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Infusing Web-based Digital Resources into the Middle School Science Classroom: Strategies and Challenges

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This study examines strategies and obstacles encountered in infusing digital resources in the middle school mathematics and science classroom. It draws on data from principals, technology coordinators and math and science teachers in three urban middle schools in United States. All three of these schools have recently invested heavily in technology hardware and high speed Internet connectivity and as such they provide an opportunity to look beyond well documented obstacles such as outdated computers and poor Internet access. The logistical, preparatory, pedagogical and curricular challenges encountered by teachers within the study have important implications for professional development efforts aimed at improving science education through the integration of Web-based resources.

Keywords : Web-based digital resources, Middle school classroom, Strategies and obstacles

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Introduction

This study examines strategies and obstacles encountered in infusing digital resources in the math and science middle school classroom. The study reports on findings from three schools in United States which have invested heavily in the past two years in technology hardware and high speed Internet connectivity. Questionnaire data reveal how, when, and for what purposes digital resources are being used, as well as factors that limit use. Classroom observations and follow-on interviews probe further into the benefits that Web-based digital resources afford to teachers and students as well as the challenges encountered.

This study looks beyond well-documented inhibitors of technology integration (e.g. lack of computers, outdated equipment, poor connectivity), by studying schools that have modern computer labs, and high-speed internet connectivity (Appleton, 2006; Sherry & Gibson, 2004). These schools allow us to research how teachers in these environments make use of Web-based resources (Payo, 2008), and to examine their assessment of the benefits that integrating these resources offer as well as the challenges that they encounter.

In the last five years there has been an explosion of creative and interactive Web-ware in almost every field of science and mathematics. The National Science Digital Library (http://nsdl.org) has created a portal to thousands of educative science and mathematics resources (McIlvain, 2010). The National Science Foundation's digital library of exemplary resource collections and services was organized in support of science and mathematics education. It was also established to catalyze and support continual improvements in science, technology, engineering, and mathematics (STEM) education at all level from K-12, higher education, and lifelong learning. Initial development began in late 1995 and the nsdl.org site launched in 2002.

Especially, NSDL supports the K-12 community by: 1) an organized point of access to the internet, 2) resources that support standards, 3) connections to real scientific data, scientists, and the scientific process, 4) collaborative online environments for dialogue, document sharing, and idea exchange, 5) a trusted source for high quality, relevant, accurate, and appropriate information, 6) peer reviewed materials, 7) developed and employed a standardized cataloging index system with meta-data, and 8) a combination of search engines for accessing science digital libraries. Most of these, are indeed, available to teachers free of charge. As such, they are more accessible than software which can be expensive to obtain, and sometimes problematic for teachers to install of school networks (Mardis & Payo, 2007).

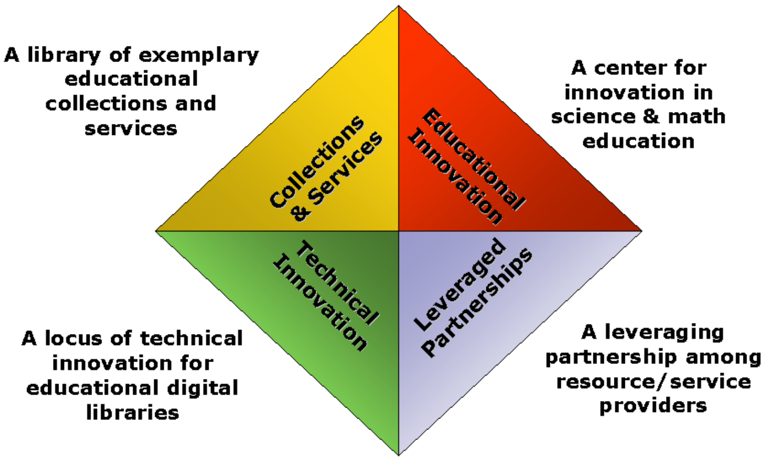

Figure 1. Four Facets of NSDL

Calls for a more inquiry- and data-rich, student-driven science classroom (NRC 1996, 2000) have been accompanied by high expectations for how digital technology can help create such a science classroom (PCAST 1997; Osbourne and Hennessy 2003). There has been an enormous investment in hardware and software, with networked computers in almost all schools and very many classrooms (NSF 2004; Tang, Avula, & Acton, 2004). There are many studies of specific tools which support more authentic investigations, give students more responsibility, and amplify teachers' effectiveness (Linn et al. 2000, Escalada & Zollman 1997; Tinker 1996).

Yet a large installed base of technology has not caused the desired, deep transformations of school science (Weiss et al. 2002). Some of this has to do with the many forces for conservatism in classrooms (Cuban 2001, 1986, 1984) including teachers' attitudes about technology and their calculation of the costs and benefits (Zhao et al 2002; Kerr 1991). Beyond that, however, the complex, unbounded and under-contextualized nature of Web materials (Dwight & Garrison 2003) present special problems for teachers in learning to evaluate the quality, reliability, usability, and characteristics in use of materials they find. Despite the availability of Web resources, they are typically used sporadically in the middle school classroom to support science and mathematics learning.

This study assessed middle school teachers' attitudes in a questionnaire, observed teachers using web-resources with their students, and then interviewed each teacher following the class. Through this study teachers share difficulties encountered when searching, implementing and assessing classes that use web-resources. They also reflect on the value such resources can add to traditional science curricula and classrooms.

Main research questions are as follow.

1. In schools that have invested significantly in computers and high speed connectivity, how are teachers using digital resources? What factors limit teachers' use of on-line digital resources with their students?

2. What are the challenges encountered by using Web-ware activities with students?

Methods

School and Subjects Selection

Three middle schools were selected to participate in this study. We selected schools that had updated computers and high speed connectivity, principals who were interested in exploring the use of digital resources and 30 math and science teachers who were willing to participate in the study. We made an in-depth interview and focus group interview with 13 teachers, technology coordinators, and media specialists in the schools.

Study Design

We reviewed the literature and collected baseline data such as school demographics, interview and survey with the subjects. We conducted workshops and developed rubric and online sharing tools for reflection and collaboration among teachers. We also collected classroom implementation data observation & follow-up interview. The data was drawn from questionnaires, interviews, and classroom observations with principals, technology coordinators, and math and science faculty.

Data Analysis

All interviews were taped, transcribed, and analyzed by two researchers for common themes. Data was subjected to quantitative as well as qualitative analysis. Qualitative data was analyzed according to the methods for naturalistic inquiry of Lincoln and Guba (1985).

Results

Question 1. In schools that have invested significantly in computers and high-speed connectivity, how are teachers using digital resources? What are the factors that limit their use?

The three schools in our study all had computer labs that allowed full classes of students to come to the lab, and for each student to have his own computer station. Typically the computers were networked to a printer. Most teachers that participated in the study reported that they had a positive attitude toward the web and toward technology. In fact when asked to rate their interest in integrating online resources within the curriculum, on teachers rated their own interest as being higher than their students, principal, colleagues, superintendent or parents. In fact, they only rated the technology coordinator as being more interested (See Figure 2).

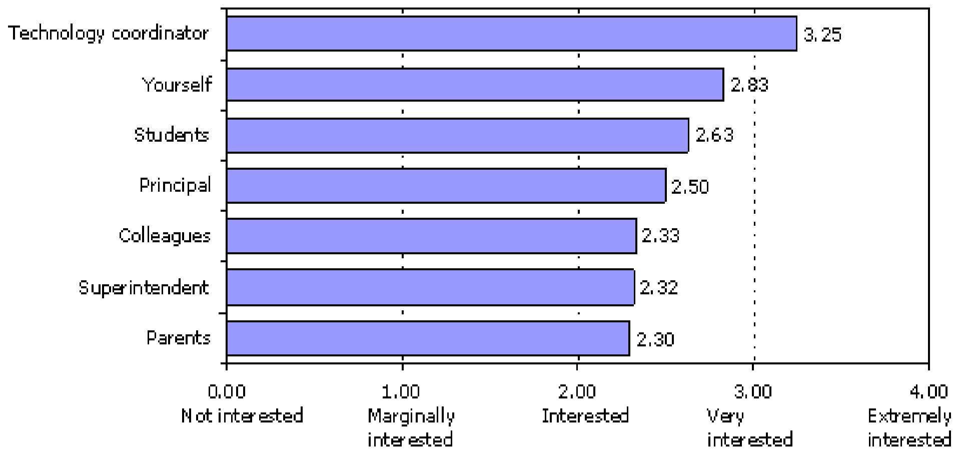

Figure 2. Teachers' perceived interest level in having on-line resources

Results from our initial questionnaire on questions of frequency of use at first seemed rather encouraging. When asked "how frequently do you currently use on-line resources with your students?" 23.3% of teachers responded "weekly" and additional 20.7% responded "monthly", 40% responded, 7-12 days per year (see Figure 3 below). Yet our interviews with teachers clarified their understanding of this question. Teachers included in their count uses such as printing a resource off the web, and handing it out to students, or discussing an item of interest that she/he may have seen on the Web. Hence the actual frequency with which teachers have students interact online with Web-resources is less than reported.

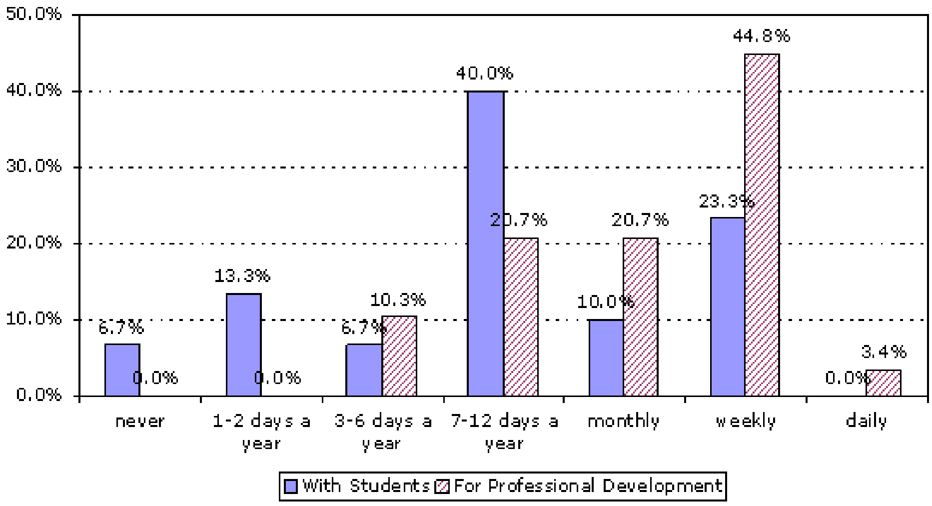

Figure 3. Frequency of teachers' use of on-line resources

Teachers reported that they were most likely to use web-resources to motivate their students, to increase their level of interactivity with the material or to provide students with enhanced content. They were least likely to use the Web for their students to have an opportunity to communicate about data, to communicate with other students, or to communicate with scientists or mathematicians.

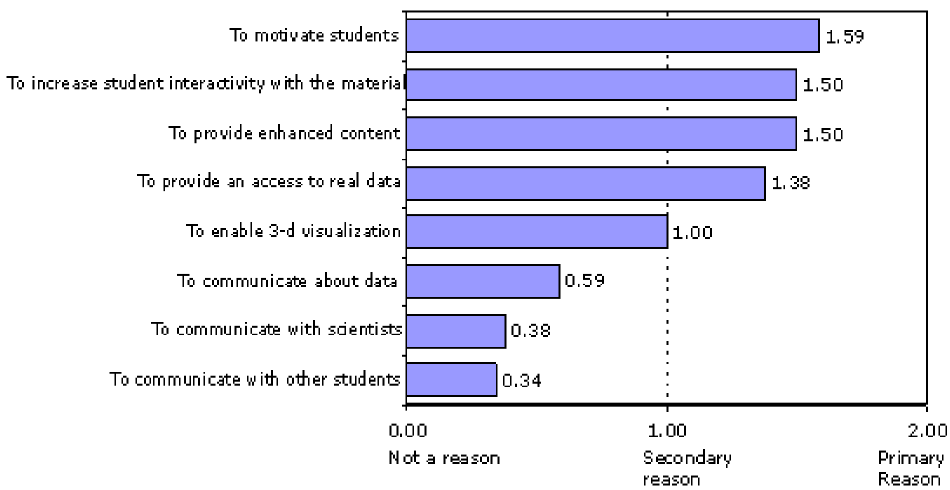

Figure 4. Reasons for using online resources with students

Yet despite teachers' positive attitudes and well-equipped computer labs, many teachers were still very hesitant to have their students interact with web-resources in the computer lab. Out of our 30 original teachers who completed questionnaires, 26 agreed to be observed using a technology with their students. Three of the 26 did not end up using technology (two said they never used it, and one could not find an appropriate resource for the lesson). An additional 4 teachers used the two computers their classroom rather than going to the lab. Use in the classroom was either constrained to two students interacting, or a teacher showing a demo. 19 teachers did in fact bring their students to the computer lab. Two teachers used software rather than Web-ware; one used Excel with her students and another used a stand-alone simulation application –Star Logo. The 17 remaining teachers did use web-ware with their students in the lab. Cumulatively they demonstrated multiple uses of digital resources.

- *Four teachers did Web-quest type activities which involved students searching and browsing. The subject content varied from researching glaciers, to the cell, to exploring the reasons why leaves change color.*
- *One teacher used an online worksheet (which could have easily have been used as offline as a standard worksheet). The content matter was plate tectonics.*
- *Two teachers used math games that offered students drill and practice on fractions and equations.*
- *Four teachers found resources that provided students with interactive graphing experience of linear graphs, stem* & *leaf graph, and network graphs.*
- *Four teachers used interactive visualizations that showed students 3D or microscopic images. These included a virtual cell lab, exploration of microscopy, images that showed the relationship of volume to surface area, and of percents to fractions.*

- *Two teachers used simulated labs that showed population change, and the relationship of speed, velocity and friction on a roller coaster.*

When we explored what limited teachers use of technology the greatest obstacle by far was "not enough computers in the classroom (86%)." (see Figure 5). In these schools, typically, teachers had two computers within their class, sometimes hooked up to a large screen TV or projector. This set-up is more suited to teacher demonstration than student interactivity. Despite the fact that there are computer labs available, teachers want to experiment within their own space. The computer lab necessitates transport of students to and from, advance planning to sign to request the room, and confidence that the web-resources will occupy the students for the whole lesson. Teachers were not enthusiastic to bring students to the lab for 15 or 30 minutes.

Other major obstacles included limited access to the computer lab (53%). While teachers generally found it easy to schedule one class for the lab, they often felt responsible to bring all their sections to the lab, in order to give all students similar experience and access. While finding a slot for one classroom proved doable, finding a slot for 5 classrooms within a short time frame often was not. A third major obstacle was the pressure that teachers feel for coverage of material (48%). Teachers needed to feel that the experience in the computer lab facilitated coverage of material that standards and state tests held students accountable for. Pressure for content coverage often trumped a desire to expose students to novel or cutting edge science experiences.

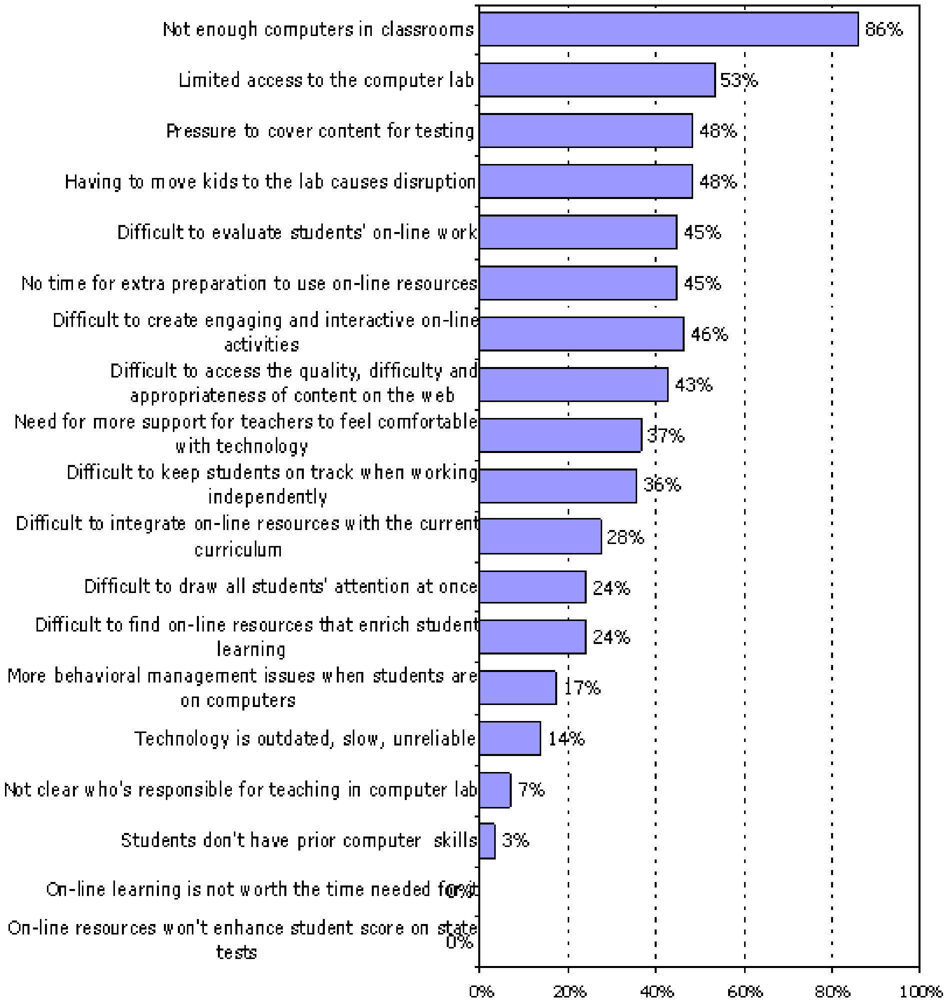

Figure 5. Factors that limit teachers' use of on-line resources

2. What are the challenges encountered by using Web-ware activities with students?

Results from the questionnaire, and more poignantly observations and follow-up interviews revealed that integrated web resources created some major challenges for teachers. We report these in the following major categories: the search, pedagogical issues, and assessment issues.

The search

None of the teachers in our study used curricula that referred them to links of supplementary web-materials. As such, the teachers themselves were left to find appropriate web-resources that complimented their lesson. When we asked teachers how they went about doing so they reported most frequently finding out about on-line resources from colleagues (76.7%). This informal teacher to teacher network was used more frequently than using a search engine on the Internet (56.7%) or consulting the Science Coordinator (40%) or the technology coordinator (16.7%). Teachers are interested in what their peers have used as colleagues can share what worked successfully for students of a particular grade, in a particular setting with a particular teaching goal in mind. This is the kind of the information that is rarely gotten through a search engine.

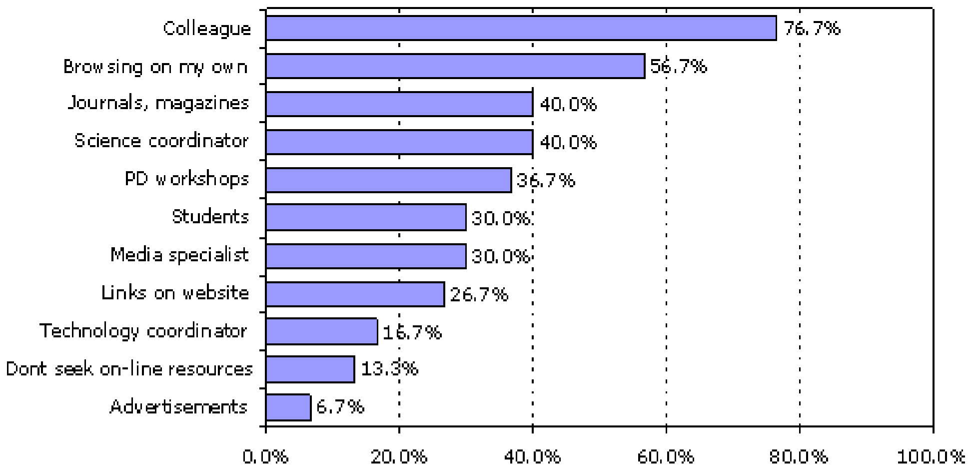

Figure 6. How teachers usually found out about on-line resources

When our participating teachers were asked how comfortable they were searching the web for educational resources, there was a wide distribution as reflected in Figure 7 below.

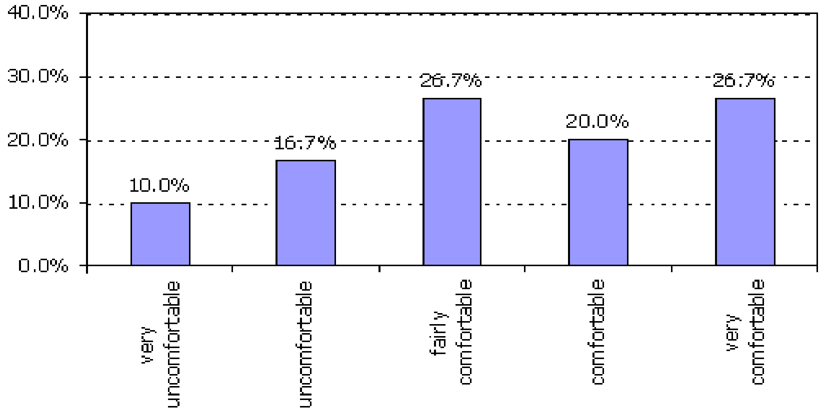

Figure 7. Teachers' comfort level in searching the Web for educational resources

Most teachers reported spending 1-5 hours a month searching for educational resources on the Web. While five hours a month is a significant commitment for teachers who are busy after school grading homework and preparing lesson plans, it is likely to be insufficient time for teachers to choose a set of resources from the hundreds out there, to evaluate the appropriateness of the resource for their students needs, and to scaffold the use of the resource so that students access the aspects of the site that the teachers were hoping for.

When teachers were observed searching for resources they were most likely to search by topic (e.g. the cell) both within NSDL and on Google. Teachers were less likely to include terms in their search that would differentiate the type of activity (e.g. visualization, animation, interactive, virtual lab). Such encountered material would not be especially motivating or interactive. Whilst sorting thru the results of their search teachers found that it was not trivial to have to assess the difficulty level, the various paths that students might encounter, and to assess the pre-requisite skills that students would need before using the site.

Pedagogy

Nineteen of the participating teachers had their students interact on computers within a computer lab setting. 16 of 19 teachers offered very limited introductions to the lesson in that the introductions were about how to use the site rather than providing context for the content that was to be explored. Hence, most introductions focused on how to use a particular program (e.g. open this program, click on this first then follow this link) or were task-related instructions (e.g. open a shared folder, find a worksheet, type your answers and save it). Three teachers offered more a explicit introduction that explained the context of the computer lab lesson in relation to the science of math that was being learned.

Students tended to work individually at computers and teachers tended to circulate to answer individual student questions as they arose. The computer lab set-up made these interactions somewhat awkward, as the teachers' back was often facing many of the students, so that the teacher could not see those students who had hands raised.

This individualized setting creates pedagogical challenges. One teacher expresses:

The most challenging issue is trying to get 20 children of different abilities working productively. And it's nice in that they are motivated but they all have questions along the way and there's one of me. So it means it's a very busy 42 minutes.

Another teacher adds:

It can be hard helping one kid and keeping an eye out on another across the room. When the students are interacting with the computer, each kid is in their own individual world and you get drawn into their world, which makes it hard to see the class as a whole.

Despite the difficulties of interacting with students when they are each working individually teachers seemed to resist having students turn away from the computer for whole class interactions. In fact, only three of the nineteen teachers had students participate in a discussion where sense making, problem solving or reflection was facilitated. (This was in marked contrast to the seven teachers observed in their classroom settings, where each one of them engaged students in a discussion at some point in the lesson.) In the computer lab only 2 of 19 teachers had students interact in pairs. In most cases (14/19) students worked independently (without group or whole class discussion) throughout the entire 45-60 minute class.

Teachers varied in their propensity to let students explore websites freely, or to direct their activity through the use of worksheets (which were often on clipboards next to each computer.) The use of worksheets was most frequently seen in one school which had an active technology coordinator who consulted with teachers before the lab, helped to find them resources (sometimes including worksheets) and then prepared clipboards at the side of each computer. Worksheets were a mixed blessing. While they provided students with a clear structure, and the teachers with an artifact to assess student's work, they often removed the excitement that comes with exploration.

Hence for the majority of time in the computer lab, each student worked on their own interacting with the computer, but rarely with each other. Teachers seemed hesitant to assert their role as facilitator, lecturer or sense maker in the computer lab. It is not clear whether these teachers found it difficult to interrupt student's interactions with the computer in order to facilitate discussions, or whether, they felt somewhat displaced being outside of their classroom environment.

Assessment

Teachers face two different assessment challenges when using digital resources. The first is to assess the appropriateness and quality of the resource. The second is to assess what the student's gained from the experience. First, assessing the resource is as follow. Our observations of 19 classrooms revealed the multiple challenges that teachers encounter when trying to assess the quality and value of a digital resource. Digital resources often have multiple paths to follow. Teachers found that even when they had spent significant time navigating though a resource that they often did not encounter links that some of their students found in the classroom. This often led students to topics not yet covered in class or content beyond their reach.

Our interviews with teachers revealed that they often did not take into account when in the sequence of the unit to introduce a digital lesson. The timing of a digital resource sometimes depended on computer lab availability and other factors not directly related to sequence of instruction. This often resulted in students not being able to make maximum use of the digital resource. For example one class played a fraction strip game that required that students add fractions. Since this class had not yet learned to add fractions with different denominators they played the game purely as a trial and error, "click and miss" exercise. These points to the necessity for teachers to not only assess the quality of the resource but to consider the sequence within an instructional unit.

Yet another challenge to teachers was to assess the scientific accuracy and behavior of virtual labs and other sophisticated science Web-ware. For example one math site had students calculating mass and volume, but the website did not offer the students any unit of measure. In another case, a virtual roller coaster lab allowed students to alter the mass, friction, speed, and height of the roller-coaster. The friction gauge, however, did not seem to impact the results. Hence a very, very slow moving car successfully navigated a large loop in the coaster. In an instant the teacher was faced with having to make a judgment as to whether or not the program was in error. Although this teacher wrote to the web-master of the site, she did not get a response.

Second, assessing the students is as follow. Teachers often found it hard to assess what students had learned. One teacher commented: they knew what they were doing,.. "I think." Discussions often serve as an informal window for teachers to hear students' ideas. Yet in the lab setting, discussions were mostly absent. Sites aimed at skill building were often very difficult, in that games presented could be navigated intentionally or by clicking everywhere until the right answer was inadvertently achieved. Worksheets tended to provide the teachers with an assessment tool, but often constrained the lesson.

Findings and Suggestion

We are at a strategically important moment to investigate the benefits and drawbacks of infusing digital resources within the mathematics and science classroom. The wealth of these resources is matched by the complexity of finding appropriate sites, assessing their expectations and content, integrating them at the appropriate time with students, and matching them to the purposes hoped to be achieved (Almasy, 2005). Understanding what this process looks like, for teachers choosing the resources and students interacting with them, will be illuminating for creators of these resources, compilers of educational digital libraries (including NSDL), professional developers, as well as educators.

From the study, participated teachers reported: 1) more efficient with their time to plan a lesson, 2) had more of a purpose to use online resources, 3) were able to match up with what they were doing in class, 4) felt more comfortable in the computer lab, 5) increased comfort level with the management of the classroom when everyone is on a different thing, 6) less afraid of losing control and let students explore on their own and gave students more freedom, and 7) had better ideas of what was working and wasn't working and why some things weren't working.

We also observed teachers' behavior and attitudes towards digital resources: 1) they better integrated online resources in a larger unit of the lessons, 2) they used wider range of activities such as peer-tutoring, group discussions, poster presentation, and creating artifacts (Cekaite, 2009), 3) they presented clearer objectives for a lesson through introductory demonstration in the beginning, utilizing worksheets, and sense-making activities.

Implications for professional developers of digital resources are as follow. First, they need to support teachers to expand their repertoire of models using online resources including more interactive uses (Chowdhury, Landoni, & Gibb, 2006). Second, They enable teachers to create inclusive lessons using digital resources that connect to other learning experiences and support materials because teachers have difficulties with disconnected applet, learning objects, and single activities. Third, they support exploration of novel uses including access to remote controlled instruments or real-time data, experience with graphing or mapping tools, and assess to human resources. Finally, they should foster teacher-to-teacher collaboration around sharing of resources.

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