Internet. Although Robbins was deliberate in his decision to teach about using the Internet rather than about science, in other classrooms, teachers have fallen into teaching the technology in lieu of the subject matter when the subject matter was unmanageable, bargaining out the content in the name of peacekeeping (e.g., Doyle & Carter, 1984; McNeil, 2000; Sedlack, Wheeler,
Pullin, & Casick, 1986) or when the technology was so problematic that it could not be used without repeated technical intervention (see Hoffman, 1999, and Wallace et al., 2000, for illustrative cases).

Summary: Challenges

An important problem of teaching with the Internet is that, especially in attempts to be innovative, teachers may face all of these challenges simultaneously, in ways not experienced in other teaching. As the case of Owens illustrates, a fairly logical-sounding, open-ended assignment on the Internet can expose the teacher to huge demands on her knowledge and skills.

How do these challenges relate to the constructs outlined at the beginning: pedagogical content knowledge (PCK) and tasks of teaching? PCK as described in the literature manifests as a measured response to a pedagogical problem entailed in teaching subject matter. It is seen in carefully constructed, nonroutine teaching episodes, specific to the topic at hand and to the students (Grossman, 1990; Shulman, 1987; Wilson et al., 1987; Wineburg & Wilson, 1988). A teacher facing all of the challenges described above could hardly be expected to respond with such deliberate teaching, or to have knowledge readily accessible to respond to so many unknowns and variables. She might be constructing or developing PCK, which might then be available the next time she teaches. Like Owens, if she launches an adventurous lesson, she may be improvising with little time or space to call on knowledge available in other teaching.

With respect to the tasks of teaching, one implication of these challenges is that the pre-active phase of teaching, including finding and selecting materials, is perhaps more significant in teaching with the Internet than in other teaching. Much of the difficulty in each of these challenges arises from dealing with the unknown: Extensive planning and preparation, even for open-ended work, could alleviate the burden of some of these challenges. Other kinds of unknowns, however, are the routines that might help teachers in their immediate interactions with students working on the Internet and in their ongoing assessment of student learning. These cases illustrate quite different approaches to the interactive work of teaching—mediating student learning—while using the Internet.

* A Framework for Understanding Teaching With the Internet

Each of these three teachers was transforming Internet resources into materials for instruction. What is it about the Internet as an instructional material that led to the diverse approaches of the three teachers? How can we understand the interplay of the Internet with their practices in a more general way? The cases have shown that features of the Internet can be assets or burdens, depending on what the teacher is trying to accomplish, and how she designs lessons. For example, the openness of the Internet means that students can have access to current information, but it also means that teachers may confront teaching about something they do not know. The goal of this study was
to formulate a way to understand the interaction between features of the
Internet and practices of teaching. In this section, I propose a framework for
understanding how the Internet and other resources function in classrooms.

Analysis of these cases suggests five affordances of resources that are of
particular significance for the work of teaching. These are described as afford-
ances rather than characteristics because they are a product of the use of the
resource, not necessarily a designed feature, and because they may not be
afforded by every resource, and certainly not in equal measure. The afford-
ances are: boundaries, authority, stability, pedagogical context, and discipl-
nary context. These five together constitute a framework for analyzing
resource use as it shapes and is shaped by practices of teaching.

Boundaries

Classroom resources can provide boundaries of two sorts, intellectual and
physical. Textbooks, for example, can provide the subject matter for a class
as well as a location for student work. The teacher can see what page stu-
dents are on or what problem they are working on. Whether desirable or
not, used effectively or poorly, textbooks can give teachers a familiar way to
organize and locate student work. Lab materials and physical artifacts can be
used similarly, providing locations for student work for specific instructional
purposes.

What about the Internet? Providing boundaries is not an automatic fea-
ture of the Internet. Indeed, breaking boundaries—geographically, intel-
lectually, and politically—is a prime motivator for much of Web use. Within
the classroom, the computer is certainly a physical location for students’ work,
but unlike a textbook, it is a door virtually open to a boundless space. In a
sense, the Internet inherently provides neither physical nor intellectual
boundaries. Student work can be located anywhere in a nearly limitless infor-
mation space, with the physical manifestation (what appears on the screen)
varying with each page change. These features of the Internet are cited as
positive, offering exciting possibilities for education, but its boundlessness
can present problems for the teacher. The three cases illustrate how bound-
aries come into play.

Varner bounded students’ use of the Internet both physically and intel-
lectually through the AMS website. Students stayed in one place and worked
on a narrow range of content within that place. Owens tried a more open-
ended approach, letting students search the Internet for themselves without
attempting to provide physical boundaries on their work. She used the topic
of radiation as an intellectual boundary, but even within that topic, students
ranged widely over the Web. The intellectual boundary was quite loose
because the topic was not well defined.

Robbins created both physical and intellectual boundaries, because his
goals had less to do with the content that students used on the Internet than
with the processes of using the Internet and performing as well-behaved stu-
dents. The computer itself provided the physical boundaries for the work.
Although students were free to search the entire Web, Robbins's concern was that they be engaged with the work. Thus he used the computer exactly in the way that he used books and library resources as physical locations for student work: The content of the students' engagement was not as important as their behavior while working. His monitoring and intervention in their searching provided intellectual boundaries. He nudged them toward relevant content in his interactions, and took them to appropriate science sites when he offered explicit help.

These different approaches to boundaries illustrate that, unlike textbooks, the Internet does not have fixed boundaries of either sort. Of course, the boundaries offered by textbooks are also illusory, for what teachers really want to know is what is going on in the students' minds, and how they are processing, digesting, interpreting, and constructing their own understanding of the material. In this sense, the Internet does not introduce a new problem to teaching, but rather uncloaks a problem that the mantle of traditional teaching typically obscures.

Authority

How can teachers decide what material to trust, what is accepted within the discipline and what is questionable, whose point of view is being represented? These are all issues of authority, establishing the source and authorship of information and evaluating its relevance and accuracy. In the case of textbooks, the work of establishing authority is usually left to others—teachers are given curriculum materials as if they were authoritative. Whether they are accurate, and whether the teacher accepts them as such, are different questions. Wineburg and Wilson (1988) suggest that accomplished teachers take a critical stance toward textbooks, inviting students to regularly interrogate the validity of claims. Teachers can question the authority and accuracy of a textbook, but they need not do so. On the Internet, however, little is authorized for classroom use, making the issue of authority ever present. If teachers seek Internet material sanctioned by the discipline, they must establish norms for finding and evaluating such material, or for helping students learn to do so. For teachers who have not taught students to question regularly the legitimacy of curricular texts, this introduces a significant and new challenge to the curriculum.

Owens, Robbins, and Varner each handled this issue in a different way. Robbins was not concerned with the validity or authority of what students found on their own. He made sure that the sites he took them to were authoritative, and he used only those sites when he worked with a student. He did not evaluate content that students found on their own or help them learn to evaluate it themselves. Owens made the work of finding and evaluating information part of the students' job, although she gave them little help in learning to do so. She verified that ample reliable information was available, assuming that students would find it themselves. Varner used the resources provided by the AMS after hearing about it from a colleague. Her method
coincided most closely with the use of conventional materials—getting the resources from a known, authoritative source.

The issue of teaching students to become critical consumers of the texts they use is a perennial one in teaching. Textbooks are often used to relieve teachers and students of the need to develop those capacities, as the textbooks (in conjunction with the teacher) become the default authority in the classroom. The Internet has the potential for disrupting this default, for if students are allowed to wander the Web at will, they bring questionable materials to the curricular table. Teachers react to this in multiple ways, ranging from resorting to old practices (namning a few sites the “authoritative” ones) to working to create new norms for students so that they can become critical consumers of those sites.

Stability

Teachers can depend on textbooks to change slowly over time. In a cycle that occurs over many years, textbooks are replaced when new ones are adopted. Even when new textbooks are adopted, teachers often surreptitiously use their tried-and-true ancestors (Stake & Easley, 1978; Weiss, 1978, 1987). Teachers can also depend on the constancy of their own supplemental materials—tools, activities, and lesson plans that they have developed and used in the past. The Internet is different. It changes rapidly and constantly and in many different ways. Websites disappear or change their configuration and content. Sites are abandoned and no longer updated. They change hands and reflect different priorities. Links on sites go bad and no longer link to anything. In many ways, the fluid mutability of the Web is a plus—it means that teachers can find up-to-date information previously unavailable in school; that students can have access to information from points of view not usually represented in textbooks; that information in schools can be more varied and unconventional.

But for the teacher, instability can create pedagogical problems. Teachers cannot predict what will happen when students visit a particular site or follow a link. This puts tremendous demands on teachers’ capacity to improvise, as well as to provide students with the skills and knowledge they need to deal with such exigencies.

Both Owens and, to a lesser extent, Robbins avoided investing in content-specific sites for their Internet teaching. They sidestepped the issue by not controlling the space that students used in their investigations. Owens provided no subject-matter websites for her students, and Robbins did so only when students sought his help. It is not clear whether the central issue was stability and predictably, but it is one possible explanation. Would teachers such as Owens or Robbins do things differently if they could depend on websites to be there year after year?

Varner depended on the AMS site—she was using it for the second time and planned to keep using it in the future. It is possible that the press of the curricular clock drove Varner to sites that she knew would be productive. Her
tried-and-true sites let her manage student work efficiently because she knew what to expect from both the site and the students.

As in Owens's case, and to some extent Robbins's, using the Internet for students to "do research" leaves what they find open to chance. This element of chance has the potential for disrupting classroom life in significant ways. For one, students need to learn to become critical consumers of the sites, which demands the development of higher-order thinking skills and the capacity to judge the validity and adequacy of "information" encountered. And the teacher needs to be willing to give up some authority and be open to new ideas. Scholars have noted how students and teachers alike consistently bargain such demanding intellectual work out of the curriculum (D. K. Cohen, 1988b; Doyle & Carter, 1984; Sedlack et al., 1986), and there is little reason to think that adding the Internet to the mix of resources will alter that pattern.

**Pedagogical Context**

Physical materials, from textbooks to lab equipment to models, give teachers a tangible context for mediating student work. Teachers develop pedagogical strategies that use the features of materials to support their teaching. An experienced teacher can observe what a student is doing in a lab and derive considerable knowledge about that student's progress. She can tell at a glance what the student has done, what he is doing now, and what he needs to do next (Carter et al., 1988). To some extent, such pedagogical support is afforded by all kinds of physical materials, including computer software. Programs such as Model It or Geometric Supposer give teachers a virtual representation of student work from which they can quickly derive much information about student progress and engagement (S. Jackson, Stratford, Krajick, & Soloway, 1996; Lampert, 1993).

On the Internet, though, pedagogical context is more elusive. Web browsers are context-free in many respects. The nature of the text—html generated—means that the same page can look different on different computers or at different times on the same computer. Images and text on the page change their relative locations. In addition, the nature of hypertext makes a student's path through a page or set of pages unpredictable. A student can follow or not follow each link and can create her own unique pathway. Browsers are not well equipped to follow user paths, and, even if they were, such trails would not reveal much about what the student saw or did on each page.

Varner solved this problem with a highly constrained assignment using a small number of pages with almost no hyperlinks. What she got from the Web was not a hyperlinked extensive collection of information, but rather a specific, up-to-date representation of data for students to use. Her familiarity with the site made it function for her like the pages of a worksheet: She could indeed tell at a glance what students were doing.

In contrast, Owens received inadequate feedback about what students were doing as they searched for information on radiation. She engaged in
conversations with students as she moved around the room, but the con-
versations were episodic. After the unit, she reflected that she did not know
what individual students had done on the Web or what they might have
learned. Her use of the Web gave her little pedagogical support.
Robbins’s goals made the appropriate pedagogical context for his stu-
dents not the Internet itself, but students’ behavior in the classroom environ-
ment. He did not need to address the problem within the space of the Internet.
What students saw and did on the Internet was not as important as how they
engaged in the work. His was a rational response to the lack of pedagogical
support: With no way to evaluate in real time what students were learning
about the subject matter, he helped them become proficient and successful
technology users and worked on subject matter in individual interactions.
The affordance of pedagogical support is closely linked to teachers’
pedagogical content knowledge. Conventional materials, and Internet ma-
terials designed for teaching, embody the PCK of their authors. While this is
not the same as the individual PCK of a teacher, it can be the basis for a
teacher’s developing PCK. Without such support, the teacher is on her own.
If, as in the case of Varner, she finds a resource that fits a pedagogical niche,
the Internet can be an invaluable resource. Then, her pedagogical content
knowledge includes knowing that the resource exists and knowing how to
use it in her curriculum.

Disciplinary Context
Materials that contain carefully sequenced subject matter that is age approp-
riate and developmentally appropriate provide disciplinary support to
teachers. One purpose of textbooks is to do this. Whether it is done well or
poorly, these decisions are most often made by people other than classroom
teachers. They are aspects of curriculum design that require not only disci-
plinary expertise and extensive knowledge of student development, but also
time to consider alternatives from various perspectives.
On the Internet, resources generally are not placed in any framework
or sequence that corresponds to teachers’ curricular needs. If teachers want
to use the Internet, they must fit it into the curriculum. Once they find a re-
source, they need to work it into a disciplinary framework. In some cases,
Internet sites designed for education may provide resources that are consis-
tent with requirements of subject matter teaching, but more frequently,
teachers must do the work through their selection of resources, their design
of activities, and their interactions with students.
Consider the three focal cases. Varner found a website and designed an
activity that matched her curriculum perfectly. She used the Web as a resource
for doing exactly what she had done in the past. In this case, one could argue
that the Web did it better and made it easier for her to teach, and for students
to learn, weather forecasting and map reading. The disciplinary context was
created by AMS, customized and implemented by Ms. Varner. This is similar
to what teachers do with conventional resources.

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Owens attempted to get disciplinary support by inserting the Web activity into a textbook-based unit on nuclear chemistry. The Web activity became peripheral. Students treated it as fun but not science. There was little scientific coherence to what students did on the Web in this unit—when they found facts about radiation, they had no scientific basis for evaluating the facts and no process for doing so. The topics students encountered were wide ranging and seemingly unrelated to the detailed, terminology-intense work that they later did in the chapter on nuclear chemistry.

Robbins's use of the Internet had no particular relationship to the discipline—as described above, he used it to teach other kinds of lessons. The science encountered on the Web was incidental. Both Owens and Robbins gave up disciplinary goals in favor of other objectives. Owens wanted students to enjoy science, to be motivated to learn more. Her primary purposes in using the Internet were to motivate students and to give them experience with using it. She hoped that their apparent enjoyment in working on the Internet would result in an increased interest in the science she wanted them to learn later. Robbins had other goals—to help his students learn to be successful in school. He used the Internet as a lever for achieving other objectives.

Summary: Affordances of Resources

The affordances suggested here create a five-dimensional space where instructional materials, as instantiated in planned activities, can be located. The affordances represent the dimensions of the space, and the tasks of teaching suggest problems that can be addressed within the space. For the sake of simplicity, we can label the material/activity pair as simply an activity. Then, each activity takes on a value with respect to each affordance, with values ranging from unavailable to maximally available. For example, a highly scripted lesson using programmed instruction would fall on the "maximally available" end of every scale. In its most extreme version, a "discovery" lesson using the out-of-doors as the instructional resource would fall on the "unavailable" end of each spectrum. In between would be all three of the cases in this article, and most classroom teaching as we know it.

What is the value of this framework? These five affordances provide a different way of thinking about instructional resources in use, potentially helpful in understanding teaching and in planning to teach with a new resource such as the Internet. One can argue that teaching in a way that makes all the affordances relatively unavailable is unlikely to succeed because of the huge demands on the teachers; and that teaching in a way that makes all the affordances maximally available is likely to cut off opportunities for students to think and learn. In the space between these extremes, we can analyze teaching and learning to understand better what combinations of features of materials and of assignments work together to produce activities that can be integrated into teaching practices and that both take advantage of features of the material and foster meaningful learning. This is particularly important for the Internet because it is relatively unexplored as a classroom resource.
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With this framework, we can think about how to design activities that take advantage of Internet resources while supporting practices of teaching.

For example, if we want to leave the intellectual boundaries open, how can we provide disciplinary and pedagogical support to allow for anticipating student work and assessing student progress? Or, if we want to teach a topic that is unfamiliar, how can we design an activity in a way that lets us learn along with the students, bounding the space physically or intellectually, or perhaps using authoritative sources?

Conclusion

Looking at teaching with the Internet through the lens of the framework developed in this article suggests that the Internet might uncover some dilemmas that are present in all teaching but that remain controlled or obscured by traditional texts and practices. Teachers may explicitly become curriculum makers, with all the time and knowledge intensity required to consider disciplinary and pedagogical issues as they choose resources and design activities. They may find themselves thrust into the role of novices, even though they have years of experience, as they and their students encounter new and unfamiliar content in a virtual setting. Alternatively, teachers may choose to use the Internet in ways that replicate textbook use, forgoing some of the proposed benefits of innovating with the Internet in favor of meeting the demands of curriculum standards and testing in more conventional ways.

The cases in this article illustrate that teaching with the Internet is a complex endeavor that varies widely in implementation and impact. Evidence presented here and in other studies shows that the Internet is far from uniform in its impact on schools and teachers (Becker & Ravitz, 1999; Feldman, Konold, & Coulter, 2000; Schofield & Davidson, 2002). It is good or bad, useful or useless, depending not only on its implementation but also on one’s perspective about the purposes and goals of education and how technology might contribute to those goals.

Yet the Internet is not just a neutral tool that can be molded to the desires of a teacher or community. It has commanded enormous resources, financial and human, in schools across the country, and it continues to function as a source of pressure and frustration for many teachers and of excitement for others. Policymakers, administrators, and parents have, essentially, demanded that teachers use the Internet. That demand has not been accompanied by serious efforts to understand what it takes for teachers to be able to use the Internet effectively in teaching. In fact, when schools respond to the mantra “Train the teachers,” they almost always neglect to answer the question, “To do what?”

Although the Internet can be used as a “textbook,” placing it near the “maximally available” end of the five dimensions, such use is not what most Internet advocates have in mind, except as a rather desperate substitute for
decent materials in schools with poor resources. Given the difficulty for teachers of finding the time, energy, and knowledge to make something more of the Internet, and given the widespread movement toward commercialization of the World Wide Web, one likely direction is for the Internet to become an extension of textbooks. Already, book publishers are providing websites accessible only to those who have adopted their texts. Although some of these sites may provide links to interesting content and activities, the longstanding criticisms leveled at textbooks may also be applicable to the textbook publishers' websites. Instead of encouraging inquiry and understanding, they may skim the surface and cover multiple topics. More important, such use of the Web fails to empower teachers in the ways imagined by some of the early pioneers and advocates of connected classrooms.

This article provides evidence that the Internet can be used effectively in a variety of settings for a range of purposes and also that its use can place unexpected demands on teachers. Unless prescribed by others, Internet activities demand a commitment of time, energy, and attention that must be traded off with other activities that a teacher might pursue. Finally, Internet activities demand that each teacher create new ways to cope with differences between teaching with the Internet and with conventional materials. These demands have not been carefully considered in research or policy settings—for the most part, we have left teachers to figure things out on their own.

APPENDIX

Derived Codes

A complete list of my initial coding scheme can be found on-line (http://www.msu.edu/user/ravenmuk/AERdata/).

1. Tasks of teaching with the Internet
   • Finding and selecting resources
   • Developing activities that use Internet resources
   • Interacting with students doing Internet activities
   • Assessing what students learn from or with Internet resources and activities

2. Challenges of teaching
   • Knowing subject matter
   • Knowing what students know and can do
   • Keeping track of student work
   • Developing a coherent progression of ideas

3. Affordances of resources
   • Boundaries: intellectual and physical/virtual
   • Authority: source, relevance, accuracy
   • Stability: origin, frequency of change
   • Pedagogical support: history of work, common artifacts of work
   • Disciplinary support: selection of topics, coherence of sequencing, connections across topic

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Notes

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¹In this article the term “technology” is used to mean a combination of hardware, software, and content: usually computers connected to the Internet using a Web browser or other software to access a Web-based resource.

²Pseudonyms have been assigned to the teachers and schools reported in this study.

³A video camera recorded activity in the classroom with a remote microphone worn by the teacher. In Owens’s class, the camera tracked the teacher around the room: Because of the setup of computers, it was nearly impossible to see the teacher from a fixed video position. In Varner’s class, the camera was in a fixed position. Robbins’s school did not allow collection of any electronic classroom data. Video output from the computer was captured with audio recordings of the voices of the student or students working at the computer. This approach yielded a record of what the students were looking at as they worked and what they said. In Varner’s classroom, two computers were attached to process video equipment during the Internet work. In Owens’s class, because of technical difficulties, process video was taken from one computer for 2 days while students were on-line. Robbins’s school did not allow collection of electronic records.

⁴A complete list of my codes is available on-line (http://www.msu.edu/user/ravenmw/ABRdata/).

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