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Abstract

Recent research indicates that the Internet is widely available in K-12 schools, and also widely used. However, teachers report that they are not well prepared to teach with the Internet. This study examines how teachers go about making the Internet into a useful and usable classroom resource. Case studies of three high school science teachers are used to illustrate a framework for understanding teaching with the Internet as a case of curriculum making. These teachers found Internet resources and developed them into suitable activities. They also developed ways of interacting with students and assessing student work. The framework includes five features of classroom resources that address the following questions: 1) How can teachers create intellectual and physical boundaries on the work students do on the Internet? 2) How can teachers evaluate the accuracy or authority of information students use? 3) How can teachers plan for and use a resource that is unstable, changing even during a unit of work? 4) How can the resources and activities provide contextual support for the students as well as for teaching, so that teachers can tell what students have done and what they need to do next? 5) How can teachers create disciplinary coherence using virtual resources? These are questions pose fundamental issues in using classroom resources, whether traditional or Internet-provided. The answers are most often embedded in the materials themselves as part of a school or district curriculum. This study illustrates the different ways three high school science teachers addressed these questions in their uses of the Internet, and suggests that these five features – boundaries, authority, stability, contextual support, and disciplinary support – frame a new understanding of what it takes to teach effectively with the Internet.
For the last decade, the Internet has been promoted as an important resource for K-12 education and a source of improvement in teaching and learning. In 2002, with over 99% of all K-12 public schools and 50% of all instructional classrooms having Internet access (National Center for Education Statistics, 2001), it is clear that there are exciting possibilities for using the Internet. For example, a number of recent research projects demonstrate that the Internet can be used in ways that lead to meaningful learning in science education. Some examples from recent research illustrate this point. Students can engage in inquiry-based or project-based activities using Internet resources (Edelson, 2001; Songer, Lee, & Kam, 2001). Teachers can increase communication with other teachers and can benefit from these professional contacts (Schofield & Davidson, 2000). Students can access resources previously unavailable in the classroom (Songer, 1998). Internet resources can be used to represent complex ideas in a variety of ways, including graphical representations that would otherwise be difficult to obtain (Lento, O'Neil, & Gomez, 1998; Linn, Bell, & Hsi, 1998). Students can communicate directly with experts and can contribute to authentic scientific activities (Cohen, 1997). These research projects prove the point that the Internet can positively affect K-12 education. However, they do not provide any evidence that these kinds of results can or will be widespread. They are what Pea has referred to as “gee whiz learning scenarios” (quoted in Yarnall, 1999).

In fact, innovative projects have been difficult to “scale up” to include schools in which the control or influence of project personnel is minimal (Edelson, Gordin, & Pea, 1999; Fishman, Soloway, Krajcik, Marx, & Blumenfeld, 2001). Difficulties are
attributed to a variety of causes including lack of teacher training and commitment, inadequate technology or technical support, structural barriers in school schedules and policies, and inconsistent administrative support (Cuban, 2001; Dede, 1998b; Peck, Cuban, & Kirkpatrick, 2002). At the same time, projects attempting to scale up have moved toward providing more support for teachers, including curriculum materials and professional development. In some cases, the move to create curriculum materials came after disappointment with developing Internet-based tools and resources that went unused or underused because they did not "fit" in the existing, and already packed, curricula (Reiser et al., 2000; Schneider, Krajcik, & Marx, 2000).

While small, innovative projects seem promising, the vast majority of teachers find themselves alone trying to figure out how to use Internet-based resources in their teaching (Becker & Ravitz, 1999; Fishman, 2002). Thus, a central question for educators is: What happens in classrooms of teachers who are trying to use the Internet without the benefit of well-funded projects or other extensive technological and curricular support? These teachers constitute most of the Internet users in K-12 education, and survey research indicates that their uses of the Internet are far from the deep and engaging activities implemented by research projects. What are they being asked to do, and what kind of knowledge and skills does it take for them to do it? Why is it hard for teachers to implement successful Internet uses in their classrooms? This study focuses on these questions, with a particular emphasis on what it is about the juncture of teaching and the Internet that makes success elusive.

One possible answer to these questions is that teachers need to know more about technology and need more advanced technological skills. Research about teacher
knowledge and skills for teaching with technology have concentrated on what teachers need to know about the technology itself (International Society for Technology in Education, 2000). But by considering the Internet as a kind of instructional material or resource, the questions can be viewed more broadly as about understanding the work of creating curriculum from a resource that is not part of the official curriculum (Brophy, 1982). Viewed this way, the question becomes not what teachers need to know about technology, but what they need to know about curriculum-making – creating curriculum from a wide range of relevant resources and materials – and how technologies available through the Internet support or inhibit that work. Since teachers routinely create curriculum through their adaptation and use of conventional resources (Ben-Peretz, 1990; Clandinin & Connelly, 1992; Connelly & Clandinin, 1988; Hawthorne, 1992), the interesting aspect of this work is understanding what makes it different when the resource in question is the Internet, and how those differences might impact teachers’ knowledge and work.

Conceptual Framework

Teacher knowledge for teaching with technology has been treated as an add-on to other knowledge that teachers need. Policy makers, teacher educators, and technology advocates write about "teacher training" for teaching with technology and they describe the knowledge and skills needed as learning to use technology and learning about technology (Dede, 1998a; Harmon, 2000; International Society for Technology in Education, 2000). "Integrating technology into the curriculum" has been added to the list of technology competencies teachers need, operationalized as familiarity with a range of technologies and tools that could be used in educational settings. This generalized
approach to teacher knowledge for teaching with technology has spawned workshops or
teacher education courses about general productivity tools like word processors and
spread sheets and about specific tools designed for students, like multimedia presentation
software, that have general application across contexts.

This conception of what teachers need to know to teach effectively with
technology is similar to understandings of teacher knowledge prior to the 1980s, when it
was thought that what teachers needed to know was a set of general pedagogical skills
combined with an adequate base of domain knowledge. Shulman and his colleagues’
work on pedagogical content knowledge challenged those ideas, moving from models of
teacher knowledge that focus on content knowledge and general pedagogical skills to
models that account for teachers' use of subject and grade specific pedagogies (cf.,
Shulman, 1986). Shulman’s conception of pedagogical content knowledge placed the
knowledge of expert teachers at the intersection of content and pedagogy, where they use
representations of content in ways that make subject matter accessible to students. This
kind of knowledge and expertise, he argues, is different from the knowledge of a
disciplinary expert, and from the general pedagogical knowledge shared across teachers
(e.g., how to line students up for recess or go over homework with the whole class).
Thus, teacher knowledge for teaching with technology appears to be stuck in the old
model, as if knowing about technology (content) and otherwise knowing how to teach
(pedagogy) automatically enables effective teaching with technology.

How else can knowledge for teaching with technology be understood? There are
at least two alternatives: a disciplinary view that builds on conceptions of pedagogical
content knowledge, and a curriculum-making view that starts at a different point in the
work of teaching. In the disciplinary view, technology is embedded as another representational tool of the discipline. Teacher knowledge fits into map laid out by Shulman and colleagues. In this model, knowledge of technology would be like knowledge of television or an overhead projector. What matters is the subject matter knowledge, pedagogical knowledge, and most important, the pedagogical content knowledge that the teacher brings to bear on deciding when and how to use the technology. For example, a science teacher trying to help students understand light might know that the methods and representations provided by WISE (an Internet-based site for science inquiry, (see Linn & Slotta, 2000) would be especially useful for her students at a particular point in their work on light. She uses her knowledge of content (the underlying science of light), pedagogy (e.g., the state of development and knowledge of her students) and pedagogical content knowledge (the existence and usefulness of WISE for particular students in particular settings, and how to make use of the representations that WISE offers) to decide when and how to use this Internet-based resource. Knowledge about how to use technology per se is taken for granted, as it is taken for granted that a teacher knows how to "use" a television when she wants to show a video. Once a technology is identified that meets the teacher’s needs, this conception seems right – what the teacher needs 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.

While promising, the problem with this view is twofold: first, it assumes the existence across the curriculum of technological tools that meet specific pedagogical needs, aimed at the appropriate grade level in the appropriate discipline; and second, it
Teaching with the Internet
does not address the question of how a teacher identifies those tools, learns about them, and develops the understandings that constitute pedagogical content knowledge.

While keeping in mind what we have learned from the conceptualization of pedagogical content knowledge, in this paper I present an alternative understanding of teacher knowledge, a curriculum-making view. This starts at a different point in the work of teaching. If teaching is thought of in three phases – preactive, interactive, and reflective (Jackson, 1968) – the work of teaching with the Internet, and the knowledge needed to engage in that work, begins in the first phase. It is this phase that has been ignored in projects that provide ready-made resources, and in conventional conceptions of teacher knowledge for teaching with technology. In this preactive or planning phase, the teacher preparing to use the Internet first must find and choose resources and develop them into meaningful activities. Unlike using prescribed curriculum materials, in teaching with the Internet, the teacher may have sole responsibility for this work. In the interactive phase, he pilots those activities. And in the reflective phase, he evaluates and modifies them for future uses. The teacher is a curriculum-maker. She needs knowledge not only for successful use of particular applications or tools, as in the disciplinary view above, but also for finding, selecting, and developing resources into meaningful classroom activities. It is not enough for a teacher to be an effective science teacher and to be technologically competent. She must also be able to develop a repertoire of technological tools and resources that meet the needs of her students within her curriculum. This view of teaching and teacher knowledge for effective teaching with technology was developed through the current study, and it is this view of teaching that is depicted and explained here.
The site for this study is science, chosen because it is a subject for which many Internet-based resources and projects were developed early in the history of the Internet in schools. By the mid-1990s, generous funding from government agencies resulted in excellent Internet-based resources for science education, and in 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, it was relatively easy to find science teachers who had used the Internet in their teaching for several years.

Method

This study grows out of observations in eleven middle and high school classrooms between 1995 and 1999. Nine of the classrooms were in science, one in language arts, and one in social studies. Three of the science classrooms were selected for detailed, systematic observation and data collection, with data collected in the spring of 1999. The teachers were from two districts and three very different schools. One was located in a blue-collar suburb in a large mid-western metropolitan area. This school, North High, 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, Central High was a large comprehensive high school (2000 students), about 80% Caucasian, with a primarily middle to upper-middle class student body. Most students were college bound. East High was a very small (100 students) alternative high school aimed at a population of students who were failing in the comprehensive schools. Its population was primarily 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. All three teachers taught high school science: Owens taught chemistry at North High; Varner physical science at Central; and Robbins biology at East. Each teacher was observed for the duration of a unit during which students used the Internet, 5-10 days for each teacher. Data collected included pre- and post-interviews; video records from the classroom; "process video" records from two computers while they were in use; and observation notes. “Process video” is a recording of the computer screen taken while the computer is in use with audio of the conversation of the student(s) who are using the computer. This gives a limited students’-eye view of the lesson, including any discussions with the teacher that happen at the computer.

Data were analyzed based on methods of grounded theory (Strauss & Corbin, 1990). Transcripts of all video and interviews were coded using categories from prior research on teaching (Berlak & Berlak, 1981; Cohen, undated; Green, 1971; Lampert, 2001) and on proposed educational affordances of the Internet (Owston, 1997; Wallace, Krajcik, & Soloway, 1996; Windschitl, 1998). As data analysis proceeded, codes were modified and a framework was developed for understanding the data as cases of using the Internet as a classroom resource. Categories were then developed to frame the work of teaching with the Internet as an instance of developing resources into curriculum materials. These categories provide a uniform lens for looking at these cases of teaching and, as argued below, offer some insights into understanding the work of teaching with the Internet.
To explore these assertions, I will first describe a composite teacher, developed as a prototype of the eleven teachers observed, to illustrate the circumstances in which these problems might be apparent. Then I will present a framework for understanding features of classroom resources across which the Internet varies from more traditional resources. I will illustrate these ideas with examples from classroom observations showing how the three focus teachers addressed these problems as they created curriculum from the Internet, and how features of materials – in these cases, the Internet – play a role in the teacher’s work. For the sake of illustration, I assume this composite teacher does not have technological problems and thus he is able to focus on teaching science rather than fixing or fussing with computers, an assumption that rarely holds in the classrooms I have observed.

A Teaching Example: The Story of Mr. Able

Mr. Able is a science teacher who has no special technology expertise, although he has used whatever technology his school made available over the years and is a competent computer user. His school – a medium sized public high school in a medium sized community – got connected to the Internet several years ago, and he is able to use a lab with 25 Internet-connected computers for his classes. For the past two years, he has taken his science classes to the lab to do open-ended research projects on topics of their choosing using the Internet, with results that have varied. To him, it felt too much like “library research” of years gone by when he sent students off to do reports and graded them on their final product. He is trying to find better ways to use the Internet with his students to take advantage of what he believes the Internet has to offer. Although other teachers in his school use the Internet, no one currently teaches the same classes he
teaches, and so their suggestions are off the mark for what he is doing. In addition, he feels a great deal of pressure to cover the curriculum, since many of the topics in the classes he teaches are included on the state’s mandatory performance assessment. He wants to find a way to do something using the Internet that meets his expectations, accomplishes some of the mandated objectives, and fits into the flow of his teaching.

So, what are his problems as he sets out to do this? First, he needs to find or design some activity that uses the Internet and fits his curriculum. He reads professional magazines, which are filled with great sounding ideas, but many of the Web links he checks no longer work. He finally settles on a WebQuest he finds at a well-known WebQuest site (Dodge, 2002). The topic of the WebQuest is genetically modified food and it features a driving question that he finds appealing: “Should our city council ban genetically modified foods from our city's grocery stores?” He works to adapt the WebQuest to his class, spending many hours on the Internet checking links, finding new ones, and creating a Web page customized to his class.

If the Internet were like any other classroom resource, the work described above would not exist. A teacher would rarely find herself trying to figure out how to fit the use of video into her class, or how to make use of the public library or the local museum as an end in itself. Instead, the teacher might notice an exhibit at the museum that fits with her class and arrange a field trip; or she might see an article about a relevant video and order a copy. With the Internet, the order of events is turned upside down: the medium is given in the form of a huge collection of “stuff” of variable quality. Because of the expectation and, in some cases, the demand that teachers use technology, the teacher needs to find a way to use the Internet. When teachers are directed to use the Internet in
their teaching, or believe that they should use it, their purpose may become figuring out some way to fit it into their class, as Mr. Able has done. The technology is driving the pedagogy.

Second, given that he needs to create or adapt activities for his class, Mr. Able needs to be able to use the Internet himself for his planning. Can he use the Internet at home or only at school? Does he have strategies for searching? Does he have starting points, perhaps from professional publications or colleagues? Does he have a kind of lesson or unit in mind – collaborative data collection, research with primary resources, or an inquiry-based project? How much time can he – or should he – spend looking for a good resource or set of resources? How does he evaluate what he finds? How much does he need to find? These are big issues. In the normal course of things, teachers might develop a repertoire of supplementary activities and materials, which they would use as topics came up in the course of the year, or as students needed additional help (Carter, 1990; Hawthorne, 1992; Stake & Easley, 1978; Weiss, 1987). In the case of the Internet, though, the resource, rather than the needs of students with respect to particular subject matter issues, can easily become the driving force. This is especially true in situations in which teachers are required to develop activities that use the Internet.

Mr. Able has resolved most of his dilemmas, found Internet resources appropriate for his class, designed activities, and he is now teaching the lessons during which students are doing the WebQuest. The activity Mr. Able settled on involves using information from the WebQuest in a debate about the issue of genetically modified food. They will also share information with other classes doing the similar activities in other locations. It is a combination of collaboration and information gathering, which he
teaches will motivate his students to engage with complex concepts about genetics and public policy.

When he approaches a student to offer help or check in, Mr. Able realizes that he needs to quickly grasp what the student is doing or has done, what she might plan to do next, and what she is learning or needs to learn. The routines for working with students who are in a virtual space are new to him. Mr. Able knows how to pass out papers and go over homework; he knows how to give tests and hold class discussions; he knows how to manage student work on computers when they work with a modeling program in a unit on pond ecology. But how does he teach in a collection of virtual spaces where students are doing different things? He sees on the screen what a student is doing right now, but where has that student been? What ideas has the student encountered? Where in this virtual space does Mr. Able find supports for understanding what students are doing and how he might help them?

This fortunate teacher has 25 computers and 25 students, but whether students are working individually on their own computer, paired up, working in larger groups with a single computer, or alternating use of a small number of computers, he faces the same problem: how does he enter into the space in which his students are working with the Internet? It is a virtual space, created as a dialog or interaction between student(s) and the virtual world of the Internet through the medium of the computer. Without some intervention on the part of the teacher (e.g., a requirement to keep notes, a form to fill in), there is unlikely to be any trace of the work that has gone on in this virtual space, and yet the teacher cannot stay with any single student-computer group for long. In addition, unless he has specified a set of Web pages and the students cooperate by not wandering
outside of those sites, students may be reading information he has never seen before, or ideas with which he is unfamiliar.

Mr. Able tries to use methods he has used before for small group work, moving methodically around the room asking and answering questions and entering into discussions with students. However, he finds that he has few tangible hints about what the students are doing. The students seem to be collecting facts or ideas, but they talk about them in isolation. Mr. Able has specified Web sites, but they are sites on which the information changes daily, and the sites have links that quickly take students outside the designated set. He is not sure where they are with respect to their understanding of the subject matter, nor can he tell readily how they are progressing on the assignment at hand. In some cases, he suspects that students are not working at all until he approaches them, when they quickly change screens to feign engagement. When he asks students what they read on a particular Web pages, their answers are superficial and far from satisfactory. It is so text-based, he thinks, yet his students think of it more like a video game. They do not seem to read on-line.

Mr. Able realizes that he needs more structure for student work, perhaps some artifacts which demonstrate the progression of work and through which he can more readily understand student thinking. At the moment, he is at a loss as to how to design such artifacts. He once tried having students keep notes on what they did on the Internet, but the notes were usually too compressed to be useful; he uses the BACK button to see where students have been, but this trail is a poor indication of what students have done, especially since the version of Netscape available to him includes only the most recent trail. Even with a complete record of sites visited, though, Mr. Able realizes he could not
make much sense of their work without knowing more about what is on each page and what they did there. Doing so for every student and every student group would be simply impossible. He considered giving them worksheets to record aspects of their work, but he feared turning the activity into a fill-in-the-blank experience for students. He realizes now that he needs to design some combination of approaches to give himself more clues, and to give the students more structure for the assignment. Now he wonders, though, if he will even be able to use these Web sites again next year or if they will have changed so much, or even disappeared, that he will have to start over.

In the collaborative part of the work, his students are exchanging email with students from around the country. The volume of email is huge, so Mr. Able does not have nearly enough time to read it. On a long weekend, he finally settles down to read what students have been saying to each other – they have had guidelines about the kind of information they should exchange, and especially, the kind of email that is not acceptable. As Mr. Able reads the email, though, he realizes that the students on both ends have avoided discussion of the ideas they are sharing (as often happens in online discussions. For example, see Gunawardena, Lowe, & Anderson, 1997; Kanuka & Anderson, 1998). Many are offering what appear to be uninformed opinions. There has been a parade of ideas, but none of his students engaged in thoughtful discussion in this email exchange. Mr. Able wonders what he could do foster meaningful discussions in this medium.

The debate at the end of the unit leaves Mr. Able wondering what students got from the information they used on the Internet. The two sides made interesting but superficial points about genetically modified foods, and he had a hard time keeping their
focus on scientific evidence rather than mere opinion. He once again feels that he did not adequately integrate use of the Internet into his teaching. He wonders whether students learned any of the important ideas he hoped to cover, and he is not sure his assessments match the work they did on the Internet. He is stumped, but he doesn't know where to turn. He figures he'll try again next year.

Tasks and Problems of Teaching

The vignette about Mr. Able illustrates some of the issues teachers face in using the Internet. What is it about the Internet itself that might lead to the kinds of problems with which Mr. Able struggles? Is it really any different from using other materials and resources? Or is it just new, and Mr. Able poorly trained to use it? To explore these questions, I first present a framework for making distinctions among materials used in the classroom. This framework, and the elements of teaching practice that are problematized in the story of Mr. Able, were derived from the case study research described above. I will illustrate the framework with examples from that research.

Table 2 proposes a set of tasks and problems of teaching that seem particularly pertinent to Internet use. I propose that these are tasks and problems common to all teaching that makes use of resources, from textbooks to lab equipment; and that when the Internet is the resource in question, carrying out these tasks and solving these problems may be significantly different from using conventional resources. The tasks relevant to using resources in teaching are finding and selecting resources, developing those resources into activities, implementing the activities which use the resources, and monitoring and assessing student work. These are common tasks of teaching, things that
teachers do all the time (Ben-Peretz, 1990; Clandinin & Connelly, 1992; Green, 1971; Jackson, 1986).

-- Insert Table 2 here --

The **problems** of teaching shown in Table 2 are common problems for all teachers, roughly corresponding to subject matter knowledge, knowledge of students, pedagogical knowledge, and pedagogical content knowledge (Shulman, 1986; Wilson, Shulman, & Richert, 1987). These are explained in more detail below, with illustrations and examples from the three focal case studies, Ms. Owens, Mr. Robbins, and Ms. Varner.

**Tasks of teaching with classroom resources**

There are at least four tasks teachers must do to teach with the Internet that mark it as different from teaching with other resources.

**Task 1. Finding and selecting resources.** Teachers routinely decide what resources to use in their teaching, including textbooks, lab equipment or manipulatives, and video, and they routinely plan activities and tasks for students that make use of these resources. Although they choose what to use, teachers are not often in a position of needing to search for an entirely new resource. More often, over time, teachers fill in the curriculum with supplementary resources, accumulated gradually to meet specific needs (Carter, 1990; Weiss, 1978; Weiss, 1987). Finding resources in the vast and chaotic world of the Internet, and developing them into appropriate activities, can be seen as fundamentally different work.

**2. Developing activities that use resources.** No matter what resource a teacher uses, he must turn it into an activity or task for students. With conventional materials
such as textbooks or curriculum kits, teachers have at least two kinds of help in developing activities: explicit guidance that comes with materials, and their own history when using those materials (Ball & Cohen, 1996). On the Internet, they may be on their own with neither guidance nor experience with a given resource.

Task 3. Interacting with students as they use resources. Teachers have much experience interacting with students as they use various materials, but physical materials are embodied and contextualized in ways that images on a computer screen are not. Physical materials do not change as rapidly and completely as the image on a computer screen, and they often provide physical evidence of how they have been used. For example, the arrangement of manipulatives on students’ desks, or the state of a lab experiment gives an experienced teacher insights into what students are doing.

Interacting with students as they use virtual resources is fundamentally different from interacting with students using “real” resources. Virtual resources are evanescent, available one screen at a time with few traces of what has gone before, or what will likely come next.

Task 4. Assessing what students learned from or with resources. Assessing student work on the Internet can be like assessing other student work, but it can also be vastly different. For example, if the teacher has students doing work that allows or encourages students to use different Web sites, the content each student encounters may be unique. The further away from conventional assignments the teacher moves with the Internet, the more problematic assessing student learning becomes. This is similar to problems teachers face in inquiry- or problem-based teaching, magnified by the nature of the resource itself. As Cohen (1988) notes, this kind of teaching creates an
interdependency between students and teachers that makes teaching much more challenging work.

These tasks present problems in several aspects of the teachers work: the teacher’s subject matter knowledge; her knowledge of what students know and can do; her routines for keeping track of and managing student work; and her methods of maintaining coherent subject matter learning for individual students and for the class as a whole. These problems are discussed next, and in this discussion, I turn to the three focal cases to provide examples of how the tasks of teaching were manifest in practice, and how these three teachers addressed the problems suggested in Table 2.

**Problems of teaching with classroom resources**

Problem 1: Knowing subject matter. Teachers always need to know their subject. However, teaching with the Internet can place unusual demands on their knowledge. At North High School, Ms. Owens used the Internet to teach a unit on radiation in her high school chemistry classes. She had originally designed the activities when she took a Master’s level course at a local university about using the Internet. She planned to do an extensive interdisciplinary unit with a history teacher on the bombing of Hiroshima and Nagasaki. By the time she was ready to teach it, though, the history teacher could not participate. Owens modified the unit to consider only the science of radiation, expanding the assignment to include research on any uses of radiation students chose to study. Owens realized that her own knowledge of radiation was weak – it was not covered in her college curriculum. However, based on what she learned in her education classes about the teacher as a coach or guide (Dede, 1998a), she thought she could facilitate students’ learning and learn along with them as they explored Web sites dealing with radiation.
Although she majored in biology in college, and had taken chemistry only a few years earlier, she had not studied nuclear chemistry. She assumed that her strong background in science would carry her through somewhat unfamiliar content.

In practice, though, Owens did not make links between the content students found on the Web and “the science” of radiation (a phrase she used repeatedly). Her goal was for students to gain an understanding of the chemistry of radiation and she thought that dealing with the social implications of various uses of radiation would motivate them to learn the chemistry. But societal issues were not necessarily presented scientifically, and the science got lost. Students found many “facts” about many aspects of radiation. Owens, like the students, found the facts interesting but did not use them to delve into the science they entailed. In their final assignment, students debated ideas about topics ranging from smoke detectors to cell phones to nuclear power plants. The class was swamped with claims – you get more radiation from a flight between New York and San Francisco than living next to a nuclear power plant for a lifetime; 80% of policemen who use radar guns get brain cancer; nuclear weapons plants are known to be safe; they are known to be dangerous; medical radiation saves lives; it kills people. Owens’ knowledge about these things often consisted of her own beliefs, based on what she had read and heard in popular media. For her, the fact that they were claims about science made them interesting, even though she did not make explicit connection to the scientific basis of the claims. She engaged in conversations with students about these topics, but with little reference to what the science might be that justified or explained the claims.

Owens realized that she needed a much deeper knowledge of nuclear chemistry to deal with the kinds of information her students encountered, but in many cases, she was
not sure what it was that she did not know. Even though she was a biology major in college, Owens had neither the substantive nor the syntactic knowledge (Schwab, 1964) that might have enabled her to learn with her students and to help them make connections between what they found on the Internet and what she wanted them to learn about nuclear chemistry. Like the fictional Mr. Able, Owens was not satisfied with what happened in this unit, even after all her careful preparation, her excitement, and the apparent motivation of the students who eagerly participated in the radiation unit.

As illustrated by this vignette from Ms. Owens’ teaching, subject matter knowledge can be a problem in teaching with the Internet. What kind of subject matter knowledge is required to know how to search the Internet for appropriate material, to identify and evaluate material, and to develop it into plans? In doing this work, the teacher is creating curriculum materials, a knowledge-intensive and time-consuming undertaking (Ben-Peretz, 1990; Clandinin & Connelly, 1992; Schwab, 1978). Although teachers do this in other circumstances, it is rarely so open-ended and ill-defined as when the Internet is involved.

Problem 2: Knowing what students know and can do. Another common challenge for teachers is knowing what to expect from students. Expert teachers are familiar with the kind of thinking their students are likely to do, while remaining open to hearing unusual ideas that students contribute (Carter, Cushing, Sabers, Pamela, & Berliner, 1988; Huberman, 1993; Leinhardt & Greeno, 1986). This knowledge is linked to subject matter and grade level, and also to the context of the school itself. Teachers develop a base of knowledge about their students, perhaps building on what they learn about child development and subject matter learning in their pre-service education.
Teaching with the Internet makes special demands in at least two ways: First, the teaching is still relatively new and unfamiliar to most teachers. 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 are likely to be somewhat unfamiliar to the teacher. Second, unlike content printed in texts, the content itself is variable on the Internet. Web pages change frequently and unpredictably. There is no guarantee that something a teacher does this year will be available to her next year. With new materials or even activities every year, it would be difficult to anticipate how students might react.

Consider the case of Mr. Robbins who taught at East High, a school with a very small population of students struggling to complete high school (see Table 1). His students were writing short research reports on infectious diseases in an open-ended research project. They were free to use any Web sites they could find, but if they asked a question, he directed them to sites he knew well. At those sites, he was able to guide them through the information with ease, modeling for them how to use keywords, how to evaluate search results quickly, and how to skim Web pages to decide on their relevance. The sites he chose (for example, the Center for Disease Control site, http://www.cdc.gov/health/diseases.html) were longstanding, unlikely to disappear. Robbins solved the problem of knowing what his students know and can do by limiting his interactions with them on the Internet to a few specific sites where he could predict how they would respond. He demonstrated the same procedures with several different students each class period, creating a routine for using the Internet that both helped students learn a process of finding and using Internet information, and solved his problem of building on students’ prior knowledge and skills. His focus on process rather than
science content meant that he knew what to expect from his students and how to help them.

Ms. Varner took an approach to this problem similar to Mr. Robbins. Her class, an advanced physical science class at a large comprehensive high school, used the American Meteorological Society ((AMS)2002) Web site to learn to read and interpret weather maps and make simple forecasts. Although the maps changed each hour, reflecting the current weather, she knew both the site and how her students would use it so well that she could respond to student questions from across the room. She taught five sections of the same course, so that, by the end of the day, she knew what questions to anticipate and how to respond to them. Ms. Varner had taught weather for several years before she began using the Internet and she knew what students were likely to know and be able to do before they started this unit. In her case, she was doing the same thing she had done for many years, only using a different, and arguably better, medium.

By contrast, Ms. Owens saw no consistent patterns in what her students did online or the kinds of questions they asked. She commented that in the unit about radiation, she was not at all sure what students knew when they started, or what they took away from it. She had no way of knowing. She tried to prepare them for their research about radiation by having them read the first sections of the chapter on nuclear chemistry from the textbook prior to starting the Internet work, but she was sure that few students read it, and those who did, probably did not understand what they had read. At the end of the unit, she thought it might have worked better to do some of the work from the chapter before they started Internet exploration.
In Ms. Owens 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 Ms. Owens did, giving students open-ended assignments to “do research” (Becker & Anderson, 1999). The problem of knowing what students know – with its implications for being able to help them learn more – could well be as problematic for many of those teachers as it was for Ms. Owens.

Problem 3: Keeping track of student work. Knowing what each student is doing, and what they have 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, yet another kind of difficulty is entailed in monitoring their progress. Nonetheless, keeping track of student work can be an important part of assessment, for evaluating student work, deciding what to do next, and reflecting on one’s own teaching. For example, one factor in deciding what to do next with a class is evaluating what students have mastered so far. On the Internet, students may be doing different things in small groups or individually, and what they are doing may be "virtual." The computer itself provides few clues to help the teacher.

In the science classrooms of Owens, Robbins, and Varner, the teachers dealt with this problem in very different ways. Varner, who taught a weather unit to a physical science class, was perhaps most successful in knowing what her students were doing. First, she limited them to 3 or 4 Web sites with which she was quite familiar, the AMS weather maps (American Meteorological Society, 2002). Second, she designed the assignment so that they were doing what they were supposed to learn, not simply reading
about it. They were learning to read and interpret weather maps by doing it, guided by
daily questions she posed. The questions were specific to the day’s weather and students
wrote answers on paper. They were not learning what the weather was on a given day;
they were learning to read the map in a context that let them check their own success.
Third, she had them hand in the answers to the questions over four days during which
they used the Internet. This put the responsibility on the students to do the work. Finally,
the unit quiz on weather tested their ability to read and interpret a weather map taken
from the Web site, holding them accountable for the work they did on the Web by asking
them to do the same thing as part of the test.

It is interesting to note that Varner did not try to track students’ work moment to
moment. She moved around the room offering help and answering questions, but did not
worry about tracking the progress of each student. She gathered mental data about how
the class was doing, what common questions came up. The assignment itself provided
the structure she needed to insure that, in the end, she would know whether students had
done the work. One reason she could do this is that the students were high achievers,
quite clearly motivated to get good grades and do well on tests. Her approach might have
been less successful with a different population of students. Even with these students,
one drawback to her approach was that only at the end of the unit, when the assignments
were turned in and the tests were taken, did she learn that some students had not taken the
Internet work seriously.

In her chemistry class, Owens took a different approach. As she moved around
the room answering questions and offering help, her most frequent interaction was a
check in, e.g., “Are you finding what you need? … Are you doing OK?” She had no
structure in place for evaluating what each student was doing, or for assessing the progress of the class as a whole. The final assignment was a debate, in which students were to use what they had found on the Internet. It was unstructured and did not provide Owens with the insights she wanted about what students accomplished on the Internet.

The students’ overall assignment – gathering information about radiation in preparation for a class debate about the benefits and harm it causes – became marginal. Owens did not hold them accountable for what they did on the Internet. She talked to them about what they were doing in ways that signaled it was not part of “the science” they were expected to learn, joining in to express her opinions without reference to scientific evidence or warrants. She wanted them to get interested in the science and to have some positive experiences with using the Internet in science class, but her subject matter goals were not specific.

Robbins took a third approach. His biology class included students who had struggled in school, not only with academic work but also with behavior and work habits. His purposes were quite different from the other teachers observed. He wanted to teach his students to be good students, to persist in their work and turn it in on time, and to develop good study and attendance habits. Robbins also wanted his students to learn to use the Internet and to have ample opportunity to do so. He used the Internet as a site for student work on these dispositions and experiences more than as a site for learning science. His class was small – 15 students when all were present – and he was able to actively and continuously monitor every student’s work while they were on the Internet. However, he monitored them for behavior and diligence, not for the science content they were learning. Keeping track of science learning was not among his goals.
The point of these three examples is that all three teachers dealt with the problem of keeping track of student work, but they pursued different strategies and had different goals in mind. The Internet and the hardware through which it is available did not provide inherent support for solving this problem.

Problem 4: 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 with the additional problem of being unbounded and large (Dillon, 1994; Foltz, 1996; Marchionini & Schneiderman, 1988; Rouet, Levonen, Dillon, & Spiro, 1996). Some Web sites have been designed to meet the needs of students in a particular grade or subject. However, on the Internet as a whole, 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 disciplinary and pedagogical 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, using the AMS weather site, sidestepped the issues of hypertext altogether. There were no links out of that site, and no links at all on the weather maps themselves. The site was designed for educational purposes, and Varner had taken an extensive training course offered by AMS to learn to teach with the site. The approach was coherent with respect to the content Varner wanted students to learn, and she used it in a way that kept them focused on the task at hand. She concentrated on a small set of ideas and processes that were well represented on a single Web page.
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 have solution for providing those connections. She felt she had not successfully helped students understand connections between science and “the real world” as she had hoped.

In the third case, Robbins’ 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 Web sites to see if they were helpful. He constructed a progression of 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, or when the technology was so problematic that it could not be used without repeated technical intervention (e.g., see Hoffman 1999; and Wallace 2000 for illustrative cases).

Resources as the Makings of Curriculum

Given the tasks and problems outlined above, how do teachers transform resources into curriculum? Table 3 describes five features that curriculum materials have conventionally offered to teachers, features that define essential characteristics of curriculum. Data from these cases suggest that, in order to incorporate Internet resources
into their curriculum, teachers must address these features, either implicitly or explicitly, by omission or commission. These features define a map of knowledge of resource development and use that is essential for effective teaching with the Internet. Each feature is explained and illustrated below.

-- Insert Table 3 here --

Feature 1: Boundaries

Classroom resources can provide boundaries of two sorts, intellectual and physical. The textbook, for example, can be used to layout subject matter that the course will include. Thus, a textbook can provide intellectual boundaries around the content of a course. It can answer the question that every teacher must pose of what subject matter to teach. Although recent textbooks are so packed with topics that they provide more than can be taught (Schmidt, McKnight, & Raizen, 1997), they at least set the outer limits of content.

In a different way, the textbook and other printed material provide physical boundaries for the course. They can be used as the place where students do their work. For example, having students do a worksheet or answer questions from the book locates the work within the boundary of that material, both physically and intellectually. The teacher can see in a physical artifact what a student is working on, what page they are on in the book or what problem they are doing on a worksheet. Whether this is desirable or not, used effectively or poorly, the textbook or worksheet can give the teacher a routine way to answer two important questions: what will students do today, and where will I locate their work? Lab materials and physical artifacts can be used in similar ways – they
provide a location for student work, and are used in an intellectually bounded arena for specific instructional purposes.

What about the Internet? Providing boundaries is not an automatic feature of the Internet. It provides opportunities for students’ work to be located anywhere in a nearly limitless information space, and lets the teacher choose from a seemingly unbounded universe. These are often cited as positive features of the Internet, characteristics that offer exciting possibilities for education. Although the Internet does provide the unbounded opportunities advocates claim, its boundlessness can present big problems for the teacher. The three focal cases illustrate some of the problems, and some possible solutions, to the problem of boundaries.

Varner bounded students’ use of the Internet through the AMS Web site. They 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 the intellectual boundary and spent hours searching the Internet to make sure they could find "good stuff" about radiation. In the end, she reported that the domain was too ill-defined and far-reaching, that she wished she had kept students closer to the science of nuclear chemistry. Although they seemed engaged in the work of finding controversial information about radiation, the connection between those ideas and the science was not obvious and they were not motivated to pursue the science as Owens had hoped and expected. She established neither intellectual nor physical boundaries around the work.
In contrast, Robbins created both physical and intellectual boundaries because his goals did not have to do with the content students used on the Internet but rather with the processes of using the Internet and performing as well-behaved students. The Internet in his classroom provided the physical boundaries for the work, and his monitoring and intervention in their searching provided intellectual boundaries. These boundaries were not about science – they were about technology and behavior. Being on the Internet, engaged with using it, was what Robbins aimed for, whatever the content they encountered.

Feature 2: 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 truth. In the case of textbooks and other curriculum materials, 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. The teacher can question the authority and accuracy of a textbook, but she does not need to do so. In contrast, on the Internet, almost nothing is authorized for classroom use. If a teacher seeks material sanctioned by his discipline, he must establish norms for finding and evaluating such material. The same is true for other teacher-provided materials, but there is little evidence that teachers are expected or pressed to find and use other supplementary materials the way they are now encouraged to use the Internet.
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 let students search the Web freely and use whatever they found, but when he offered assistance, he directed them to sites that he knew and trusted. Since his purpose was to help them learn to search, he made sure the sites he took them to were authoritative, but he focused on the process of getting to the site by using search engines, and on finding content within the site. He did not use questionable or unfamiliar content when he worked with a student, but neither did he evaluate content 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. She verified that there was ample reliable information available, but did not direct students to it. Her criteria for judging content were not specific: she looked for a variety of information about the topic of radiation. She encouraged students to figure out the source of each Web site and decide whether to believe it or not. The problem emerged, though, that students did not know enough about radiation to be able to evaluate the information they encountered. They could sometimes identify the provider of a given page, but they rarely had scientific evidence to bring to bear on content from Web sites. The kinds of evaluations they were able to make were stereotypical judgments: a "gov" site is good; a "com" is suspect, for example. Students encountered questionable evidence about radiation, but the sources, and the information itself, went unchallenged.

Varner used the resources provided by the American Meteorological Society (AMS), which she found by attending a class they offered. She did not go out looking for Web resources but rather heard about this class from a colleague and signed up for it.
The AMS, an authoritative source about weather, provided all the Web pages her class used. Her method coincided most closely with using conventional materials – getting the resources from a known, authoritative source.

Feature 3: Stability

Teachers can depend on textbooks and other printed material not to change over time. Textbooks are replaced when new ones are adopted, but that cycle occurs over many years. Teachers can also depend on the constancy of their own supplemental materials – tools, activities, and lesson plans they have developed and provided. The Internet is different. It changes rapidly and constantly and in many different ways. Web sites disappear or change their configuration and content. Sites are abandoned and no longer updated, or change hands and reflect different priorities. Links on sites go bad and no longer link to anything. In many ways, the changeability 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 creates pedagogical problems.

Both Owens' and Robbins' avoided investing in content-specific sites for their Internet teaching. They did not explicitly link their decisions to the instability of sites on the Web, but it is an interesting question to pose about how teachers decide what to have their students do on the Web. Would teachers like Owens or Robbins do things differently if they could depend on Web sites to be there year after year? Varner certainly depended on the AMS site – she was using it for the second time and planned to keep using it in the future. The Internet as it exists today may not support the investment of
teacher time that it takes to create projects that focus on subject matter learning. Most teachers use it for students to "do research," leaving what they find open to chance, perhaps with good reason.

Feature 4: Contextual Support

Physical materials, from textbooks to lab equipment to models, give teachers a tangible context for mediating student work. An experienced teacher can observe what a student is doing in a lab and derive considerable knowledge about that student's progress. He 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, this kind of contextual support is provided by all kinds of physical materials in classrooms. Even some computer software provides contextual support for teaching. Programs like ModelIt or Geometric Supposer, for example, give the teacher a virtual representation of student work from which she can quickly derive much information about student progress and engagement (Jackson, Stratford, Krajcik, & Soloway, 1996; Lampert, 1993).

On the Internet, though, contextual support is weak to nonexistent. 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. On the other hand, Owens realized that she had inadequate feedback about what students were doing as they searched for information on radiation, but did not figure out a way to resolve the problem. She engaged in conversation with students as she moved around the room, but the conversations 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.

Robbins' goals made the appropriate pedagogical context for his students not the Internet itself, but students’ behavior in the classroom environment. 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. This is a slightly different version of a strategy often seen in teaching with technology: the teacher turns to teaching the technology rather than the subject matter. It is a rational response to the problem of contextual support: with no way to evaluate in real time what a student is learning about the subject matter, the teacher can at least provide support for becoming a proficient and successful technology user.

**Feature 5: Disciplinary Support**

Materials that contain carefully sequenced subject matter that is age and developmentally appropriate provide disciplinary support to teachers. Textbooks do this, as do other kinds of supplementary materials. Whether it is done well or poorly, these decisions are among those that are most often made by people other than classroom
teachers. They are aspects of curriculum design that require not only disciplinary expertise and extensive knowledge of student development, but also time to consider alternatives from various perspectives.

On the Internet, resources are generally not placed in any framework or sequence that corresponds to teachers' curricular needs. If a teacher wants to use the Internet, she must fit it into the curriculum. Once he finds a resource, he needs to fit the content within the resource into a disciplinary framework. In some cases, Internet sites designed for education may provide resources that are consistent with developmental and pedagogical needs, 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 Web site and designed an activity that matched her curriculum perfectly. She wanted students to learn about weather and to learn to read weather maps and to make basic forecasts. The AMS site gave her a tool for doing these things. In a way, what she did was very traditional – she used the Web as an interactive source for doing exactly what she had done in the past without the Web. In this case, one could argue that the Web did it better and (technological issues aside) 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.

Owens attempted to get disciplinary support by inserting the Web activity into a textbook-based unit on nuclear chemistry, but the fit was loose. The Web activity became peripheral. Students treated it as fun but not science, and Ms. Owens did not succeed at making it anything else. 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 they later did in the chapter on nuclear chemistry.

Robbins 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. In a way, 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 the Internet. 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. For his students, the Internet was motivating. They wanted to know how to use it and they took pride in that knowledge. The Internet was a lever for achieving other objectives. Neither of these teachers found or created any disciplinary coherence in their use of the Internet, although both used it successfully to meet other goals.

Discussion

Owens, Robbins, and Varner were three very different teachers. They not only taught in dissimilar schools and student populations, but also used the Internet for different reasons. Yet, each can be seen as dealing with the tasks and problems delineated above, and each made curriculum in his or her own way. By their own estimation, each succeeded in some ways and not in others.
• Owens thought her students gained valuable experience in using the Internet and enjoyed science class in a way not typical in her school. She was pleased with students' variety of experience and with their level of engagement in the debate about radiation. She was disappointed that their work did not carry over from the Internet to nuclear chemistry.

• Robbins reported that some of his students were able to focus on Internet work better than other kinds of schoolwork, that it gave them an arena in which they could be successful. He was pleased that his students were becoming competent Internet users, knowing how to find and use a search engine and how to use hypertext. He wanted them to make stronger connections to biology, and especially to learning about themselves as living creatures, but his top priority was on helping them develop good school habits and technology skills.

• Varner was pleased with the AMS weather unit and thought students learned what she intended. She wanted to do more open-ended, inquiry-based activities, but felt she had neither the time in her curriculum nor the access to technology to allow for real inquiry.

The experiences of these teachers suggest both the variation that can occur in teaching with the Internet and the similarity in what teachers need to know and be able to do. In these three cases, in the classrooms of the other eight teachers observed in the course of this study, and in interviews with five additional teachers, all were in the position of figuring out for themselves how to use the Internet with their students. While it is common practice for teachers to have autonomy in their teaching, it is not common
for them to have not only freedom but also pressure to find and use supplemental resources. Supplemental resources more typically trickle into classrooms over years of practice as teachers learn about new resources, representations, or lesson plans from colleagues, conferences, and reading. To mold the Internet into useful resources and effective activities, these teachers created and implemented new elements of curriculum.

What can we learn from the cases of these three teachers? From Owens, we learn that the rather natural Internet assignment – having students “do research” – can be problematic. It places huge demands on teachers’ subject matter knowledge and calls for new ways of managing classroom interactions to engage with students about content. Although it is easy to do at a basic level, making such an assignment into a source of meaningful learning for students is filled with difficulties. The five features of resources suggested in Table 3 all come into play in such an assignment. The teacher needs to consider all five, and act on some of them. Observations in Ms. Owens’ classroom and in other classrooms where the students were doing Internet research suggest that if all five features are ignored, there is little likelihood that meaningful engagement with subject matter will occur. In such a classroom, students would be free to use any resources they could find, and to evaluate those resources themselves; there would be no preselected sites or starting points; the teacher would have no mechanism for managing the substance of student work or for connecting what they do to the structure of the discipline or the intellectual mandates of the topics being studied. Although this is an extreme example, it is similar to other classrooms I have observed, and it fits with descriptions of teacher-assigned library research of the past (Kuhlthau, 1993; Pitts, 1994).
From Varner, we see that a teacher can develop effective use of the Internet when it matches her mode of teaching and fits into the curriculum. The weather unit she designed was one element of a repertoire of tools and activities she used in her teaching to respond to particular pedagogical problems, in this case, teaching students to read weather maps. However, two factors influence how Varner’s teaching can be interpreted. First, her teaching was traditional. What she did might not satisfy the technology advocates who envision technology as a catalyst for reform. It might not be seen as effective or successful teaching with the Internet, if the standard is inquiry-based teaching. Second, her students were high achieving and highly motivated. The assignment, strategies, and routines she used to teach this class might not work as well with another kind of student population. One important lesson from Varner’s classroom that perhaps transcends those factors is the effectiveness of using the Internet to learn to do something by doing it. Her students read weather maps, and that is what she was teaching them to do. Other teachers have used this strategy – Robbins is one example – teaching students to search the Internet by having them do so. However, Varner managed to find subject matter objectives, not technology objectives, that could be experienced on the Internet.

The elusiveness of finding an appropriate match between subject matter goals and what is available on the Internet points to another lesson from these three teachers. The planning phase is hugely significant in effective teaching with the Internet. Whether it happens by serendipity, or by extensive and time consuming searching, what teachers decide to do with the Internet, what tools or resources they select, and how they structure those activities are important factors in what students have the opportunity to learn. In
these three cases, Varner identified the resources she wanted to use in a conventional way, through colleagues in her school. The other two teachers made up their own approach, spending hours searching the Internet and preparing for their teaching. Yet, particularly in the case of Owens, preparation did not pay off in the ways she anticipated.

It is clear that, given the vast and unpredictable content available on the Internet, it is unreasonable for teachers or students to expect to find and use meaningful science content in the time frames they have available. But that is what Owens and Robbins and many other teachers have tried to do.

Another interpretation of these cases is that the teachers were not well prepared to teach with the Internet and did not do an adequate job. One can point to ways in which these teachers could have improved what they did. Owens could have given her students a narrower topic; Robbins could have paid more attention to subject matter; Varner could have given her students more open-ended investigations to pursue with the weather maps.

On the other hand, these three teachers were well-prepared, experienced science teachers who in many ways appeared to be exemplary Internet-using teachers. They all worked diligently to prepare for these Internet units and followed plans that they had confidence in. Both Robbins and Owens expressed disappointment with what happened, and, in Varner’s case, some would see it as merely using the Internet as an expensive replacement for other media. This points to the questions that motivated this study: What constitutes effective teaching with the Internet? What would be adequate preparation to do this effective teaching? What would teachers then know and how would they come to know these things? The three cases described here, and the framework itself, provide a seed for further investigation and discussion of these important questions.
Conclusions

Looking at teaching with the Internet through the lens of the framework developed in this paper suggests that teachers have substantively different work to do in this teaching. They become curriculum makers, with all the time and knowledge intensity required to consider disciplinary and pedagogical issues as they choose resources and design activities. It is not surprising that teachers engaging in this work develop many different approaches and that outcomes vary considerably.

The cases in this paper illustrate that teaching with the Internet is a highly 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, of excitement for others. Policy makers, 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. In fact, the mantra to "train the teachers" is almost always left to beg the question, "to do what?"
Although the Internet can be used as a "textbook," 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. However, 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 Web sites accessible only to those who have adopted their texts. While some of these sites may provide links to interesting content and activities, the longstanding criticisms leveled at textbooks can also be applied to such Web sites. For example, instead of encouraging inquiry and understanding, they may skim the surface and cover multiple topics. More importantly, 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 paper provides evidence that the Internet can be used effectively in a variety of settings for a range of purposes, but that its use places huge demands on teachers. It demands a commitment of time that must be traded off with other activities the teacher might pursue. It demands a commitment of energy and attention that also competes with other things on which the teacher might focus. Finally, it demands that each teacher create a new set of routines – perhaps so different that they constitute a new domain of pedagogical knowledge – to cope with the real differences between teaching with virtual resources and with tangible resources. These demands have not been carefully considered in research or policy settings – we have mostly left teachers to figure these things out on their own.